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Preface

In today's world, which has recently seen fractures and isolation forming among states, international and interdisciplinary collaboration is an increasingly important source of progress. Collaboration is a rich source of innovation and growth. It is the goal of the Collaborative European Research Conference (CERC 2019) to foster collaboration among friends and colleagues across disciplines and nations within Europe. CERC emerged from a long-standing cooperation between the Cork Institute of Technology, Ireland and Hochschule Darmstadt - University of Applied Sciences, Germany. CERC has grown to include more well-established partners in Germany (Hochschule Karlsruhe and FernuniversitÃ¤t Hagen), United Kingdom, Greece, Spain, Italy, and many more.

CERC is truly interdisciplinary, bringing together new and experienced researchers from science, engineering, business, humanities, and the arts. At CERC researchers not only present their findings as published in their research papers. They are also challenged to collaboratively work out joint aspects of their research during conference sessions and informal social events and gatherings.

To organize such an event involves the hard work of many people. Thanks go to the international program committee and my fellow program chairs, particularly to Prof Udo Bleimann and Prof Ingo Stengel for supporting me in the review process. Dirk Burkhardt and Dr Robert Loew put a great effort into setting up the website and conference management system and preparing the conference programme and proceedings. Many of my colleagues from Hochschule Darmstadt were invaluable for local organization. Thanks also to Hochschule Darmstadt and the Research Center for Applied Informatics (FZAI) for financial support.

Bernhard Humm, conference and program chair, CERC 2019
Darmstadt, Germany, March 2019

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Chapter 1

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Word Embedding Based Extension of Text Categorization Topic Taxonomies

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Abstract. Collaborative interdisciplinary research has the added difficulty, that researchers from different fields have different backgrounds and employ heterogeneous technical vocabularies. Certain problems could have already been solved in one field, but the solution is described in such a fashion, that it is difficult for researchers from another field to understand, yet alone to know the correct terms to search for. Text categorization (TC) is the act of automatically placing text into content-based categories. These categories can be interrelated forming hierarchical taxonomies of knowledge. Different from classic querying-based information retrieval (IR), TC-based IR allows for an exploration of topics without prior knowledge about them, by inspecting the individual topics and related documents within the taxonomies. TC also plays a major role in argumentation mining (AM), the automated extraction of arguments from large quantities of text. In AM, TC is used to identify argument structures within analyzed texts. Another potential use for TC in AM is the restriction of data sources to relevant topics because AM in too-large text corpora can be prohibitively time consuming. As mankind's knowledge constantly expands it is logical to conclude, that the taxonomies organizing this knowledge must expand as well. We propose a method to aid in extending existing topic taxonomies by using word embeddings. These extended topic taxonomies can then be used in the categorization of texts, and to filter argument-extraction sources. We additionally outline an alternative usage of these techniques in argumentation mining.

Keywords: Taxonomies, word embedding, text categorization

1 Introduction and Motivation

The main goal of argumentation mining (AM) is to automatically extract arguments from generic texts to provide structured data for computational models of argument and reasoning engines. To accomplish this goal, argumentation models are used. These models form parts of individual arguments (Lippi and Torroni, 2016). According to

Habernal and Gurevych (2015), the prevailing model of arguments in AM is that of a discourse structure consisting of several argument components, such as premises and claims. Text categorization (TC) is the act of automatically assigning texts of arbitrary length to a predefined set of categories (Sebastiani, 2002). When modeling sentences within the mined text corpora as texts and argument components—using, for example, premises and claims as categories—TC is the foundation for a plethora of AM systems (Mochales and Moens, 2011; Feng and Hirst, 2011; Rooney et al., 2012; Stab and Gurevych, 2014).

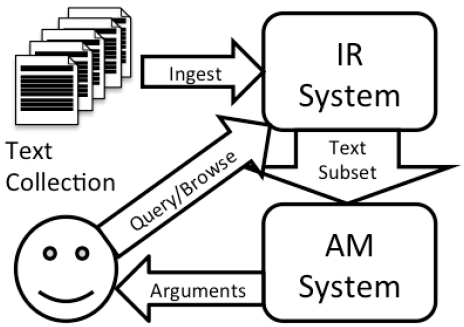

Fig. 1: Information retrieval (IR) before argumentation mining (AM).

ArgumenText is a practical implementation of an AM engine (Stab et al., 2018). It employs a two-step mechanism in which a large collection of documents (http://commoncrawl.org/, in Stab et al.'s experiment with 683 GiB) is first indexed into an information retrieval (IR) engine. The user can then query the engine using search terms. The resulting subset of documents is subsequently mined for arguments (see Figure 1). This is done in order to reduce computation time because AM on this scale takes too much time with access only to ordinary hardware. In order to query the engine, the user must know the exact search terms to be used.

Having a taxonomy of topics could allow the browsing of different facets of topics without prior knowledge about their exact structure and common sub-topics. This way, TC could be used as an alternative to the regular querying-based IR engine, allowing browsing-based topic exploration. Such taxonomies also directly benefit collaborative interdisciplinary research. Our research originates from the RecomRatio project. The goal of RecomRatio is to provide medical professionals with treatment recommendations that were extracted from current medical literature, arguments for or against these treatments, and the analyzed medical literature itself. Therefore our experiments have a strong medical focus. Before TC can be performed, one needs a set of categories, *C*. This is obviously given for argument structures but could be lacking when one models a topic taxonomy for exploration. The aim of our work is to help in the creation of such a topic taxonomy by suggesting extensions to an existing proto-taxonomy (see Figure 2). Because TC usually works in a supervised-learning fashion, one also requires example text-to-category assignments. This need has been remediated in newer unsupervised TC techniques (Dai et al., 2017; Eljasik-Swoboda et al., 2018). These techniques are based on word embeddings (see section 2). Following Dai et al.'s and Eljasik-Swoboda et al.'s examples, we propose a method to sug-

gest taxonomy extensions for existing topic taxonomies using unsupervised machine learning while processing no data other than a large collection of example texts and an existing initial topic taxonomy. Given natural language texts about the topic and an initial proto-taxonomy as input, our system will then suggest sub-topics for a given topic in this taxonomy. For example, when analyzing texts about *melanoma*, the system will suggest sub-topics for *melanoma* in a taxonomy tree that models different diseases. This example taxonomy could model *cancer* as a family of diseases and have *melanoma* as a sub-category of *cancer*.

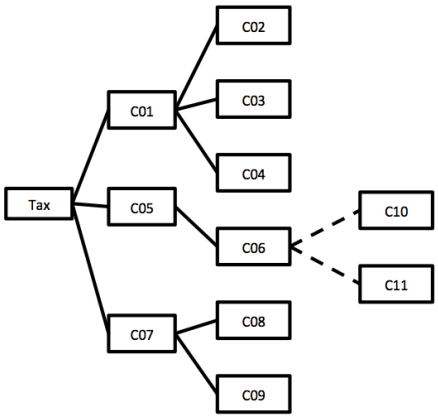

Fig. 2: Topic taxonomy extension.

Even though plenty of resources are available for the medical domain, we limit ourselves to this because these resources might not be available for emerging cutting-edge topics, as medical researchers are likely to first describe them using natural language before making them machine readable in any fashion or agreeing upon their technical vocabulary definitions (Nawroth et al., 2018). This makes our approach transferable to any natural language and uniquely suited for emerging knowledge domains because, during the adoption phase of TC for any application, additional—especially manually compiled—information resources are difficult to obtain. Our contribution is two-fold. First, we propose a novel unsupervised method to help in the introduction of TC as an IR method for AM or any other application by proposing new categories. Second, we analyze and discuss what influences the effectiveness of our system—such as, for example, the utilized word embedding algorithm.

2 State of the Art and Related Work

In order to model any topic relationships, one needs a way to model the semantics of individual terms. Ontologies are manually created encodings of semantics. They are commonly used in all types of natural language processing applications. Given the high amount of work put into developing ontologies, the ontologies are very precise in capturing the semantic understanding of their creators (Busse et al., 2015). Their drawback is that they need to be manually created. Blei et.al (2003) proposed another fundamental approach to capturing semantics for words. Their latent dirichlet allocation (LDA) statistically splits documents into topic distributions and divides topics

into term distributions. Each term is assigned a topic vector that comprises its probability of being part of each topic. LDA is also referred to as topic modeling. Here, terms are regarded as similar if they occur in the same document. Camiña (2010) described multiple methods to generate taxonomies based on term similarities in LDA topic distributions. The same is true for Kashyap et al.'s TaxaMiner experimentation framework for automated taxonomy bootstrapping. Even though these methods are appealing, we pursuit a different goal in trying to extend an existing proto-taxonomy instead of starting from scratch.

Another intriguing approach lies in word embeddings. These are unsupervised learning methods that can capture semantic relatedness by analyzing large texts or concatenations of multiple smaller texts. Word2Vec is a prominent implementation of word embeddings that Mikolov et al. (2013) developed. Word2Vec consists of two algorithms, continuous bag of words (CBOW) and skip-gram. Both produce high-dimensional coordinates for every word and operate by optimizing the cosine similarity between each word. In CBOW, the similarity of terms that are surrounded by the same context terms is maximized. In skip-gram, the similarity of the context terms surrounding the same central terms is optimized. Words are considered to surround a term if they are in a context window of n words before or after the term. Using this pattern, semantic relatedness becomes encoded by similar offsets that capture multiple dimensions of meaning. To the best of our knowledge, this has not been observed in LDA-based term vectors. A reason for that can be the higher granularity of word embeddings regarding what terms are in the other words' contexts.

Habernal and Gurevych (2015) utilized this in the context of AM by creating clusters of terms commonly used in arguments in order to support the annotation of arguments within text. Fu et al. (2014) also used word embeddings to extract hypernym/hyponym relationships between terms in order to create an ontology. Their experiments suggest that a simple hypernym/hyponym vector offset does not exist; rather, one offset exists per class of terms. For example:

v(shrimp) - v(prawn) ≈ v(fish) - v(goldfish) and v(laborer) - v(carpenter) ≈ v(actor) - v(clown) but v(laborer) - v(carpenter) ≉ v(fish) - v(goldfish).

Our objective is similar to that of Fu et al. (2014). Instead of extracting hypernym/hyponym relationships between terms, we attempt to extend topic taxonomies with sub-categories. These sub-categories are not necessarily hyponyms, as they could also cover certain aspects of their parent categories. As we limit ourselves to only the existing text and initial taxonomies, word embeddings are an optimal foundation for our method. As previously mentioned, our topical focus is in the medical domain. A cornerstone of medical literature is PubMed, the National Institutes of Health's U.S. National Library of Medicine database (U.S. National Library of Medicine, 1996). PubMed includes a querying-based search engine and abstracts for most indexed articles. The articles themselves are stored elsewhere, with their references and DOIs available in PubMed. Additionally, articles are annotated with Medical Subject Headings (MeSH) (U.S. National Library of Medicine, 1999). MeSH is updated annually, currently defines 28,378 medical topics, and organizes these topics 58,025 times in 16 topical taxonomies such as *anatomy* and *diseases*. In these taxonomies, every topic has one or multiple paths from the taxonomy root to its entry. Even

though these taxonomies form directed acyclic graphs (DAGs), some topics are listed multiple times in the same taxonomy.

Kaufmann et al. (2017) created the big-data management canvas (BMDC). The fundamental insight is that the aim of any big-data project is the effectuation: the creation of a benefit through the analysis of big amounts of data. The same is true for any data- or text-mining endeavor. In order to not lose sight of this, the BDMC planning method splits endeavors into five main fields of activities. These fields form a loop of activities going from the datafication (which is the capturing of data for later analysis) to the said effectuation. These are further split into a business aspect and a technology aspect. The business aspect describes and plans what should be done whereas the technology aspect describes and plans how it should be implemented. We used this method during the planning and modeling of our system.

3 Model and Implementation

As mentioned, we organized this research using the BDMC that Kaufmann et al. (2017) proposed. The following sub-sections reflect the BDMC's fields of activity. This illustrates the workflow we propose for the extension of topic taxonomies. We named our system Taxonomy Extension system for Emerging Knowledge (TEEK), as its primary task is to capture emerging topics for usage in TC. We used the BDMC to structure the creation of our prototype as well as the performed evaluation experiments.

3.1 Datafication

The BDMC defines datafication as the act of transforming real-world events and properties into usable data. It also closes the loop to the effectuation, as every effectuation influences the world we live in and hence creates new data to capture. In our envisioned application, the relevance feedback provided by the domain experts curating the taxonomy is the datafication of this endeavor. If a domain expert agrees with the system and adds a category to the system, the available taxonomy changes. The datafication of our experiments is performed with the evaluation of the proposed categories as described in section 3.4.

3.2 Data Integration

The BDMC field of data integration describes which data is used, how it is obtained, and how it is centrally managed and stored. As mentioned before, our system works on taxonomies and text files about a given knowledge domain. We performed experiments for the medical terms *neoplasms* (cancers/tumors), *melanoma*, *leukemia*, *Herpesviridae*, and *Simplexvirus*. Each of these terms has one or multiple entries in a MeSH taxonomy. *Melanoma*, *leukemia*, and *neoplasms* are part of the *diseases* taxonomy whereas *Simplexvirus* and *Herpesviridae* are part of the *anatomy* taxonomy. *Simplexvirus* is a descendant of *Herpesviridae* whereas *melanoma* and *leukemia* are descendants of *neoplasms* within MeSH.

The finished system will have access to a multitude of documents from which it can learn the relationships between terms in order to propose new topics. For our prototype, we simulate this using PubMed. We queried PubMed for each of the above-mentioned terms and used the export-to-XML function in order to download all metadata and abstracts for a given topic. Word2Vec requires lowercase texts without special characters. Because the resulting XML files were up to 31.01 GiB in size (neoplasms), we implemented a buffered XML parser in Java that extracts the abstracts from all articles in the individual result sets and stores them into simple text files, removing all special characters. For easy integration in multiple applications, we packaged the original C implementation of Word2Vec (https://github.com/tmikolov/word2vec), into a Docker container, which we used to run CBOW and skip-gram on these extracted text files. This means that we have two word embedding files for each PubMed search term to experiment on. We parameterized them to have 200 dimensions and use a five-word (before and after) context window.

3.3 Data Analytics

The data analytics field describes how the available data is analyzed. As previously stated, the available data is a set of word embeddings and an initial taxonomy. Every taxonomy—$T = \{C, E, L\}$—has a set of categories—C—and a set of labels for each category, L. Additionally, the set of edges, E, between the categories form a DAG with $r \in C$ at its root. The labels consist of one or multiple words.

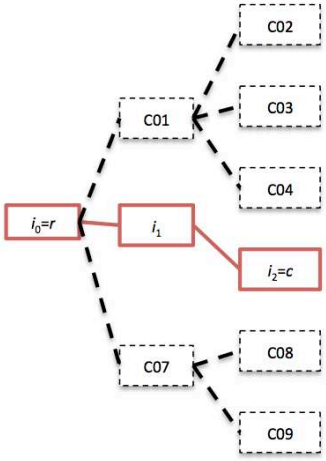

Fig. 3: Path from root to category *c*.

Word embeddings are high-dimensional vectors for all terms that the algorithm encounters during training. We denote them as *v*(word). This way, a word embedding vector can represent every category with single-word labels. If the label of one category consists of multiple words, we compute its vector representation by calculating the arithmetic mean of all the individual word vectors. Because T forms a DAG, every $c \in C$ has a path $i_0, \ldots, i_n$, where $i_0 = r$ and $i_n = c$. With the word embeddings, every node has a representation in vector space. The rest of the taxonomy is ignored (see Figure 3).

The task of suggesting new sub-categories for c is essentially that of extending the path to $i_0, \ldots, i_n, i_{n+1}$. Our approach for TEEK is to compute the most-likely next category label vector by using the information provided by the existing path $i_0, \ldots, i_n$. Once this vector is computed, the 10 closest terms to this next vector in word embedding space are calculated using cosine similarity. It is noteworthy that the closest term in all our experiments is the label of c. The system therefore creates nine suggestions per category.

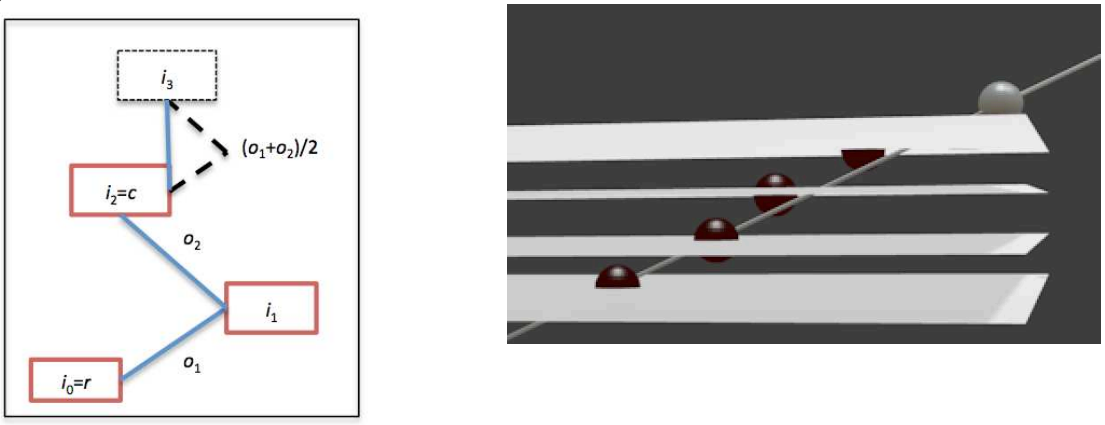

Fig. 4: AVSP and RVSP illustration and comparison.

We experimented with two possible variations for this task. The first variation begins with the computation of the offsets between individual categories on the path: $o_j = v(i_j) - v(i_{j-1})$. In the next step, it adds the average offset between all categories on the path to the vector of i_n:

$$(i_{n+1}) = v(i_n) + \frac{1}{n}\sum_{j=1}^{n} o_j \tag{1}$$

This equation essentially adds the arithmetic mean of the individual offsets to the last vector. We therefore refer to it as arithmetic vector-stream predictor (AVSP). Figure 4 portrays this approach in an example two-dimensional word embedding space.

The second variation applies linear regression to the problem of finding the hyperplane closest to all $v(i)$. Using the following equations, this hyperplane is expressed as function of path index j:

$$\bar{j} = \frac{n^2+n}{2n+2} \tag{2}$$

$$\bar{v} = \frac{1}{n}\sum_{j=0}^{n} v(i_j) \tag{3}$$

$$b = \frac{\sum_{j=0}^{n}(j-\bar{j})*(v(i_j)-\bar{v})}{\sum_{j=0}^{n}(j-\bar{j})^2} \tag{4}$$

$$a = \bar{v} - b * \bar{j} \tag{5}$$

This way, the next word embedding vector is found through the following equation:

$$v(i_{n+1}) = a + b * (n+1) \tag{6}$$

Because this is standard linear regression applied to vectors instead of scalars, we named our second approach regression vector-stream predictor (RVSP). Figure 4 portrays this using two-dimensional word embedding spaces. The word embedding space is shown for each term with the distance from the root of the taxonomy forming an additional dimension. The dark-red spheres represent the individual categories, the planes symbolize the word embeddings that the categories are in, and the line represents the hyperplane closest to all these points. The white sphere represents the suggested categories, as it extends the taxonomy-depth dimension by one.

Our prototype implements these two methods in Java after reading word embeddings as text files and the taxonomy as an XML file from the file system. Both approaches essentially create a direction in the word embedding space that reflects the direction of the path from the taxonomy root to the individual topic category. This captures Fu et al.'s (2014) finding regarding the lack of a common hyponymy direction between different classes of terms. Here we use the available information provided by the taxonomy structure to discern different dimensions appropriate for each topic category.

3.4 Data Interaction and Data Effectuation

The data interaction field describes how users interact with the data in order to benefit from the data effectuation. In our case, a domain expert can review the category suggestions before accepting them for usage in the topic taxonomy. After a suggested topic is accepted, a TC algorithm can assign content to this category. This review and acceptance component will be implemented through a Web interface that will show the user the top nine suggestions to extend for a given taxonomy. This forms a type of relevance feedback for the suggested categories. For our prototype, the results are stored in a Microsoft Excel file to ease their review and validation by the medical professionals that support us in this project (see section 3.2). The goal of our proposed system is the automatic suggestion of additional topic categories in order to extend an existing taxonomy. A TC-oriented IR system subsequently uses these categories to allow uninformed IR. This uninformed IR can then used to narrow down the source material used for AM. This narrowing down is crucial for performing AM in a timely fashion.

4 Evaluation and Result Interpretation

The purpose of our evaluation is to discuss the usefulness of suggested sub-categories for the given topic. Because our method can be parameterized differently, we can investigate the effect of the selected parameters on the results. As mentioned before, we use MeSH and PubMed as data sources for our experiments. The assessed topics are not leafs in MeSH but rather are inner nodes that already have a set of sub-topics in MeSH. The already existing sub-topics are hidden from our algorithm. This allows for four types of true positive results for our system: First, suggested sub-categories that are actual existing sub-categories of the investigated topic and, second, suggested categories that are not already sub-categories in MeSH but would make sense as sub-categories according to publically available medical sources. Examples for these find-

ings are *myeloblastic* as a sub-class of *leukemia* and *lentiginous melanoma*. *Myeloblastic leukemia* and *lentiginous melanoma* are types of their diseases that have been described in literature but are not modeled as sub-categories in MeSH. We published all detailed results including references for potentially meaningful sub-categories at: https://github.com/SirTobiSwobi/TEEKeval . We regard different spellings of the category name as correct sub-category suggestions and therefore TP because our system correctly interpreted them as types of the category. Our system correctly captured, that a misspelling of *leukemia* (like *leukeamia*) must be some kind of *leukemia* because experts wrote about in the same way. We interpret the plural of a category as fourth type of TP result, because the system correctly captured that sub-categories are different types of the original category. For example, it recognized, that the sub-categories of *melanoma* are (different types of) *melanomas*. Albeit plural- and different spelling results are not directly helpful in extending an existing taxonomy, they aid in comparing the effectiveness of different parameters and approaches. This allows us to compare which word embedding algorithm and extrapolation method produce better results. Additional insights can be gained by using different source material for the word embeddings. *Leukemia* and *melanoma* are descendants of *neoplasms*. Therefore, we can compare the performance of word embeddings generated through the PubMed abstracts to the more specific search term or through the larger amount of abstracts using the more general search term. The same is true for *Herpesviridae* and *Simplexvirus*.

Although *melanoma* occurs three times in 2018's MeSH, all other examined medical terms have only one entry. This allows another investigation about how the path length influences the performance of the system. Of these three entries, two entries are six steps removed from the taxonomy root whereas one entry is only four steps removed. The effectiveness of IR systems is usually measured in *precision* and *recall* (Sebastiani, 2002). They are not directly applicable because we do not perform information retrieval but attempt to extend topic taxonomies. To compare different word embedding algorithms, source material and path lengths for individual terms, we use a modified version of *precision*. Results that are on the path between the root and the term as well as other relative terms and completely unrelated terms are treated as False Positive (FP). Because we know the existing proto-taxonomy, results on the path or other relative terms could be filtered from the result set, so that the system instead outputs the next closest term in word embedding space. We decide not to do this for the sake of comparing different parameters. Precision is the ratio between TP and FP with 1.0 meaning only TP and 0.0 meaning only FP. For the recall measure, one needs to know all possible correct relevant sub terms, which nobody in our team did. Therefore, we only measure precision for our system. Table 1 contains the precision values for all our performed experiments.

Table 1. Experimental results.

		Ab-	AVSP		RVSP	
Term	Depth	stracts	CBOW	skip-gram	CBOW	skip-gram
Neoplasms	1		44%	44%	56%	33%
Melanoma 1	6	Low level	11%	11%	0%	0%

Melanoma 2	6	Low level	11%	11%	0%	0%
Melanoma 3	4	Low level	33%	22%	67%	67%
Melanoma 1	6	High level	44%	56%	33%	33%
Melanoma 2	6	High level	44%	56%	33%	33%
Melanoma 3	4	High level	67%	56%	67%	56%
Leukemia	3	Low level	67%	33%	56%	11%
Leukemia	3	High level	56%	89%	78%	89%
Herpesviridae	3		22%	56%	44%	56%
Simplexvirus	5	Low level	22%	11%	0%	0%
Simplexvirus	5	High level	22%	0%	22%	11%

On average, the AVSP (37%) and the RVSP (35%) performed almost equally as well. The RVSP found no TP in 6 out of 24 experiments. This only happened to the AVSP in one experiment. The RVSP is almost on par, because it delivered better results in other experiments. When comparing the average precision of the CBOW (38%) and skip-gram (35%) word embedding algorithms, both delivered comparable results no matter the extrapolation method. Albeit CBOW delivered on average slightly better results, skip-gram produced the best single result (89%).

Training the word embeddings on larger (high-level) text collections (E.g. Neoplasms instead of melanoma) had the biggest impact on performance. Low-level representations only yielded an average effectiveness of 22%, providing almost all cases in which no TP were found, while high-level representations had an average effectiveness of 47%. Metaphorically speaking this means that the more the system "knows", the better it is at generating sub-category suggestions. Another influencing factor is the depth of the investigated term within the taxonomy. With depth 1, the average precision was 44%, with depth 3 60%, and depth 4 54%. With depth 5, only 11% precision was achieved while depth 6 on average generated 24%. This means that with a depth>4, less than half the precision that with depth < 4 was achievable. We see two reasons for this behavior: The deeper a category is in a taxonomy, the more intermediate steps the system can use for extrapolation of sub-categories. On the other hand, the more specialized a topic is, the less likely there are many sub-topics.

5 Conclusions and potential AM usage

Our work shows a new way to extend existing topic taxonomies by using no other information than texts about the knowledge domain and an initial topic taxonomy. Therefore, domain experts do not need to perform any manual effort besides accepting suggested categories. As initially explained, text categorization using topic taxonomies supports uninformed information retrieval in any application and can specifically be applied for narrowing down documents before AM. To do so, TC systems require appropriate topic taxonomies. Our prototype aids in creating these taxonomies with only little labeled data. This directly benefits ArgumenText, RecomRatio, and other AM systems. Besides this filtering application, another potential utilization for this approach in AR is the detection of pros and cons for individual terms. To utilize this system as such, one could construct a taxonomy of topics or simply use an existing one such as MeSH. Afterward, known pros are manually modeled as sub-

categories for the topic categories. For each new topic-pro-leaf, the average offset or regression-based extrapolation vector can be computed. Adding this vector to $v(i_{n-1})$ instead of $v(i_n)$ would allow a user to find other pros for the leaf topic. The same can be done for cons. Using this technique, potential features for spotting pros and cons for topics can be extracted. These can then be used in AM TC or by a user to manually come up with arguments for or against something that are not already written down in the texts mined for arguments. In addition to describing a new way to extend taxonomies, we investigated how different parameters influence the approach. Albeit CBOW slightly outperforms skip-gram, the latter achieved the best individual results. Similarly, the AVSP slightly outperformed the RVSP on average. The RVSP however had many more results without TPs. Upon investigation, we found that it delivered many terms describing topics on the path from the root to the term in question. As mentioned, these can easily be filtered in future works. The strongest influence on performance comes from the texts that the word embeddings are based on. The more text about more general topics is analyzed, the better the system performs. This means that the hypothetical best results would come from word embeddings that are generated through the use of all abstracts on PubMed. Due to resource constraints, we were not able to practically test this. The taxonomy depth of the extended category also plays an ambiguous role: The further the category is removed from the root, the more intermediate steps can be used in the analysis. However, the more specific a topic is, the less likely it is to have more sub-topics.

Acknowledgements

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Student-centric Learning Analytics: Putting analytics into the hands of students

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Abstract. Learning Analytics is growing rapidly across Higher Education institutions across the globe. There are some software solutions to learning analytics which are mainly focusing on intervention, retention and resource allocation, driving institutions to collect and analyse data at an institutional level. Such data only provides a small window into a student and how they spend their time learning. Institutions link progression to specific interactions and neglect students' self-study, any social factors and any individual learning needs. Therefore, this paper is looking at Learning Analytics and how data can help each student individually. To achieve this, the data should examine and analyse a student providing intuitive data that can be used to reflect and alter learning behaviour. The proposed solution is more than just contributing to a data-driven education system allowing students to add learning activities, set personal targets and interact with members of staff during sessions; this enhances students self-regulated learning skills and their engagement while providing a clearer picture of a student's learning behaviour.

Keywords: Learning Analytics · Student Engagement · Higher Education · Big Data · Analytics

1 Introduction

In recent years various learning pedagogies have emerged and suggested that there are changes in the way students learn. Personalised learning is becoming core amongst Institutional Education Strategies, and the use of technologies spreads rather fast. Learning, whether it takes place online, face to face, or as flipped classroom approach, changes the group dynamics and puts the learner in the heart of the education system. For a student, engaging in the process of learning has been an area of research at the University of Plymouth. With aims and goals around student motivation, student engagement and participation, learning becomes more profound, the learner becomes a collaborator, and the institution needs to participate in instructional planning. With Learning Analytics, institutions can enhance their reputation by increasing student learning retention and success. By using Learning Analytics, institutions value their

learners, and the latter can shape their experiences and learn according to their goals and ambitions.

Learning Analytics refers to those applications that analyse educational data in an attempt to provide both the learner and the tutor with patterns of behaviour to improve learning and its related activities. The UK Higher Education sector is trying to respond to forces and changes that either stakeholders or the government is pushing and introducing. Moreover, there are great opportunities that are arising where current practices can be examined and new solutions to emerge.

Kolb's traditional experiential learning cycle[1] which was based on Piaget and Dewey theories[2,3], which has been there as a foundation for all recent developments of teaching and learning. In addition Lewin's suggestions of how a student can learn via the route of feedback[4], making a stronger case of visualising the student data, and the need for generating data that will be able to measure and guide any intervention needed. Being open and transparent with the Institutional data, we develop greater social acceptability[5]. By seeing the students as partners, by understanding what student engagement means for each individual, we understand better as educators the challenges we are facing[6,7]. This, of course, is undoubtedly not a straightforward scenario and it can be affected by data protection legislation. Using personal data is becoming more sensitive nowadays. In this research, Learning Analytics were used fundamentally to try and bridge the gap between student data, measuring student engagement and institutional policies. The research, is proposing strategies on understanding the student data, how the data can be used at the local level and proposes a conceptual framework for achieving such strategies to improve desired outcomes.

2 Student Engagement in Higher Education

Student Engagement is becoming a core area of research across many UK Institutions. Gradually students are invited to suggest views and often make changes to the curriculum and/or research. The growth of roles, responsibilities and opportunities that arise from such potential collaborations, increase the student involvement but at the same time it creates a lack of clarity over the definition of "Student Engagement". Common questions we often hear at conferences, policy and curriculum meetings are "when is a student engaged?", "how do we measure student engagement?", and "what stops students from engaging?".

In 2016 the UK Higher Education faced the introduction of the Teaching Excellence Framework (TEF)[8]. This framework aims to measure the retention rates of each institution, student satisfaction and employability. The UK HE sector is making an attempt to analyse and understand the various data that it is holding and extract common patterns for which policies can be implemented. In order, though to achieve this, the HE sector needs to fund the area of learning and data analytics in order to understand the complex nature of the data already

collected but also the future data. The figure below shows how student experience is being influenced these days and the main areas students can affect.

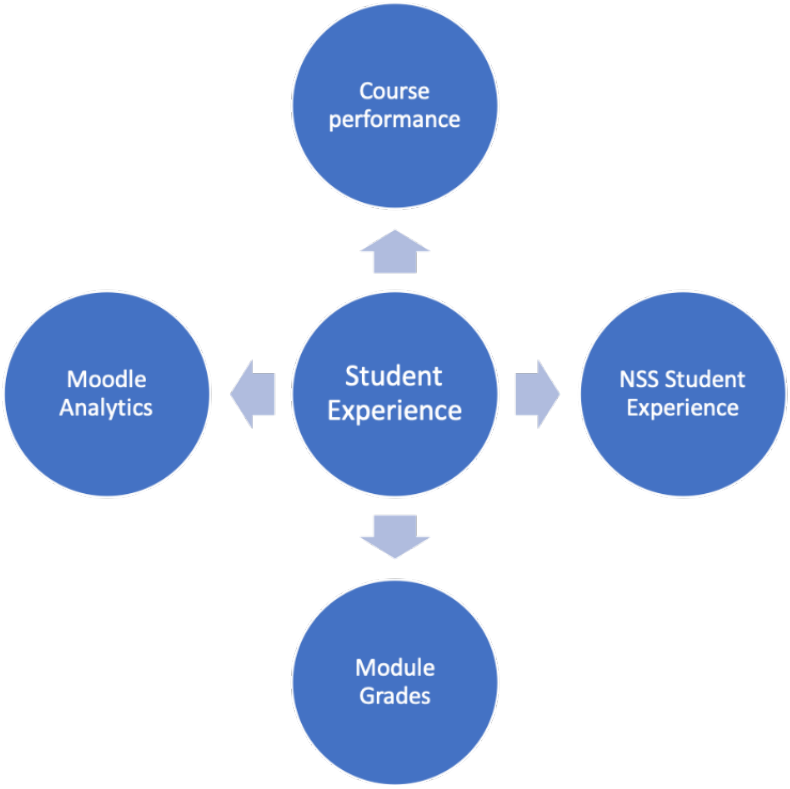

Fig. 1. The student experience that influences institutional NSS result and ranking.

The authors, reinvestigated the current UK Higher Education climate, analysing the current Learning Analytics process and it was apparent that the institutional focus across the UK was mainly on data collected by the establishment and what the latter can do with such data. For the purpose of this study, the authors approached the data from the student perspective. Thus, the data collected and analysed had to tell a story where the student can use the data for their continuous personal development and reinforcing their learning. The questions that started formulating were around attendance, module grades, overall course grade and of course how all these define student engagement. Some argue that when face to face interaction is present, then the students perform better.

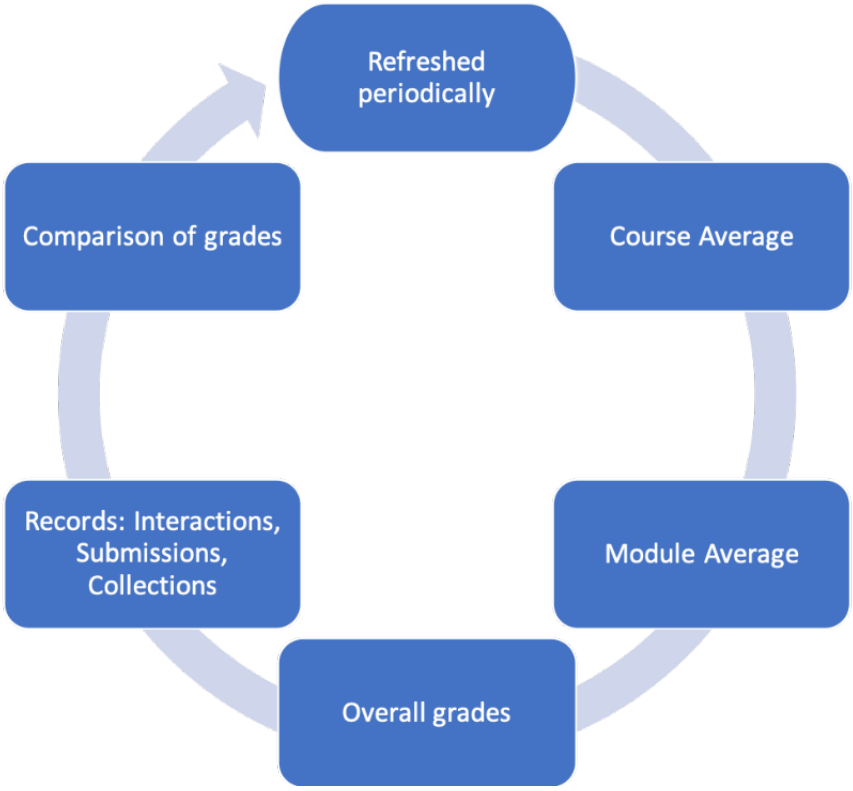

Fig. 2. Learning Analytics application cycle.

3 The Case Study

Higher education institutions are collecting vast quantities of data; however, the data collected only shows a narrow insight into students learning and development. The institutions can only analyse the data that has been produced on university systems or while a student is on campus, this can produce a bias in the data which during analysis can lead to misinterpretation. The literature suggests that student engagement is closely linked to the students' desired outcomes from university and can attribute to students persistence, educational attainment and their learning and development [9].

The authors designed an application to provide students with a broad picture of their learning behaviours while fostering student engagement. It was identified that student participation is essential to gain a comprehensive view as there are many learning activities for example "Writing up Notes" that without participation from the students it would be impossible for universities to collect and analyse. Ifenthaler and Schumacher[10] conducted a study on "Students perceptions of privacy principles for learning analytics". The results show students are more willing to share their data with a learning analytics solution that also provides them with detailed and meaningful information. The aim of the application was not merely to get students to add data without anything in return; the application provides students with intuitive data that can be used in self-evaluation.

The application has three main components; the first allows the student to view and add learning activities, giving the student the ability to monitor how long they are spending on each learning activity they are also able to compare themselves with the average of his or her peers. The second component of the application allows users to set personal targets for learning activities and modules which can keep them on track or to push themselves to spend more time on a particular activity. The final component of the application facilitates interaction with a member of staff during sessions. Students can ask anonymous questions which the lecturer can see in real time, giving students the ability to engage in a dialogue without fear of asking a question that might seem irrelevant to their peers. The lecturer is also able to poll the room they can define the question and what each of the three responses are, allowing them to quickly gauge students' understanding of the material and make their sessions more interactive.

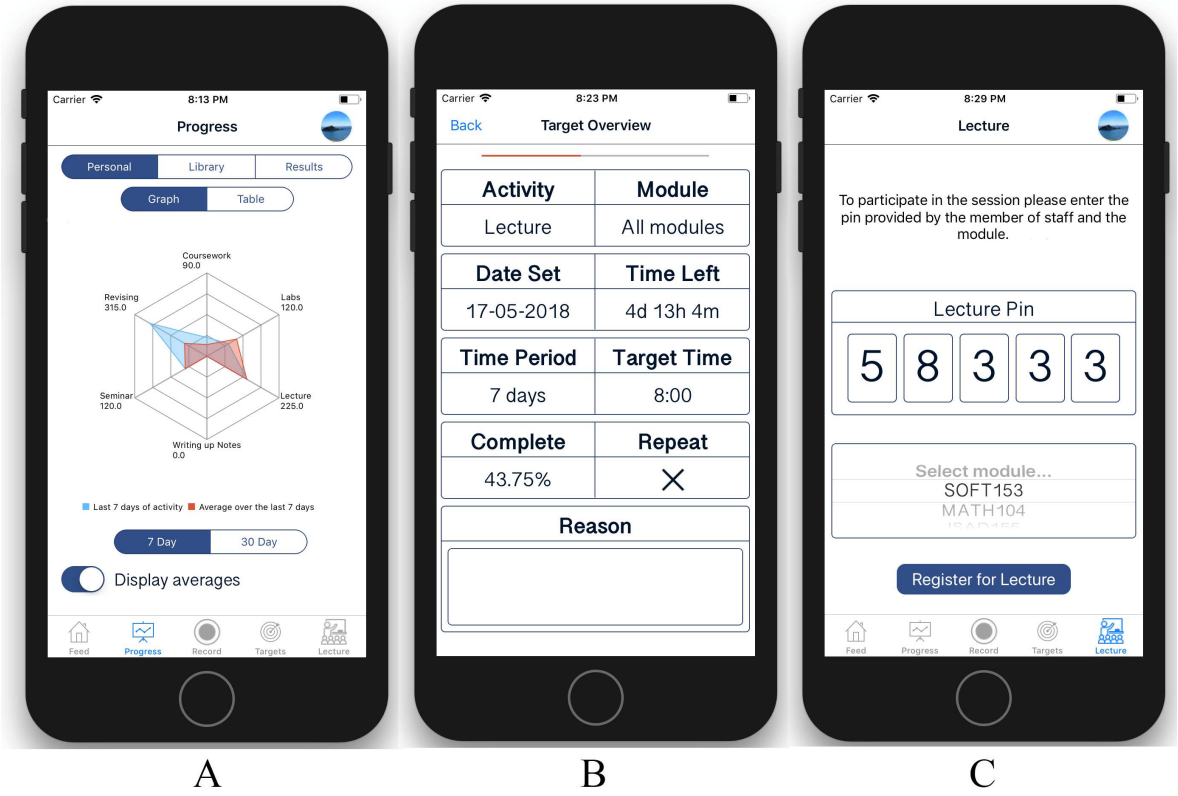

Fig. 3. User interface of proposed application: A: Overview of students progress, B: Detailed overview of a target and C: Lecture registration

4 Discussion

As the authors reflected on the outcomes of the app, it was evident that there is a high need to use the available institutional data not only for the benefit of improving HE policies, but also to offer the students direct access to their profiles, give them the opportunity to identify areas of development and self

awareness. Big Data is becoming increasingly important research across the society. In Education, the collection of data over the years has been massive, but it has not been used in an attempt to provide definitions and terminology that will be useful to both educators and students. During this research, by reversing the focus of data and the outcome of them we have defined the below definitions of Learning Analytics[11].

Table 1. Definitions of various types of Analytics suitable in HE

Term	Definition
Academic Analytics	This is where the focus lies with processing the analysis of assessment and perform comparisons across individuals, institutions and programme/courses. This helps Schools and Faculties to define the career pathways they are offering and the development of them. In addition, it helps to evaluate teaching and learning approaches and identify areas where intervention is needed.
Learning Analytics	Interpreting the data that are being gathered on behalf of the students and identifying their learning objectives and how that feeds back to the module and its allocated assessed element is an aspect that at least UK establishments are not implementing fully. The desire though to produce and predict student progress is vital; this can be achieved by observing learning behaviours and data associated with it.
Predictive Analytics	In this category the need to identify patterns of reliable conclusions in order to lead to actions that demonstrate impact and change across one or more educational establishments.
Action Analytics	Recognising the high need for academic productivity can be achieved by focusing on encompassing practices, and measuring the innovation and performance by cultivating and shifting behaviours and cultures.

The development of the proposed app has led the authors to propose a conceptual framework of how an establishment can use the data collected to support students' personal and continuous development. Since it is acknowledged that data are collected at different levels and for different needs, it is proposed that Higher Education should start focusing on using Learning Analytics for the benefit of the individual learner and not just for benefiting the institution's goals[12]. The figure below shows how decision making can be influenced, informed and reinforced by the process of applying analytics to a Higher Education establishment.

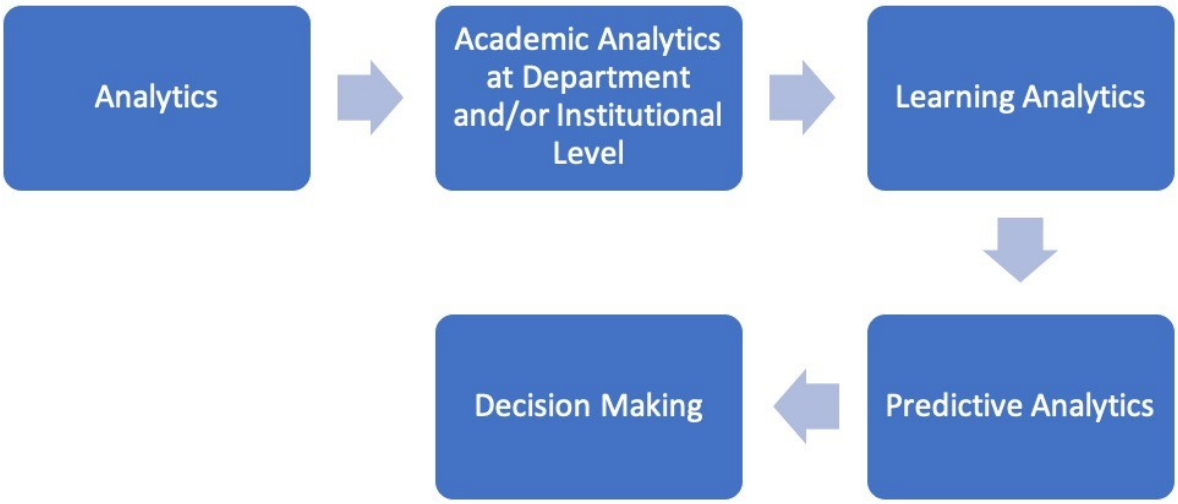

Fig. 4. Conceptual framework of Learning Analytics and Decision Making in Higher Education

5 Conclusion

Learning in Higher Education is increasingly becoming a large area of research. It is mostly common that Institutions develop and research this field for the benefit of the tutor. However, in our research we have placed the focus on the student and it is aiming at developing such an approach where learning analytics will be used by the students. This is the beginning of our research and case study and we intend to investigate in a variety of future research questions such as what institutional resources do we need? How can we integrate analytics and learning to design teacher inquiry? What is the technical, financial, social and cultural impact on institutions?

Data can change everything. Learning Analytics in Higher Education is an evolving process, with no clear start point and no clear end point. Predictive analytics should help not only individual students, but in the bigger picture, it could help institutions to identify recommendations around realities and implications. Analytics is becoming an important part not only for Higher Education, but also businesses. It is an emerging technology and the interactions behind it can lead to successful summarised reports and displays. Business intelligence techniques assist the analytics techniques to continue to grow and to enable better decision making. The responsibility of the researchers investigating and manipulating such data is great and this is an area that still lacks guidance in the modern world. With the 4th Industrial revolution the philosophical approach and personal beliefs of the researchers can impact on efficacy. Researchers often focus mostly on exploring the various dimensions of learning analytics. What it tends to be missing is the analysis of learning outcomes, how those are measured, what patterns can be formulated and how the latter can enforce and reinforce decisions. Transparency is a key aspect of any form of analytics and especially

when it comes to education, institutions and their direct relationship to the students and the student experience.

Social conditions change rapidly. Social networks, forms of communication, the Internet of Things and so many other things influence but at the same time inspire every individual and in this case the students. Student demand is growing. There is emerging evidence that students wish to be provoked, challenged and pushed in their learning. Moreover, they want to be more informed about their learning progress. The possibilities of expanding the Learning Analytics process for every Higher Education establishment are huge. Institutional decisions should be carefully informed by using Learning Analytics in such a way that is a collaborative approach between the educators and the students. This way, Higher Education will be in a good position to deliver but also to enable success.

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An Exploratory Data Analysis of the Ability of Western Musicians to Cope with Latency

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Abstract. Technology based on networks has long ago become state of the art for music recording, concert venues and even as a medium for collaborative performances over the Internet. However, there is a drawback attached to this technology. Latency is a permanent issue associated to any network technology. On the other hand, musicianship relies on time perception. The performance of music and playing an instrument are activities highly affected by latency. The present paper describes a methodology in order to measure how latency and the performed western musical instruments are related. In addition, the latency tolerance range (LTR) is presented as a comparison measurement between the different musical instrument groups. The results are based on the exploratory data analysis of the gathered data.

Keywords: Latency · Latency Tolerance Range · Tempo · Musical Instrument Groups.

1 Introduction

Research on the issue of latency and musicianship is focused on timing and the improvement of network technical conditions, in order to enable collaborative performances [7, 3, 4]. This paper presents the exploratory data analysis of empirical observations of solo-playing musicians performances known as non-collaborative performances. To gather the data, a methodology was developed using a listening test setup and a questionnaire. The exploratory analysis and the numerical results may enhance the knowledge framework regarding the latency issue and the performance of music, enabling comparisons between different musical instrument groups. Beyond a further understanding of musicianship and the relation between performer and musical instrument, the outcome delivers important information for the design of virtual musical instruments where issues, such as haptics, virtual acoustics and immersion play a primary role.

2 Methodology

A total of 31 test subjects playing 17 different western musical instruments took part in a listening test and answered a questionnaire. Every musician played only his or her main musical instrument. The different musical instruments were divided into the groups of aerophones, chordophones, membranophones and idiophones based on the Hornbostel-Sachs taxonomy [8].

The setup of the listening test is described in [6] and consisted of an audio interface, a cardioid pattern microphone, headphones, a laptop with a digital audio workstation (DAW) and a 7-inch monitor as shown in Figure 1. The musician played his/her instrument, the audio signal was recorded and sent back delayed (latency was introduced progressively) to the musician's headphones, until the test subject was not able to play any more and disrupted the performance. Three different metronomes (aural, visual and aural-visual) were used as a control mechanism. In addition, a predefined score was the same for every test subject. The notes of the score defined a specific pitch and it was used to enable equal conditions to all participants while playing the musical instrument, comparisons between results are possible. Some membranophones and idiophones have no definite pitch. However, variations on the timbre of all different instruments are expected due to the spectrum and envelope characteristics. Having more than one frequency component traduces in a vibration response in different places along the inner ear [9]. The impact of the musical instrument frequencies with relation to the latency issue is irrelevant at this level.

Fig. 1. Listening test setup

Every one of the 31 musicians played the music score five different times according to the tempi 90 BPM, 120 BPM, 150 BPM, 180 BPM and 210 BPM, using a different metronome each time. The three metronomes were regulated using the MIDI protocol and have not been delayed. At the end of the listening test, 15 different latency values were gathered (5 tempi and 3 metronomes).

It is possible to define the total latency of the system used in the listening test by means of the following mathematical expression:

$$Lt = La + Lc + Ld \tag{1}$$

L_t is the total latency, which is usually measured in milliseconds. The total latency is the sum of the latency due to the sound transmission L_a, the latency produced by the analog (sound waves) to digital (information in the DAW) to analog (sound waves to the headphones) conversion L_c and L_d which is the network latency simulated in the listening test.

The latencies L_a and L_c can be considered constants. The value L_c was measured and was the same for every listening test (12.208ms). On the other hand, the value of L_a is directly related to the distance of the microphone to the instrument as presented in Table 1. Prior to the beginning of each listening test, the distance microphone to instrument and the sound pressure level (SPL) of the musical instrument were measured, in order to guarantee equality of conditions. In addition to those measurements, the level gain in dB of the microphone and the headphones, as well as the reverberation time (RT60 in seconds) and noise level of the different rooms were measured. The information presented in Table 1 summarizes the range, median, mean, variance and standard deviation for the 31 test subjects (nbr.val).

Table 1. Listening test related measurments.

	Mic. dist. (m)	Inst.dBSPL (A)	Mic. gain (dB)	HP gain (dB)	RT60 (sec)	Room dBSPL(A)
nbr.val	31	31	31	31	31	31
min	0.23	75.10	0.00	-10.00	0.30	31.20
max	0.71	96.40	12.00	10.00	1.64	38.70
range	0.48	21.30	12.00	20.00	1.34	7.50
median	0.39	83.40	10.00	-5.00	0.50	33.50
mean	0.41	85.40	6.52	-3.23	0.51	33.62
var	0.01	29.48	24.26	57.58	0.06	5.82
std.dev	0.11	5.43	4.93	7.59	0.25	2.41

Based on the information presented in Table 1 it is clear that all of the instruments were recorded under similar conditions. Furthermore, the results of the first column have a very low variance, which means that the distance between microphone and instrument was almost the same. In other words, L_a, which is the latency produced due to sound transmission, can be assumed as a constant.

The value L_d, which is the simulated network latency, is the numerical outcome of the listening test. As stated before, musicians played the score while listening to their own delayed[3] signal (latency was introduced). The score consisted of two bars and was played in a loop. Every second repetition (4 bars), the delay was increased by 10ms. The latency range L_d variated from 0 to 300ms. At 0ms only L_a and L_c were present and imperceptible for the majority of musicians. The latency value L_d was obtained by a performance disruption, when the musician interrupted the performance the value L_d was notated.

3 Exploratory Data Analysis

After having collected the different latency values L_d, in addition to further numerical information of the questionnaire such as age, hours of instrument practice with and without metronome and years of experience on the instrument, it is possible to visualize the information in a scatter plot as presented in Figure 2.

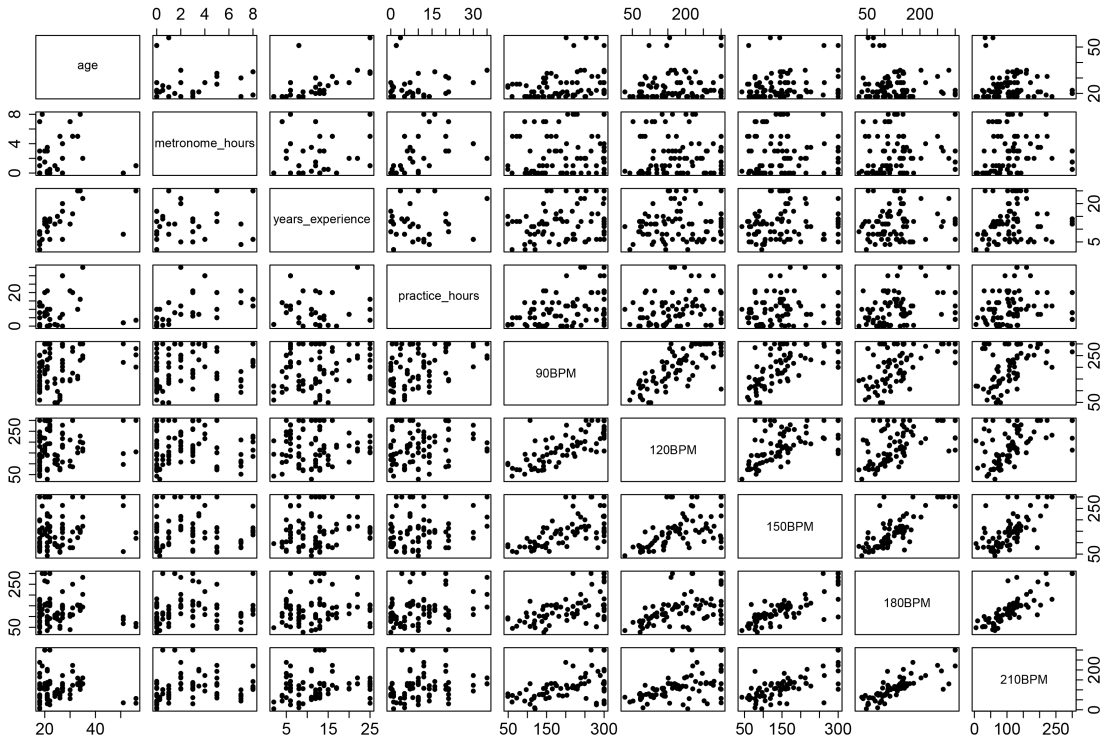

Fig. 2. Scatter plot matrix for all numerical variables

[3] The concepts of latency and delay are the same for this work.

In Figure 2, every numerical variable is plotted against each other. The variables are written on the diagonal and all relationships above and under the diagonal are mirrored. The numerical scale for age ranges from 0 to 50 years, however mainly young European musicians took part in the research. The scale for the years of experience ranges from 0 to 25 years, practice hours with metronome from 0 to 8 hours and without (practice hours) from 0 to 30 hours. Finally all latency values (L_d) distributed according to the five different tempi (90 BPM to 210 BPM) have the range 0 to 300 milliseconds.

The linear trends in Figure 2 are easy to identify for columns five to nine, which are related to the latency values L_d. Additionally, another linear relationship is present between age and years of experience (column 3, row 1) which is obvious. The older a musician is, the more years of experience he or she has. On the other hand, it is interesting that no visual relationships exists between the years of experience, musical practice with and without metronome and the latency values L_d for the different tempi. It may indicate that those variables have no meaningful role at all, regarding the ability to cope with latency.

A further procedure is to visually analyse the shape of the distribution. Figure 3 presents the explorative data analysis (EDA) for the distribution of the gathered data.

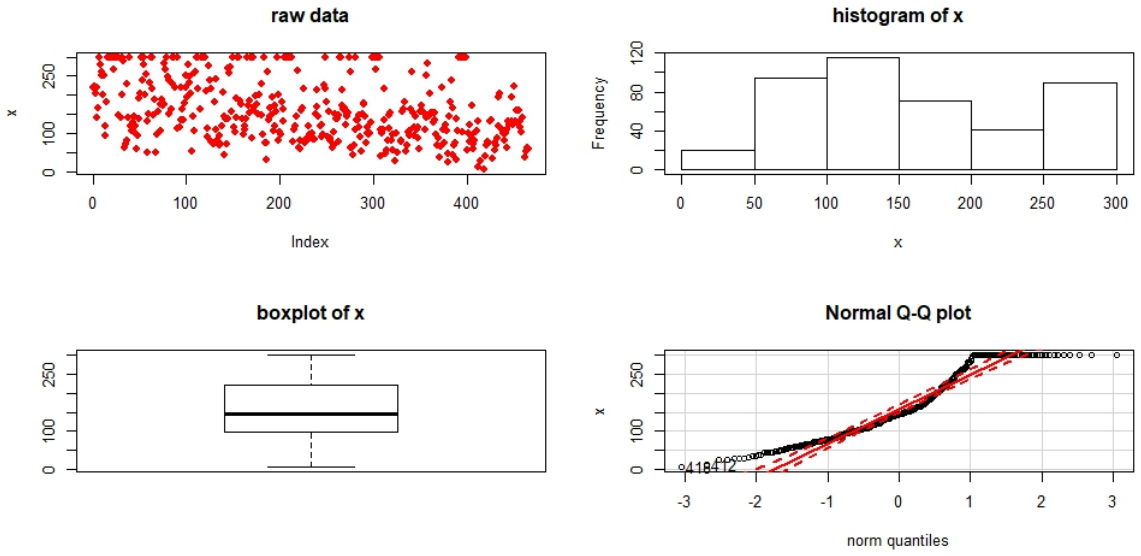

Fig. 3. EDA for the obtained data distribution

From the raw data plot in the upper left of Figure 3, two details are clear. Firstly, the data has not a random distribution and secondly, the data shows a decaying behaviour. The next plot on the right is a histogram, additional to the observation regarding a non-normal distribution. It is also possible to see the outliers (data in the 300 bar). Finally, the lower right plot (Q-Q plot) confirms that the data is non-normally distributed. The confidence intervals (red dashed lines) are clearly overpassed.

Table 2 lists all musical instruments that have been analysed. The selection of test subjects was not completely random. This purposive sample represents a virtual population and constitute a random sample [2].

Table 2. List of musical instruments

Subject	Instrument	Group	Subject	Instrument	Group
1	Piano	Chordophones	17	Trombone	Aerophones
2	Piano	Chordophones	18	Violin	Chordophones
3	Cello	Chordophones	19	Triangle	Idiophones
4	Cello	Chordophones	20	Tenor saxophone	Aerophones
5	Classical guitar	Chordophones	21	Classical guitar	Chordophones
6	French horn	Aerophones	22	Violin	Chordophones
7	Alto saxophone	Aerophones	23	Snare drum	Membranophones
8	Violin	Chordophones	24	Alto saxophone	Aerophones
9	Trumpet in B	Aerophones	25	Triangle	Idiophones
10	Snare drum	Membranophones	26	Marimba	Idiophones
11	Piano (upright)	Chordophones	27	French horn	Aerophones
12	Snare drum	Membranophones	28	Double bass	Chordophones
13	Violin	Chordophones	29	Harp	Chordophones
14	Transverse flute	Aerophones	30	Bassoon	Aerophones
15	Trombone	Aerophones	31	Tenor saxophone	Aerophones
16	Timpani	Membranophones			

In Figure 4, data from the three different metronomes (aural, visual and aural-visual) is presented and data from similar instruments, e.g. piano (1), piano (2) and piano upright (11) have been averaged. Figure 4 represents the latency value (L_d) vs. tempo in BPM. This relationship is known from Barbosa [1] as the latency adaptive tempo (LAT).

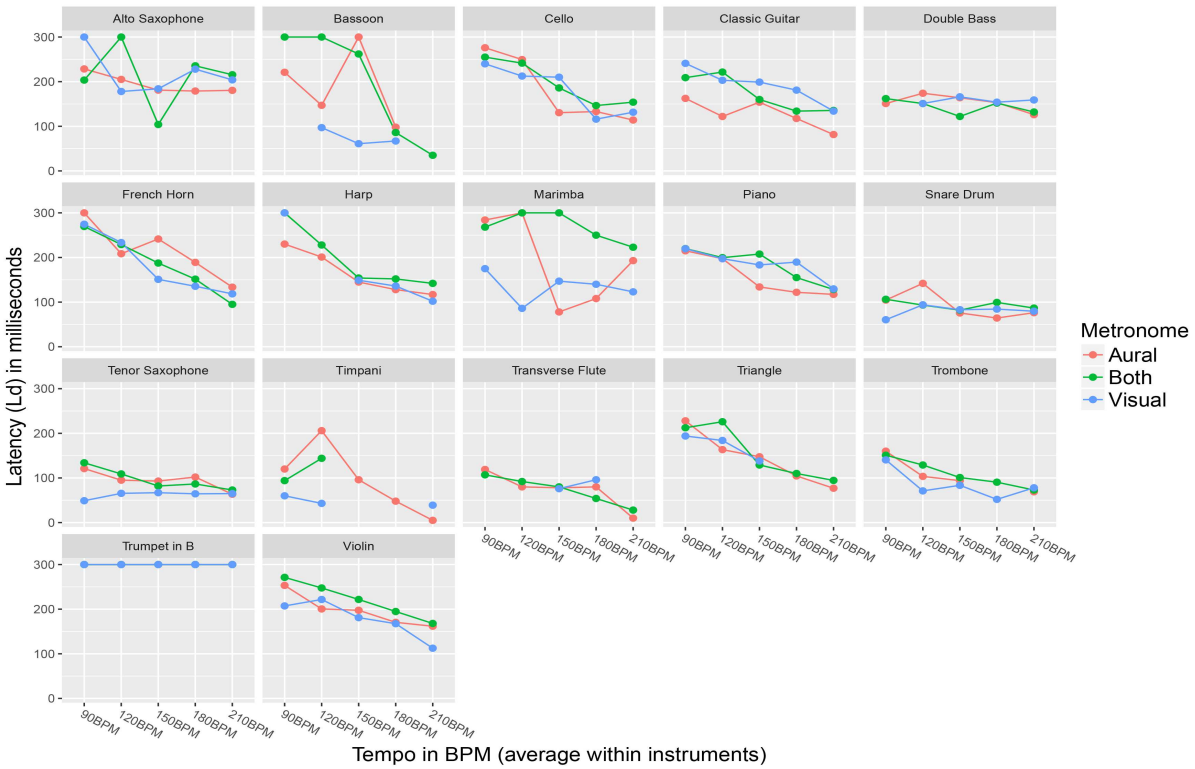

Fig. 4. Latency values (L_d) for the three metronomes (aural, visual and both) according to tempo

It can be noticed that there are very few differences between the results of the different metronomes (except for instruments such as marimba, bassoon and alto saxophone), therefore, it may be possible to average the latency results L_d of the three different metronomes. Observing Figure 4, it is clear that choosing a western musical instrument has an impact regarding the ability to cope with latency. For example, a musician playing the snare drum tends to interrupt the performance earlier (lower latency value L_d) compared to a cello player.

The data of all musical instruments, according to the different five tempi of the experiment could be presented using the kernel density estimation (KDE). The KDE is a smoothed version of the histogram [5] and determines the shape of distribution. In Figure 5 the kernel density estimation for a continuous value L_d is presented.

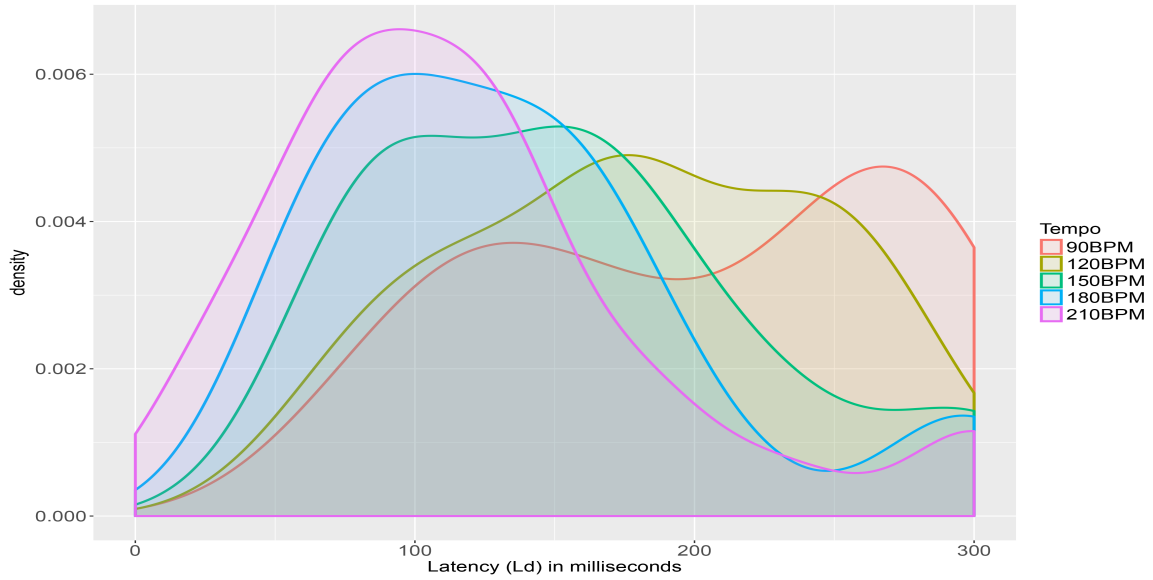

Fig. 5. Density plot for all instruments according to the different tempi (average of all 3 metronomes)

It is important to state that the listening test delivered only five discrete latency values L_d, according to every tempi and to every metronome, as seen in Figure 4. For the Kernel density estimation (KDE) in Figure 5, the values of every metronome (aural, visual and aural visual) were averaged.

Figure 5 clearly shows the peaks for the latency values L_d. The higher the tempo (210 BPM and 180 BPM) the narrower the peak. It indicates that by playing at higher tempi, all musicians stop the performance at approximately the same latency value L_d. For the tempi 90 BPM, 120 BPM and 150 BPM there is no observable narrow peak. On the contrary, for some tempi (90 BPM) there are more than one peak and different values of L_d present. It might suggest that different musical instruments have dissimilar latency values L_d, where the performance is interrupted. The lower peaks at 300ms (right side of Figure 5) are produced by those musicians who were able to play even at the higher latency values (L_d) up to 300ms (e.g. trumpet in B). Those values of L_d can be assumed as outliers.

3.1 Latency Tolerance Range

The measure of the latency tolerance range (LTR) is the estimation of a range in milliseconds where latency is tolerable according to the different musical instrument groups. The (LTR) can be defined as the difference between the third and first quartile of the gathered data and is better suited than the mean or median to describe non-normal distributions.

The latency tolerance range (LTR) is measured in milliseconds and its mathematical expression is:

$$LTR = Q3Ld - Q1Ld \tag{2}$$

Figure 6 displays the LTR for the different musical instrument groups based on the gathered data. As expected and based on the information of Figure 4, the LTR for membranophones is very narrow compared to the aerophones group. At this point, it is important to clarify that only few instruments (snare drum and timpani) are part of the membranophone group. On the contrary, the group of the aerophones involved more than six different instruments. The groups of chordophones and idiophones are similar in range but as the number of instruments differ, comparisons may be difficult.

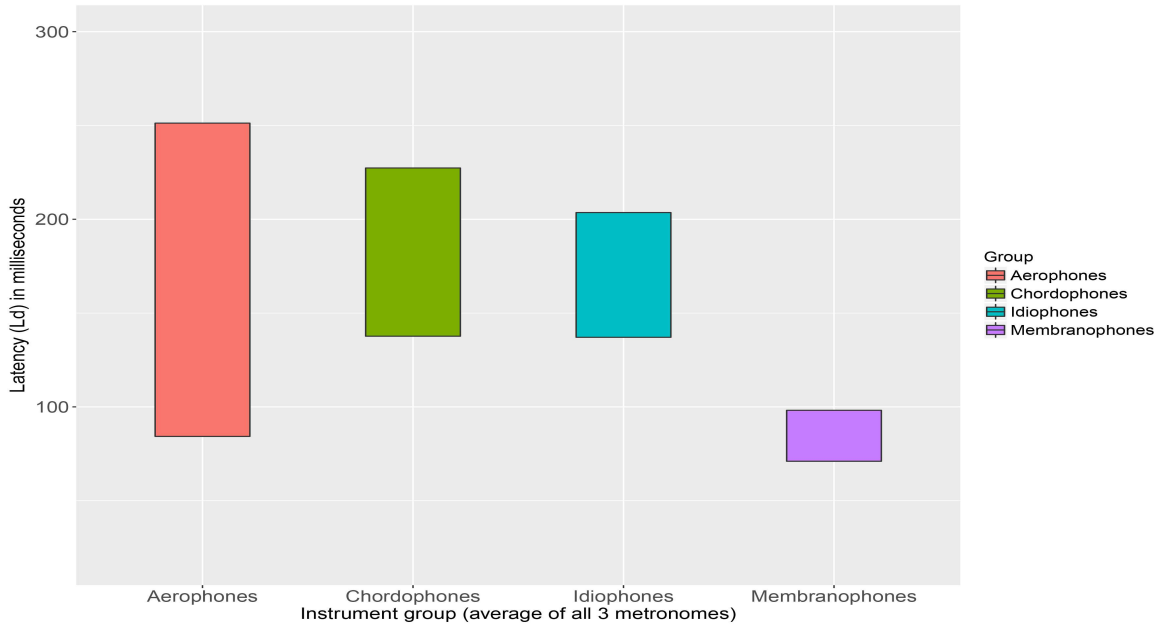

Fig. 6. Latency tolerance range (LTR) for musical instrument groups

The latency tolerance range is dependant on the amount of data gathered. However, the tendency is clear. Playing a membranophone may be a difficult task regarding latency. Aerophones, chordophones and idiophones may perform music as an ensemble within similar latency ranges, without any inconvenience.

4 Discussion and Conclusions

The present paper presented the exploratory data analysis of a controlled listening test. The research design and test characteristics such as the use of a

metronome and a score enabled comparisons of the results. Based only on the exploratory data analysis of the gathered data, it is possible to claim that the ability to cope with latency is affected by the musical instrument played. Performing on different musical instruments may have an effect on the ability to cope with latency. Furthermore, the years of experience playing an instrument, the hours of practice and even the use of a metronome while practicing may not affect this ability at all.

The unbalanced design regarding the number of musical instruments tested per instruments type and the lower number of test subjects or musicians might diminish the external validity of the outcomes. However, there are clear tendencies and patterns and the effect is far from random.

The influence of the musical instrument, regarding the latency issue, decreases while performing at faster tempi above 180 BPM. On the contrary, this influence increases by playing a musical instrument at lower tempi under 150 BPM. In addition, the latency tolerance range (LTR) enable the comparison of results regarding the issue of latency between the different musical instrument groups.

The results and the methodology presented, may constitute a further step in the modelling of musical instruments for technologies such as virtual reality. Moreover, based on the results presented, software requirements for artistic and educational projects, such as network musical live performances and distance learning programs can be further developed to fit better the requirements regarding musical instrument groups.

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Value of Smart Data for Supply Chain Decisions in a Data Rich, Uncertain World

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Abstract. Data-driven decisions are becoming increasingly relevant for supply chains as traditional paradigms are being replaced with concepts and approaches more suited for the advent of big data. However, the prevailing consensus is that companies are struggling to cope with an overabundance of data, which presents the following pertinent question: how to efficiently analyze data applying filters of relevance and insightfulness to make effective decisions? There is currently a lack of research focus on providing quantitative tools to do such analyses. This paper, besides offering thoughts on decision-making uncertainty in a digital supply chain context, describes an approach to address the research gap. The approach (which involves developing a quantitative model) is further elucidated by utilizing an example in the agricultural supply chain that illustrates how value of data can be quantified by measuring the performance impact of insights delivered using uncertainty reduction as the leverage.

Keywords: Supply Chain Management, Digital Technologies, Big Data Analytics, Uncertainty, Data Driven Decision Making, Value of Data.

1 Decision Making Under Uncertainty in Digital Supply Chains

In designing and analyzing supply chain processes, the theoretical frame of "hierarchy of decisions" has often been used [1]. This view, that segments processes according to scope and significance, into strategic, tactical and operational, acknowledges the pivotal role of decision making in Supply Chain Management (SCM).

The decision-making process in SCM, as also in the general sense, is crucially about choosing a course of action by assessing alternatives and settling on one "that is most likely to result in attaining the objective" [2]. In this way, the efficacy of the process hinges heavily on the ability to parse and understand uncertainty in the states of the world associated with the alternatives. This notion of uncertainty is at the heart of the Organizational Information Processing Theory (OIPT) that posits uncertainty as the disparity between information processing need and corresponding capacity, and links it to process and organizational performance [3].

In the current environment characterized by supply chains readily embracing digital technologies and transforming themselves into Digital Supply Chains (DSC), decision making under uncertainty presents an apparent contradiction: the abundance of data afforded by digital technologies would lead one to expect DSCs to be exploiting this

opportunity to achieve parity in the OIPT sense (between information processing need and attendant capacity) and drive improved performance resulting in a higher utilization of data. However, various studies show that most digital data that is captured is not utilized [4] and less than 1% of unstructured data is analyzed at all [5]. Research in the areas of digital transformation and Value of Information (VOI) offer up some clues to clarify this contradiction.

Digital transformation is about innovating new business models and ways of value creation and capture, focusing on the dual outcomes of customer engagement and integrated digitized solutions. It is perhaps better understood by contrasting with a related term – digitization, which on the other hand, is a narrower technology-centric view [6]. Not surprisingly, supply chains that focus on transformation perform significantly better than peers [6]. On the other hand, a lack of transformation focus leads to unmet expectations and such companies are apt to complain, as have six out of 10 respondents in this survey of 3000 executives, of having more data than they can use effectively [7].

A related line of research inquiry concerns VOI in a big data context. Research into Information Systems (IS) following IS economics tradition highlight the lack of tools to quantify data and the need to address the challenge of "finding a way to quantify the value of information that considers both insightfulness and risks" [8]. The two lines of inquiry are linked, and the convergence is in the fact that supply chains that are transformation focused are more likely to want to justify investments and therefore also want to quantify value of data - and this is where this research aims to contribute.

2 Approaches for Measuring Business Value of Data

2.1 State-of-the-Art

Using a resource-based view, which holds that heterogeneity of organizational resources is a source of value (as it differentiates a firm from competition), Melville et al. [9] argue for consideration of competition and environmental factors to measure value of data as they are seen to impact value. Higher the level of competition or industry concentration, higher is the marginal product and, conversely, lack of competition creates slack resources leading to lower productivity [10]. Environmental factors or external focus, on the other hand, is seen to enhance performance as timely and accurate information regarding a firm's external environment are preconditions for agility [11].

Besides several empirical studies that adopt a general view on the impact of data on value and emphasize the link between data-driven decision making and firm output and productivity (see [12, 13] for representative examples), there are also several studies on particular problem instances. Ketzenberg et al. [14] assessed VOI in the presence of uncertainty around demand, return, and product recovery delivering a key insight that greater the uncertainty, greater is the VOI. Dunke and Nickel [15] incorporated forward-looking information in supply chain planning and proposed an optimization model that utilizes preview of future information with help of lookahead devices (e.g. sensors) to transform an uncertain future into a certain one.

2.2 Need for Further Research

The discussion above points to a wealth of empirical studies and models for specific problems. However, a general-purpose quantitative model with a normative character (elaborated in 2.3) is lacking. In a review of 117 articles on the topic of research contributions in this area, Viet et al. [16] had found that, in a supply chain decisions' context, there is disproportionate attention being paid to inventory whilst other areas have received insufficient attention. They also report that the impact of new and innovative data sources (e.g. sensor data) remains under-explored. In laying out a research agenda for future information systems research, Abbasi et al. [8] call for research on the "value of various data sources and channels in terms of quality of insights, enabling new capabilities, and quantifiable business value."

2.3 Model Conceptualization

Before describing the proposed model, it is instructive to go over key model attributes that were considered as prerequisites: (1) Quantitative: the overarching question calls for the ability to measure the incremental value of insights from digital data. This necessitates a quantitative-based model that yields a numerical solution. (2) Predictive: The model must emulate a decision-making process where the performance potential of data-driven insights can be studied. This requires the model to embody predictive or simulative capability. (3) Relevant: Zadeh's principle of incompatibility holds that complexity makes relevance and precision impossible to obtain simultaneously [17]. Therefore, the model needs to be built on a framework that lends itself to strike the right balance. From a performance measurement perspective, it needs to be inclusive (one of the key characteristics of a good performance measurement framework [18]) and not predisposed to any specific supply chain strategy. For instance, both cost (primary focus for efficient supply chains) and agility (primary focus for responsive supply chains) measures need to be supported. (4) Usable: as the key question being addressed most interests supply chain managers, the model should, despite its quantitative rigor, include a graphical component for the decision-making process to be analyzed visually as well.

The proposed model is grounded in the Approximate Dynamic Programming (ADP) methodology [19] (also called reinforcement learning). It is an active field of research that has a long history owing to its evolution from work done in optimal control theory and stochastic approximation (dynamic programming and Markov decision processes). ADP's choice as the model's underpinning is due to its suitability vis-à-vis prerequisites set forth earlier and its effectiveness in addressing the class of problems typical of the supply chain problem domain. One way to justify this claim is by noting the subcomponents of ADP and highlighting structural similarities between ADP and Supply Chain (SC) problems. ADP problem formulation consists of policy, reward, value and model environment. The solution involves an appropriate choice of *policy*, which is a set of endogenous controllable variables (e.g. reorder point in SC) in the face of uncertainty expressed by the *model environment* (exogenous information, for e.g., customer demand in SC) to maximize cumulative *rewards* or *value* (e.g. global perspective in SC). The approximate nature of ADP allows problems involving large state-spaces

(typical of SC) to be solved by using an approximation architecture. The approximation architecture or the learning element allows better policies to be adopted as the system learns to interpret the uncertain environment better and develops a more accurate picture of the (delayed) consequence of actions on value. For the proposed model, this last aspect is crucial to modelling the recalibration of uncertainty due to infusion of digital data. [20]

The model incorporates formalisms to represent key elements of uncertainty and digital data. For this research, uncertainty is viewed as an empirical quantity [21] that can be modelled as a probability distribution. Furthermore, a Bayesian view of probability is adopted (other view being frequentist) [21], which is suitable in this problem-context of decision-making where beliefs about states of the world are conditioned on all available information. Quantification of uncertainty is a relatively untapped aspect in stochastic optimization literature [22] but will be an essential component in the model as it impacts policy selection and consequently its predictive ability. In the case of digital data, a semantic model (for example, based on W3C SSN ontology [23]) is adopted that provides similar modelling rigor. Finally, for model visualization, System Dynamics (SD) approach is the primary candidate [24]. SD provides an intuitive representation of causal relationships between variables and their impact on performance.

2.4 Illustration of Model Aspects: Example in the Agricultural Supply Chain

The example pertains to the production and sales of seeds that starts with the production stage (that involves sowing, growing, harvesting, treatment and packaging) and culminates in the sales of seeds to farmers. The problem of estimating yield is the focus of the example and it helps elicit the salient model features.

Once sales projections are made, production is planned assuming a certain yield (using factors like crop physiology). However, this is at best a noisy or imprecise estimate and the reality at harvest time tends to vary widely from projections. One key implication is the planning of treatment and packaging capacity, which is often a bottleneck. If the capacity planned is insufficient, it leads to lost sales and higher than required capacity leads to poor utilization and impinges on profits. However, advances in digital technologies provide the ability to use sensors and the like, which act as lookahead mechanisms and can provide advance insights during the lengthy sow-grow-harvest cycle, which can help revise noisy prior estimates with updated, sharper posterior estimates. The dynamics of interaction are presented in **Fig. 1**. As can be seen from the illustration, relevant sensor data (e.g. weather, water content) that are predictors of yield when captured can be utilized to revise estimates and perform contingency planning in the form of organizing additional subcontracting capacity or shaping demand (promotions) to better match demand and supply. In this way, the proposed model emulates decision making with and without insights from digital data to evaluate the impact on metrics (e.g. backorders, capacity utilization). The key objective is to make the model suitable for assessing investments (for instance by facilitating small-scale experiments) by focusing on the potential for better decision making under uncertainty whereby return on investment can be calculated as a function of incremental value due to insights.

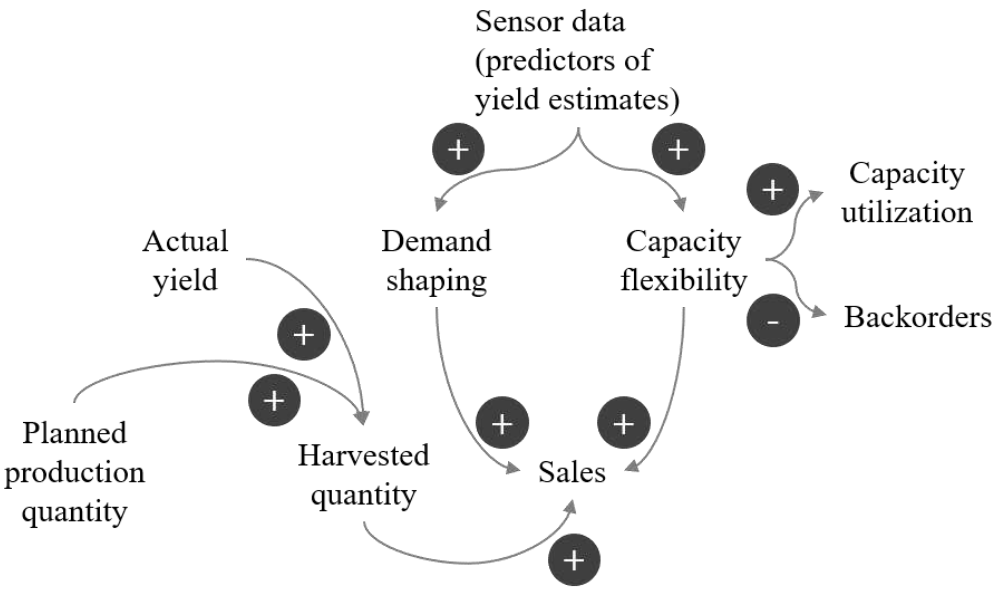

Fig. 1. An example of crop-seeds manufacturing and sales described in the text is illustrated. The increase of a certain measure causes an increase (+) or decrease (-) of the connected measure.

3 Conclusion

An implication of wide adoption of digital technologies by supply chains is the increase in decision-making complexity and uncertainty, which translates to a greater burden on information processing needs and capabilities. This strain is apparent in various studies that show that digital data is heavily under-utilized.

This paper proposed a quantitative-based model that assesses data in terms of its insightfulness, thereby enabling supply chains to address the problem of under-utilization and seeks to provide a means to evaluating digital data based on its moderating influence on uncertainty and its impact on process performance metrics.

The focus of the next stage of research is resolving design decisions pertaining to model conceptualization, which is followed by model development. The third and final stage will be model solving that is supplemented with a case-oriented proof-of-concept.

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Chapter 2

Internet of Things, Networks and Security

Beamforming Techniques Performance Evaluation for 5G massive MIMO Systems

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Abstract. The estimation of the direction of arrival (DOA) and beamforming are the effective methods for the realization of spatial diversity. Several approved algorithms already exist for DOA and beamforming. The purpose of this work is to verify the application of these existing algorithms for the massive multiple-input multiple-output (massive MIMO) antenna systems in the fifth generation wireless communication (5G). This investigation provides simulation results of adaptive beamforming techniques with various planar array configurations for massive MIMO and analyzes accuracy of the adaptive massive MIMO antenna diagram according to the 5G requirements. Results of the current research revealed that with the growth of the antenna elements from 128 not only the accuracy of the beamforming increases up to 4° resolution, but also null steering becomes precise, which provides interference suppression up to 340 dB and accordingly meets 5G requirements up to 5° precision.

Keywords: 5G, massive MIMO, DOA, adaptive beamforming, LMS, planar array, accuracy of beamforming, null steering.

1 Introduction

The development of the next generation wireless communication 5G demands much higher requirements in comparison to the previous mobile generation. According to the last technical specification, 5G technology should guarantee a higher capacity up to 7,5 Tbps/km^2, higher data rate up to 1 Gbps in DL and 500 Mbps in uplink (UL) [1] and accordingly substantially higher requirements for angular resolution in down-

link (DL) [1, 2]. 3GPP defines following angular resolution requirement: for moving UE with speed up to 0,5 m/s it is defined to be less than 5°, for the moving UE with speed up to 10 km/h it is defined to be less 10° and for the static UE it is defined be less than 30° [1]. To realize these requirements in 4th generation networks (4G) is impossible, so for 5G completely new technological solutions are needed. The massive MIMO technology in turn implies a large amount of antenna elements in arrays, which is a precondition for a successful DOA and beamforming applications. That's why the massive MIMO with its DOA and beamforming capabilities is one of the most promising technology, which can meet defined 3GPP requirements for 5G.

The combination of both techniques, DOA and beamforming, enables robust and spectrally efficient communication in a desired destination to a UE. DOA is a signal processing technique, which estimates the bearing of the source location of corresponding incoming signal. While an adaptive beamforming is a technique to form and to steer a maximum radiation pattern of antenna into the bearing direction of interest, whereas radiation pattern null are placed into the bearing direction of interfering sources [3, 4, 5]. In particular, in 5G network particular interest lies in the steering of the main lobe of the antenna, mounted on the Next Generation Node Base (gNB), to a special user equipment (UE) location [6].

Two techniques, DOA and beamforming, are associated with each other: firstly, it is necessary to estimate correctly a DOA of UE in order to set a corresponding direction of a beam from a gNB antenna, and secondly, to steer cooperatively a maximum radiation of antenna in the bearing direction of UE. This cooperation admits to carry out a reliable transmission between gNB and UE with high signal-to-noise ratio (SNR) and low interference impact.

The material in the paper is organized in the following order. DOA and Beamforming Techniques are formalized in Section 2. Simulation scenario and results are given in Section 3. Finally, we draw the conclusions in Section 4.

2 DOA and Beamforming Techniques

2.1 DOA Preliminaries

The initial condition of high precision beam steering is correct DOA availability. The estimation of the DOA is based on the measurements of time delays of incoming wave front to the different antenna elements. Desired signal for DOA is termed as signal-of-interest (SOI), whereby the interfering signal is termed as signal-not-of-interest (SNOI). There are different methods of DOA estimation [7]. The most popular of them are Capon's method, MUltiple SIgnal Classification (MUSIC) algorithm and the Estimation of Signal Parameters via Rotational Invariance Technique (ESPRIT) [3].

In this work we assume that DOA was correctly estimated beforehand, that is why we further consider mathematical preliminaries of beamforming techniques.

2.2 Beamforming techniques

The purpose of the beamforming is to generate a beam of a necessary shape and to direct it to a desired location in real time, while suppressing interference [8, 9]. To fulfill this, the signal processing on the gNB requires advanced beamforming capabilities [8]. There are various methods to accomplish beamforming, which are discussed in the further classification due to the different categories.

In [3] beamforming classification includes two realizations: *switched-beam* and *adaptive array*.

Switched-beam system realization utilizes predefined number of lobes in a beampattern and switches between them during connection. There are several switched beamforming techniques such as Butler matrix [10], Blass matrix [11], or Wullenweber array [12].

In adaptive array systems there are no predefined beams, but the antenna diagram changes its shape and direction toward each dedicated UE adaptively, providing more degrees of freedom. These technique is based on the so called *weighting* approach. This means that the complex weights w_i are instantaneously calculated by an adaptive algorithm (fig. 1), in order to direct the maximum antenna radiation pattern toward the UE and to steer null toward interference sources. In this sense the adaptive beamforming is an iterative approximation of an optimal beamforming [13].

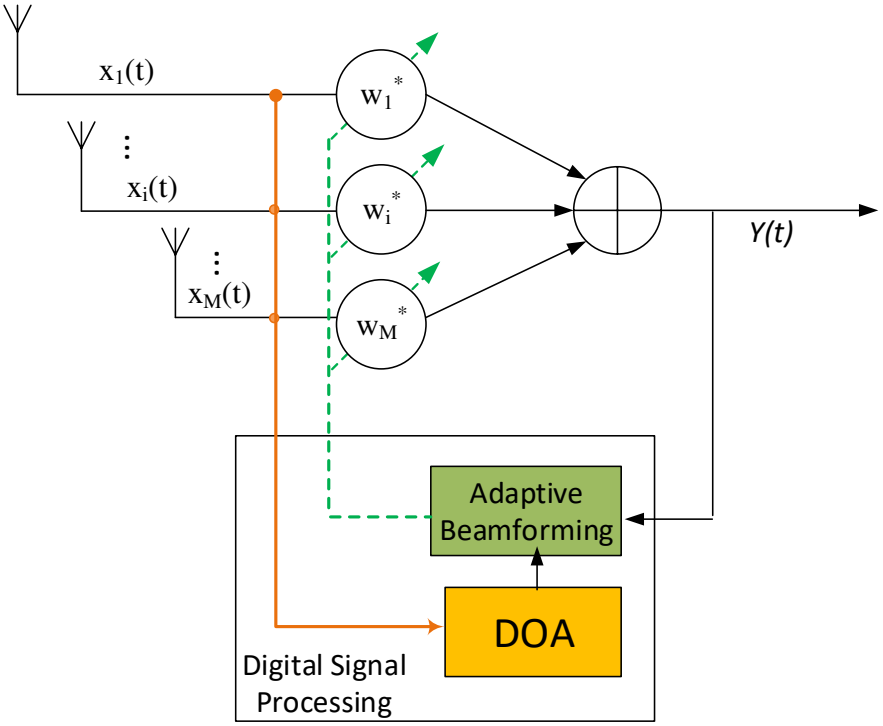

Fig. 1. Block diagram of DOA and adaptive beamforming cooperation [3]

The weights w_i can be generally described by [14]

$$w_i = p_i e^{j\varphi_i}, \quad (1)$$

where p_i is a gain magnitude and φ_i is a phase shift of i^{th} RF antenna element.

Output signal, multiplied by the beamforming weights on the receiving site, can be represented by [15]

$$y = \sum_{i=1}^{K} w_i^* x_i = \mathbf{w}^H \mathbf{x}\,, \tag{2}$$

where y is an output signal after receiving adaptive beamformer, x_i is a signal arriving from angle φ_i, **w** represents the K-length vector of weights, **x** represents the K-length vector of received signals and the superscript ^{H} is the Hermitian operator (conjugate transpose). Expressions (1) and (2) include calculations to emphasize signals from a dedicated direction while attenuating those from the non-of-interest directions, which can interfere with the useful signal. This process is called as adaptive beamforming. In this work the adaptive beamforming is the subject of investigation as the most attractive technology for the 5G wireless communications [16, 17, 18].

Various algorithms for the adaptive beamforming exist, while most widely implemented of them are Least Mean Square (LMS), Normalized Least Mean Square (NLMS), Recursive Least Square (RLS), Sample Matrix Inversion (SMI), and Hybrid Least Mean Square / Sample Matrix Inversion (LMS/SMI) [3, 19]. In current work and further simulations LMS algorithm is implemented as it is considered to have least computational complexity and high convergence stability [3, 20].

The functionality of the LMS algorithms is represented as follows. The output of the antenna array can be expressed as *y(t)* (3) [20]:

$$y(t) = s(t)a(\theta_0) + \sum_{i=1}^{N_u} u_i(t)a(\theta_i) + n(t)\,, \tag{3}$$

where *s(t)* denotes the desired signal arriving at angle θ_0 and u_i *(t)* denotes interfering signals arriving at angle θ_i ; a(θ_0) and a(θ_i) represent the steering vectors for the desired and interfering signals respectively; *n(t)* is additive noise.

According to the optimization theory approach, named gradient method of steepest decent, the definition of weights can be done by

$$w(n+1) = w(n) - \mu\nabla(E\{e^2(n)\})\,, \tag{4}$$

where *w(n+1)* is an updated weight, *w(n)* is a previous weight, μ is a step size and controls the convergence characteristics of LMS, *E* depicts an expected value of the mean square error $e^2(n)$, which can is described by

$$e^2(n) = [d - y]^2\,, \tag{5}$$

where one can observe that the $e^2(n)$ is mean square error between the beamformer output *y* and the reference signal *d*.

The gradient represents a vector of partial derivations of mean square error *E* with respect to weights:

$$\nabla(E\{e^2(n)\}) = \begin{vmatrix} \frac{\partial(E\{e^2(n)\})}{\partial w_0} \\ \vdots \\ \frac{\partial(E\{e^2(n)\})}{\partial w_L} \end{vmatrix}. \tag{5}$$

Using this LMS method, the following simulations were done in order to steer beam toward the desired signal and to place null toward the interfering one.

Another category for the beamforming classification can be defined according to the placement of digital-to-analog converter (DAC). If single DAC is used for all of antenna elements, *analog beamforming* term is used. In contrast to this, if multiple DACs are implemented after each antenna element and the processing of signals from all antenna elements is done simultaneously, then *digital beamforming* term is used. Both schemes have pros and cons.

Analog beamforming scheme has a lower power consumption and lower computation complexity then a digital one. From the other hand as only a single radio-frequency (RF) chain for all antenna elements in the analog scheme is available, it is possible to form a beam only to a single direction at any given time [6]. Whereby the digital scheme has more flexibility and allows to form a beam in many directions simultaneously. However, digital scheme requires a dedicated RF chain for each antenna element, which increases a transmit power.

To improve the power consumption parameters and still to benefit from the multiple directional beamforming at the same time the *hybrid* beamforming technique was developed. It combines the advantages from the former both and is recommended for 5G applications by 3GPP [21]. The DACs are coupled via RF chains (fig. 2) with the specified groups of antenna elements, but not with each of them, which reduces the power consumption and provides a sufficient number of analog beams into the different directions at the same time [6].

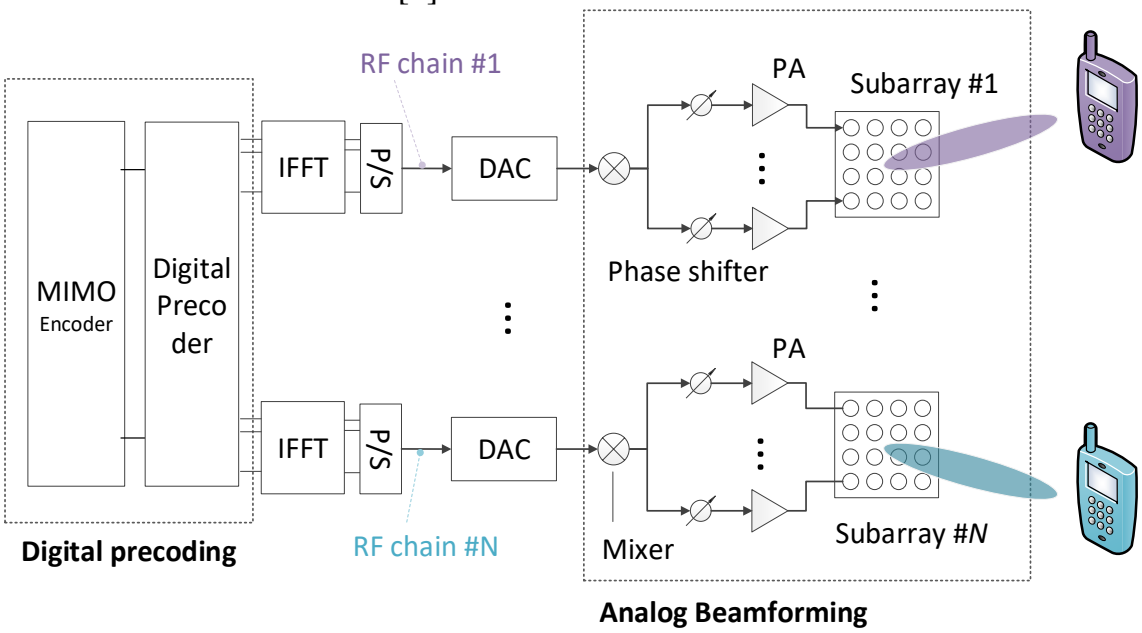

Fig. 2. Block diagram of hybrid beamformer [21]

The next one category in the beamforming classification is antenna elements configuration. Antenna elements can be arranged in various geometries, for example, in linear, circular or planar configurations [7]. In this work planar antenna array is investigated and simulated as it is recommended by 3GPP for 5G, where it is termed as uniform rectangular panel array (URPA) [22].

In the next section we will describe simulation scenario to illustrate our investigation.

3 Simulation Results

3.1 Simulation scenario

Given initial conditions in these simulations were chosen regarding to the 3GPP requirements for the angular resolution up to 5° in 5G wireless communications, as described in section 1. Namely the assumption for the simulation was made as follows (fig. 3), the UE with SOI is located with the elevation angle θ=32° and azimuth angle φ=50° related to the gNB; the interfering UE with SNOI is located close to the SOI UE with θ=36° and φ=54°, and results in only 4° deference between the SOI UE and SNOI UE in both elevation and azimuth direction. Therefore, this scenario assumption satisfies 3GPP requirement with 1° margin.

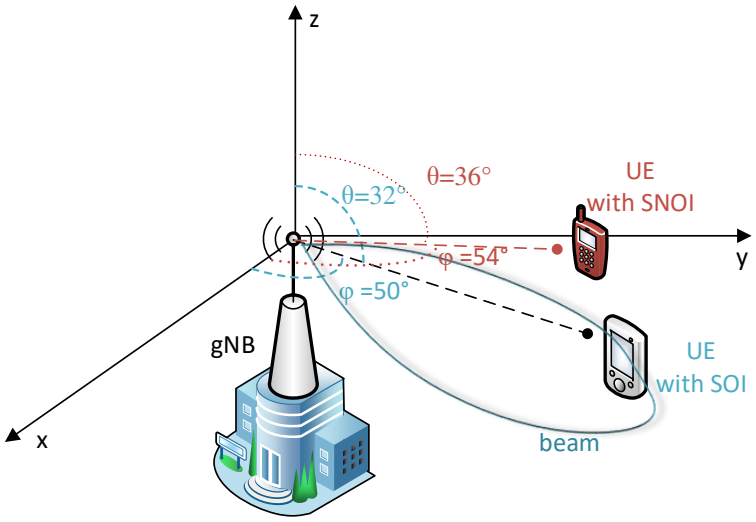

Fig. 3. Assumption of the UE positioning for beamforming simulations

The gNB antenna system is placed in the point of origin of the coordinate system. Fixing these positioning parameters for UEs and gNB, different antenna array configurations on gNB were investigated in order to investigate which configuration is appropriate to attain the beamforming accuracy in 5G requirements.

Another assumption in this simulation is that the DOA were estimated correctly and thereby known in advance.

As justified previously in this work, the adaptive beamforming with LMS algorithm and the antenna system on gNB with planar array were considered to be used for the simulation. The planar array was investigated with various number of antenna elements. As actual developments of massive MIMO systems are focused currently on antenna arrays with 64 and 128 antenna ports, in this work these antenna elements

number are taken as a foothold for the further investigations. To analyze the lower and upper boundaries, the planar arrays with 16, 256 and 1024 antennas elements were taken into the account. The sequence of simulation cases is considered as follows. The first scenario includes 4x4=16 antenna elements in a planar array; the second scenario 8x8=64 antenna elements; the third scenario 8x16=128 antenna elements; the fourth scenario 16x16=256 antenna elements and the fifth scenario includes 32x32=1024 antenna elements.

The goal of the simulation is to investigate, how precise is LMS beamforming and null steering technique realization for the scenario including UE with SOI and UE with SNOI, depending on the different antenna elements number.

3.2 Simulation results

The simulation results of the assigned task are illustrated in the fig. 4-8 and described further.

In the fig. 4. the beamforming pattern of planar array with 16 elements is presented.

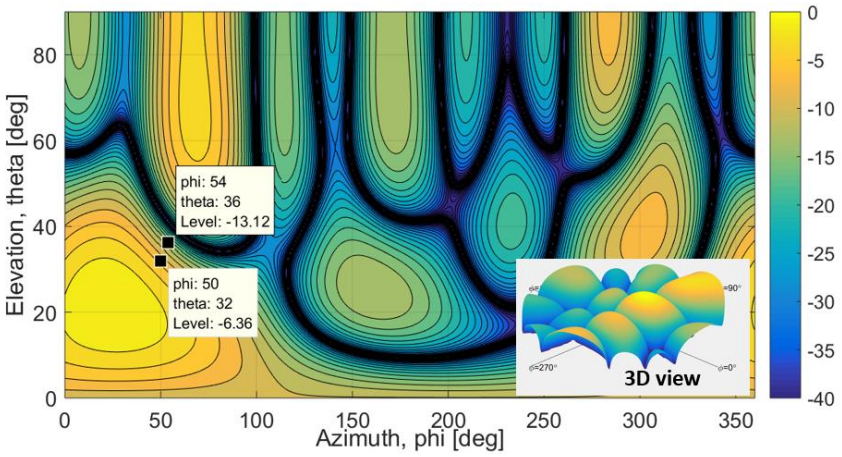

Fig. 4. Adaptive beamforming pattern using planar array with 4x4=16 elements, SOI: θ =32°, φ=50°; SNOI: θ =36°, φ=54°

The maximum radiation of antenna is depicted as a bright yellow area and in this case is directed quite close to the desired location of SOI UE (θ=32°, φ=50°). However, this maximum does not achieve the SOI UE, but SOI UE lays still in the slope of maximum (depicted as orange area) with the radiation level by -6,36 dB. The interfering source, UE SNOI, lays in the position of elevation θ=36° and azimuth φ=54°. So the radiation from gNB antenna is supposed to be suppressed in this direction by null steering (minimum of radiation is colored in black on the diagram). However, the radiation field in this location, at θ=36° and φ=54°, is -13,12 dB, which does not correspond to the null of the antenna pattern, but lays in the piedmont of the beam and marked in green color. So, the difference in the beam radiation level between the desired UE and interfering UE is 6,76 dB. For the better visuality the 3D view of the pattern is placed in the right corner of the figure, whereby the color palette replicates

2D layout, bright yellow means the highest value of the field strength, colors from dark blue till the black means the lowest value of the radiation field strength.

The next simulation case uses the same position coordinates SOI UE (θ=32°, φ=50°) and SNOI UE (θ=36°, φ=54°), but applies a planar array with 8x8=64 antenna elements. The results of the the second simulation case are depicted in the fig. 5. One can observe on this diagram, that the maximum of the beam became more concentrated on the one spot and the beam pattern grew narrow in comparison to the first simulation case. Herewith at the location of SOI UE the value of the radiation field strength is -5,076 dB and at the SNOI UE location -133,2 dB, which provides a much better diversity of about 128 dB suppression between two terminals, than in the first case. This practically exludes the interference impact.

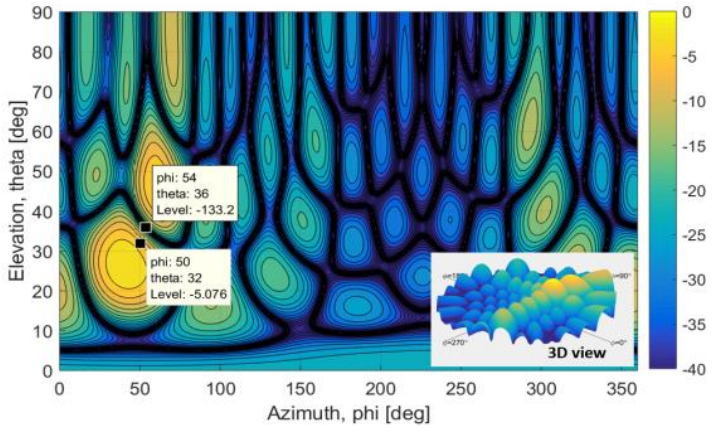

Fig. 5. Adaptive beamforming pattern using planar array with 8x8=64 elements, SOI: θ =32°, φ=50°; SNOI: θ =36°, φ=54°

The third simulation case with its 128 antenna elements represents an interest in the actual developments in massive MIMO systems. The results of this simulation are depicted in fig. 6. The radiation concentration got much more focused on the spot of interest and the beam became even more narrower than at the second case. To SOI UE is dedicated higher radiation level -1,087 dB and one can see in the diagram that the SOI UE is now inside of the bright yellow ring. From the other side the null is placed exactly on the SNOI UE spot with its radiation field strength -333,4 dB.

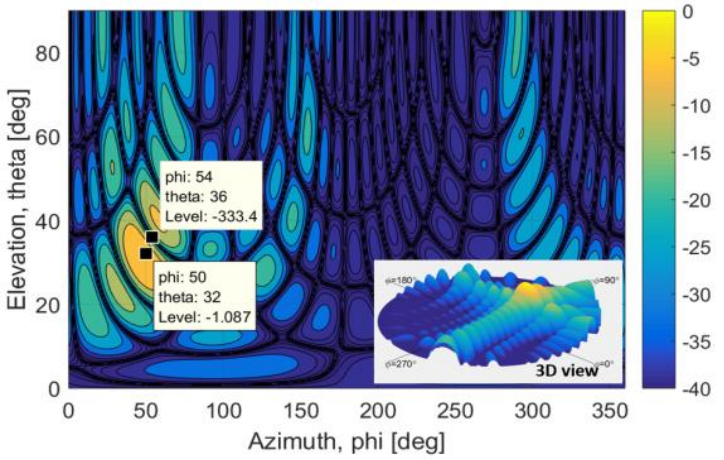

Fig. 6. Adaptive beamforming pattern using planar array with 8x16=128 elements, SOI: θ =32°, φ=50°; SNOI: θ =36°, φ=54°

The fourth simulation demonstrates the results of the case, which contains a higher antenna element number than a common development case, namely the planar array with 16x16=256 antenna elements (fig. 7). The beam maximum is directed toward the SOI UE with the radiation level -1,076 dB and one can see in the diagram that the SOI UE is now inside of the bright yellow ring. The null is placed exactly on the SNOI UE spot with its radiation field strength -335,7 dB. This simulation case has no big difference in compare to the previous one with 128 antenna elements.

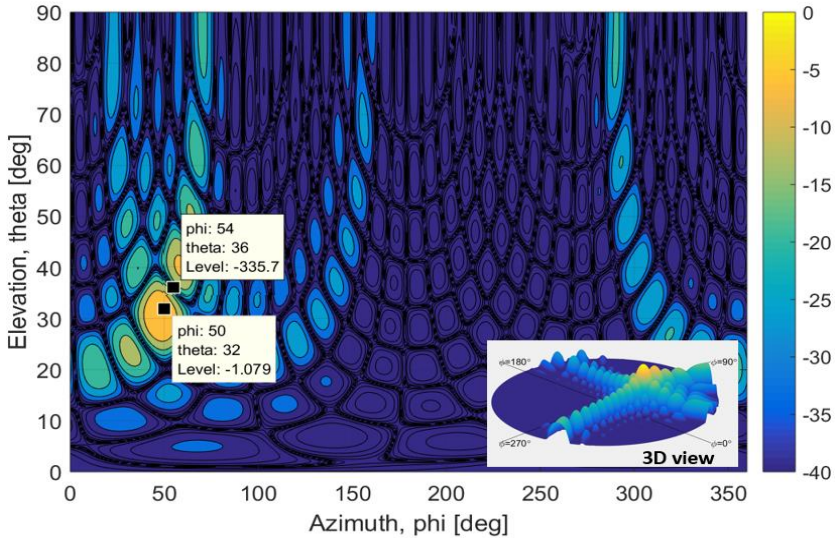

Fig. 7. Adaptive beamforming pattern using planar array
with 16x16=256 elements, SOI: θ =32°, φ=50°; SNOI: θ =36°, φ=54°

The results of the last simulation case with large number of 32x32=1024 of antenna elements are showed in the fig. 8. The beam is directed exactly to the SOI UE, since the radiation level reaches here its highest value, as one can recognize in the diagram. At the same time the beam achieves here the narrowest form. In conduction with the highest field strength among all simulation cases it means, that this configuration provides the highest resolution of the beamforming. Moreover, the null steering has in this case the highest suppression of the antenna radiation in comparison to other simulation cases.

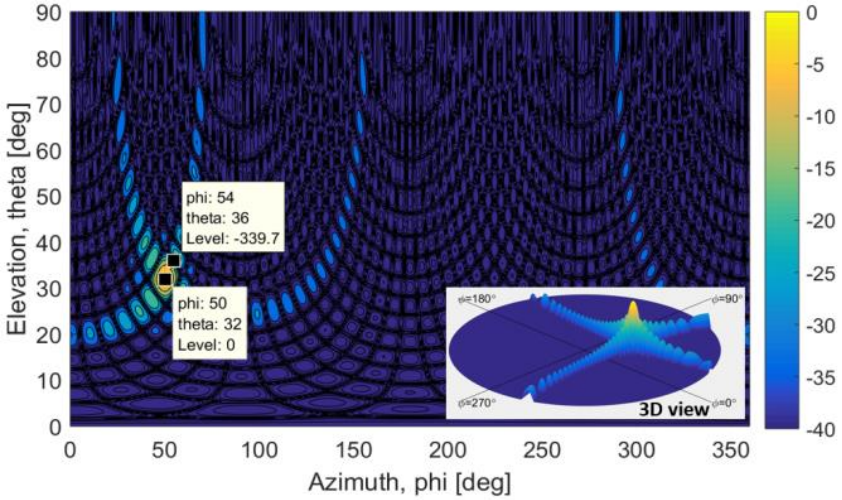

Fig. 8. Adaptive beamforming pattern using planar array
with 32x32=1024 elements, SOI: θ =32°, φ=50°; SNOI: θ =36°, φ=54°

Another interesting fact can be seen here, that with a such large number of antenna elements the side lobes of the beamforming diagram practically absent. The summary of simulation results is presented in table 1.

Table 1. Simulation results summary

Array configuration, number of elements	SNOI suppression, dB	5G requirements fulfillment for moving UE 0,5 m/s
16	6	no
64	128	partially
128	332	yes
256	334	yes
1024	339,7	yes

It is well known, that angular resolution is tightly coupled with distance between gNB and UE, that's why to reveal practical recommendations for beamforming techniques deployment in 5G wireless communication systems and networks, let's now check 4° resolution capabilities for SOI and SNOI terrestrial separation in various cell types.

In the 3GPP specification [2] the following cell types are defined: indoor, dense urban, urban macro and rural, with the corresponding cell radius in 20 m, 200 m, 500 m and 5000 m. According to this definition we calculated and plotted possible distance between SOI and SNOI, which can be provided when the beamforming accuracy 4° is sustained (fig. 9): spatial separation of UEs is possible: for indoor cells up to 1,3 m; for dense urban cells up to 13,9 m; for macro urban cells up to 34,9 m; and for rural up to 350 m.

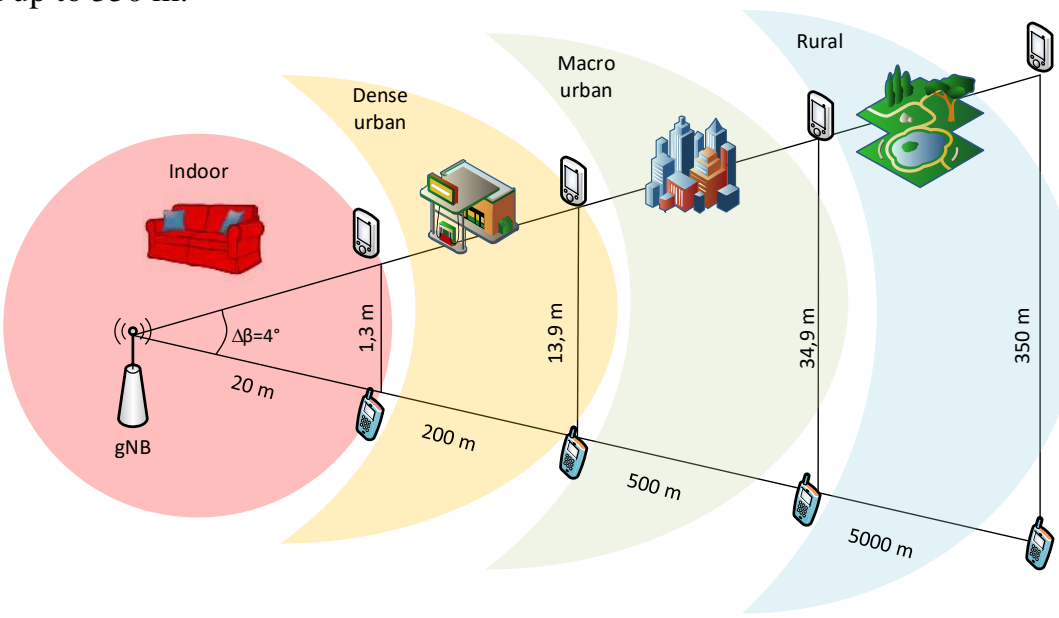

Fig. 9. Spatial separation of SOI and SNOI illustration for 3GPP cell types

4 Conclusion

Different planar array configurations, recommended by 3GPP [13] for 5G wireless communication systems and networks, were investigated in their resolution capabilities of beamforming and the null steering. LMS adaptive beamforming algorithm for planar antenna array configurations with 16, 64, 128, 256 and 1024 antenna elements was realized via simulation model so that to investigate its angular resolution bounds. Taking 3GPP requirement of 5° angular resolution for users moving up to 0,5 m/s into account, the accuracy 4° with 1° margin was investigated in this work for different planar arrays configurations.

Results of the current simulation research revealed that with the growth of the antenna elements from 128 not only the accuracy of the beamforming increases up to 4° angular resolution, but also null steering becomes precise, which provides interference suppression up to 340 dB and accordingly meets 5G requirements with margin.

Although 16 and 64 planar antenna elements configuration does not meet 3GPP accuracy requirements, it can cover another 5G goals, such as relaxed accuracy requirements of beamforming for pedestrian and static use cases, or capacity growth [23].

As for practical recommendations for beamforming techniques deployment in 5G wireless communication systems and networks, possible distance between SOI and SNOI, which can be provided when the beamforming accuracy 4° is sustained, is following: for indoor cells up to 1,3 m; for dense urban cells up to 13,9 m; for macro urban cells up to 34,9 m; and for rural up to 350 m.

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Fast Predictive Maintenance in Industrial Internet of Things (IIoT) with Deep Learning (DL): A Review

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Abstract: Applying Deep Learning in the field of Industrial Internet of Things is a very active research field. The prediction of failures of machines and equipment in industrial environments before their possible occurrence is also a very popular topic, significantly because of its cost saving potential. Predictive Maintenance (PdM) applications can benefit from DL, especially because of the fact that high complex, non-linear and unlabeled (or partially labeled) data is the normal case. Especially with PdM applications being used in connected smart factories, low latency predictions are essential. Because of this real-time processing becomes more important.
The aim of this paper is to provide a narrative review of the most current research covering trends and projects regarding the application of DL methods in IoT environments. Especially papers discussing the area of predictions and real-time processing with DL models are selected because of their potential use for PdM applications. The reviewed papers were selected by the authors based on a qualitative rather than a quantitative level.

Keywords: Predictive Maintenance, Industrial Internet of Things, IIoT, Deep Learning, Real-time, Data Streams

1 Introduction

This paper provides an analysis of selected literature applying DL techniques and Artificial Neural Networks (ANN) in the field of industrial IoT (IIoT) to produce fast predictions as required, among others, in maintenance applications. PdM attempts to predict failures before their possible occurrence to avoid unscheduled outages of machines and plants. The aim is to avoid breakdowns by their timely prediction and maximizing the service life at the same time. The predictions are based on data comprising accumulated knowledge and current conditions.

IIoT environments produce massive amounts of data. The necessity to perform data analytics on such massive data brings the characterizing features of Big Data into play, like the "5V's" volume, variety, velocity, variability, and veracity [1]. The high volume and the high complexity of data put massive demands on existing data processing techniques. Additionally, evolving data streams and real-time demands intensify the demands even more [2]. Sensors typically generate continuous streams of data. The term of data streams refers to data continuously generated typically at a high rate [3]. In fully automated industrial environments, obtaining information in real-time and react immediately becomes indispensable. In IIoT environments Machine to Machine (M2M) communication has high significance [4]. Intelligent sensors and devices not only sending data but communicating with their environment, anticipate immediate responses. In such IIoT Environments the characteristic of taking a snapshot of the entire data set and performing calculations with unpredictable response time contrasts with the demand for real-time communication and the presence of continuous flowing data streams [5]. To cope with such demands self-adaptive algorithms continuously learning and improving their models are essential. In addition, such algorithms should provide high performance and real-time behaviour. This is not only true when they are running on powerful cloud systems but also on fog and edge systems or IoT devices [6].

The methodological approach of this paper is a narrative review. The reviewed papers were selected by the authors based on a qualitative rather than a quantitative level. Papers covering the most current research for the topic fast predictions in IIoT with DL were given priority. There are many papers covering the topic of DL in (I)IoT. To the best of our knowledge, there is no paper in literature covering the specific topic of PdM in connection with DL an (I)IoT.

This review provides a classification of different DL approaches mentioned for use in industry und IoT. It also covers the topics of real-time processing and data streams in regard to the mentioned DL approaches. Techniques intended to improve the real-time and stream processing ability of different approaches mentioned in the reviewed papers are evaluated and classified. Special focus is set on the ability of the mentioned approaches to provide predictions. The paper concludes with a summary and outlook on future developments.

2 Deep Learning Approaches in Industrial Internet of Things

This section starts with a short introduction into DL and ANN. A classification of different DL methods mentioned for the use in industry und IoT will then be provided. The classification will be done by the theoretic approaches, application areas and strength and weaknesses in regard to the demands of PdM in IIoT environments. The

reviewed papers covering the topics of DL methods in Cyber Physical Systems (CPS), IoT, Industry 4.0 (I4.0), as well as the topics of real-time and data stream processing.

DL can be defined as a subcategory of Machine Learning (ML) whereas ML is a segment in the field of Artificial Intelligence (AI). DL itself is often defined as a class of optimized ANNs comprising numerous layers (hidden layers). The high number of layers and neurons allow the abstraction of more complex problems and support further characteristics like the ability to unsupervised learning or automatic feature extraction [7]. Examples are Deep Neural Networks (DNN), Deep Belief Networks (DBN) or Recurrent Neural Networks (RNN).

The basic idea behind an ANN is to imitate the biological neural network in mammalian brains. Components of an ANN are neurons (in ANNs often called nodes) and connections between those nodes. The nodes are organized in layers producing non-linear output data based on the input data. The connections between the nodes transfer the output of one node to the input of another node. Weights assigned to each connection determine the relevance of the transferred signal. As in biological neural networks the output signal of a neuron (node) is ruled by a threshold function. To set up an ANN all weights have to be set to an initial value (often just simple estimates). By training the network those weights are adjusted in a holistic way following a defined learning rate to achieve a valid and balanced network. This is also often referred to as “connections developing over time with training". ANNs are known for more than 50 years and various ways have been developed since [21], [22], [23].

In [6] the following DL models are listed for IoT application: Auto-encoder (AE), RNN, Restricted Boltzmann Machine (RBN), DBN, Long Short-term Memory (LSTM), Convolutional Neural Network (CNN), Variational Auto-encoder (VAE), Generative Adversarial Network (GAN) and Ladder Net. The DL models are categorized in [6] into the three main groups of generative approaches (AE, RBM, DBN, VAE), discriminative approaches (RNN, LSTM, CNN) and hybrid (GAN, Ladder Net) as a combination of the two approaches mentioned before. This categorisation mainly refer to the underlying learning method whereas generative approaches basically follow the principle of unsupervised learning and discriminative approaches follow the principle supervised learning. Beside the definition of the required number of layers (complexity) the underlying learning method is a decisive factor for the selection of a DL approach. The categorization in generative and discriminative approaches chosen by [6] can be fundamentally found in many other works. In [6] different DL models are also categorized by their suitability in IoT applications. The relevant characteristics mentioned in [6] are the ability to work with (partially) unlabelled data (feature extraction, feature discovery), the magnitude of needed training dataset, dimensionality reduction abilities, the ability to deal with noisy data and time series data and their general performance classification. For the reduction of high dimensional data and to cope with unlabelled data [6] recommends the combination of RNN with DBN and AE. If the system is meant to make predictions like in PdM

systems, DBN and AEs are often used as an upfront layer providing classified data to a subsequent RNN [6].

In case of spatial-temporal data like mobility data, RNNs are recommended because they show good results when data is developing in a sequential way. But if data also comprises long term dependencies, RNNs are not a good choice because RNNs does not memorize previous states and results [8]. An approach to handle sequential data streams from human mobility and transportation transition models containing long term dependencies (behaviours) is described in [8]. The described solution is a combination of RNN with LSTM in the form of a specialized RNN architecture. Besides the ability to handle long term dependencies the LMST also adds labelling and predictive functionality to that combination. The combination of RNN with LSTM to cope with data streams or time-series data comprising long-term dependencies (like certain behaviours or wear and tear of machineries) can be found in many other works [8], [9], [11], [18].

The paper “IoT Data Analytics Using Deep Learning” [9] describes how to select the right ANN to archive predictions from data streams and time-series data. To retrieve trends and predictions and also validate those trends and predictions in parallel by anomaly detection, a combination of LSTM with Naive Bayes models is proposed. The LSTM produces the predictions on data streams whereas the Naive Bayes model is responsible for anomaly detection performed on the results of the LSTM.

This paper also reflects on the fact that Simple Feedforward ANN (FNN) like Single-layer Perceptron (SLP) and Multi-layer Perceptron (MLP) using standard back-propagation (BP) for training are often not a good choice because they does not perform well in complex situations and on data streams with long-term dependencies. This is especially true when data streams comprise time series data and the aim of the model is to predict future events or trends. Data streams and time-series data usually have dependencies over time. Such dependencies are typical for IoT data and provide relevant insights. In simple ANNs data moves straight through the layers with the assumption that input data is independent from output data. Because of this, there is no way to remember previous input and output states (previous results). This is bad if previous data is linked to current data. Using RNN instead can archive better results in data streams and time-series data. Because the connections between nodes in a RNN are in the form of sequences or loops, it is possible to remember previous states. To avoid gradient explosions normally only a view states are remembered. Therefore only short-term dependencies are recognized. Because of this [9] recommends the application of LSTM in complex IoT environments to recognize long-term dependencies in the data. LSTM are a variant of RNN introducing memory units. Those memory units are able to remember important previous states and forget the unimportant ones [9].

To predict the behaviour of energy systems in the manner of smart grids [10] remark that more intelligent systems are necessary to produce accurate predictions on the future energy consumptions. In the paper "Deep learning for estimating building energy consumption" [10] it is stated that ANN-based prediction methods are a promising approach because of their ability to handle massive and highly non-linear time series data coming from different heterogeneous data sources (e.g. SmartMeter) and containing a lot of uncertainty (unlabelled data). In the paper [10] they benchmarked two different approaches of the RBN, namely Conditional Restricted Boltzmann Machine (CRBM) and Factored Conditional Restricted Boltzmann Machine (FCRBM), on a synthetic benchmark dataset. Based on this experiment the authors come to the conclusion that FCRBN outperforms in comparison to RNN, Support Vector Machine (SVM), as well as CBRM because of its added factored conditional history layer. A RBM is a stochastic ANN consisting of two layers, a visible layer and a hidden layer. In simple terms, the visible layer of a RBM contains a node for each possible value in the input data whereas the hidden layer defines categories of values. Because in a RBM each visible layer node is connected to any hidden layer node a RBN is good in feature classification, feature extraction and complexity reduction (by identifying the most important features). For DL RBMs can be stacked. In [10] RBM is extended by a conditional history layer (CRBM) enabling the RBN to detect long-term dependencies in time-series data. Additionally the output of one stacked CRMB layer is factored (FCRBM) to reduce the number of possible compositions.

Another paper in the field of energy management also emphasizes the very powerful forecasting abilities of DL. In [11] the application of AE and LSTM is described for predicting the power generation of solar systems. The accuracy reached by a combination of AE and LMST (Auto-LSTM) is compared to other neural networks (namely MLP) as well as to a physical model. The benchmark data is taken from 21 real solar power plants and the benchmark is taken from an experimental setup described in [11]. The following measurements are taken as benchmarks: average root-mean-square deviation (RMSD), average mean absolute error (MAE), average absolute deviation (Abs. Dev.), average BIAS and average correlation. The measured results show that all ANN- and DL-based models show far better results than the physical model. Among all ANN- and DL-based models Auto-LSTM is the best choice in this specific scenario and specific data set. The capability to extraction features in unlabelled data is mentioned as a decisive factor in making predictions.

The paper "An enhancement deep feature fusion method for rotating machinery fault diagnosis " [12] points out the strength of AEs in feature extraction and feature learning. The paper describes how to further improve the feature learning ability with reduced influence of background noises by stacking Deep AE (noise reduction) and contractive AE (enhanced feature recognition), called deep feature fusion method.

3 Fast Predictions using DL

In many IoT applications real-time processing is essential. For example in a PdM system high latency could lead to unintentional reactive maintenance because of insufficient lead time to plan the maintenance tasks [5]. How fast real-time processing needs to be, strongly depends on the application case. According [13] in micro manufacturing systems, where vast volumes of micro parts are manufactured with high speed, the term real-time means microseconds. [13] shows that with systems for fault detection and PdM the rejection rate of the manufactured micro parts decrease by increasing processing speed [13]. In other scenarios, the term of real-time can mean seconds, minutes or hours. For example in PdM Applications for offshore wind turbines the frequency with which the data is available is mostly minutes and hours [14].

The paper "Metro Density Prediction with Recurrent Neural Network on Streaming CDR Data" [15] describes the implementation of a real-time public transportation crowd prediction system using a weight-sharing recurrent neural network in combination with parallel streaming analytical programming. Fast response time to emergent situations (e.g. entrance records in metro stations combined with telecommunication data) demand real-time analysis. The use of a powerful neural network model with strong learning capability offers a wide range of new insights but contrast with the need for fast response time. The way to meet this goal is described in [15] with three steps: a) adopting a RNN model to improve its ability to work on data streams, b) implement strategies for parallelization of RNNs and c) the use of parallel streaming analytical algorithms over a cloud-based stream processing platform. In the project described in [15] each metro station is modelled by an independent RNN. Shared layers are introduced to share weights from stations which are in similar "situations" (e.g. a downtown station during rush hour) across several models dynamically. Weight-sharing also enables co-training in parallel [15].

The application of RNNs and their many variations for fast data analytics is also recommended in [6]. Especially on typical sensor data like serial data, time-series data and data streams, RNNs can provide better performance than other models. Such sensor data is dominating in most PdM applications [1].

In order to be able to develop and permanently adapt models on massive data comprising the behaviour of people and their spatial and temporal attributes together with transportation capacities, real-time processing and real-time learning capabilities are essential. The paper [8] describes a multi-task deep LSTM learning architecture. The basic idea of this concept is not to use a joint feature vector but various LSTM tasks separated by their domain (e.g. respectively a separate task for mobility and transportation mode prediction). This architecture performs parallel learning whereas the results are aggregated depending on the intended insights [8].

Assistance systems in cars like traffic sign recognition must deliver accurate results with low latency. The paper [16] describes how to apply DNN in this field. The model

of the system is continuously updated (online learning) and fed only with completely unlabelled data (raw images). A CNN with 9 layers is used for image recognition. To improve the performance of system max-pooling layers are combined with convolutional layers in an alternating way. The convolutional layers perform convolution on 2D input pixel maps. The max-pooling layer works like a pre-processor between two convolutional layers transforming the output of a preceding convolutional layer to the input of a subsequent convolutional layer by eliminating overlapping regions in the pixel maps. This eliminates redundant processing in the complex and time consuming convolutional layers. The approach described in [16] is referred to as Multi-Column DNN (MCDNN).

The paper [17] describes a real-time oriented solution for traffic sign detection and recognition. The primary focus is on the need for parallel processing because of the need to detect diverse traffic sign at the same time. In this approach also CNN is used for image processing in combination with AdaBoost to improve performance and parallel GPU processing.

Because of its memory cells LSTM models are good if data comprises long-term dependencies. If the data structure allows the separation of single entities with their specific behaviour as well as the formation of groups of entities, it could be then possible to process each entity and every group with its own neural network. This opens up parallel processing possibilities of the single neural networks. Normally each single and parallel processed neural network provides its result to an aggregation layer aggregating all outputs to an overall result. The paper “A Hierarchical Deep Temporal Model for Group Activity Recognition” [18] describes how to recognize situations in a volleyball match. One LSTM model per player predicts the behaviour of this player, remembering his previous behaviour in the match (long-term dependencies). Each single situation of the match is then modelled as a group of the players. The LSTMs are hierarchically ordered where the LSTM models of all involved players are subordinated to a scene. The scenes and the players behaviour is extracted based on images using CNN [18].

The paper [7] mentions that because of the demands for real-time processing, the organization of layers and connections have changed. Fully connected networks where each node of a layer is connected to all nodes of the subsequent layer can handle complex problems but also demand a lot computing power. Dropout all connections not really influencing the result is a strategy to reduce the complexity of a DL network, and therefore its computing demand, without affecting accuracy in a relevant manner. Besides dropout [7] also mention max pooling layers, batch normalization and transfer learning as additional strategies for performance optimization.

Despite all the mentioned papers discussing performance enhancements and real-time abilities of DL models, [19] considers that highest accuracy still stands over all in mostly all current DL projects. The paper “An Analysis of Deep Neural Network Models for practical Applications” [19] argues that numerous DL approaches de-

scribed in literature are simply not suitable for practical use. This is for example because of their long processing time or excessive power consumption. In his paper he demands to spend more attention to performance issues because they are key factors in practical DL applications. The paper compares 14 different specific DL projects like AlexNet or GoogLeNet by comparing their accuracy, memory footprint, parameters, operations count, inference time, and power consumption. The paper shows that a small increase in accuracy lead to an enormous increase in computational power and computation time. It is recommended to define a maximum energy consumption for each DL project and adjust the accuracy according to it [19].

4 Conclusions

In this paper we provided a narrative review of selected literature applying DL techniques in the field of IIoT to produce fast predictions of maintenance issues. The papers have shown that the use of DL in IoT and PdM is a vital topic in industry. Many different applications are in use in practice and are constantly being developed and improved.

Frequently reported are combinations of different DL models to combine different advantages and strengths in one application. Also, the need for real-time processing of complex data and data streams has been demonstrated in certain application scenarios. This include in particular applications for predictions such as PdM. In order to increase the real-time capability, concepts of parallel DL networks using a final aggregation layer, or intermediate layers for the reduction of complexity are frequently used. Although many activities can be observed in the area of real-time processing of DL models, there are also critical voices criticizing the absolute focus on accuracy and calling for a greater focus on performance and lighter applications suitable for practical use. Almost all reports agree that a lot of research is still needed in this area.

Table 1 Summary of reviews papers with the DL-Methods mentioned

Ref.	DL-Methods	Characteristics	Typical applications
[6] Mohammadi, et al., 2018	AE, CNN, DBN, GAN, LSTM, RBM, RNN, VAE, Ladder Net	Feature extraction and dimensionality reduction of IoT Data with AE, DBN CNN for image recognition but needs large training set GAN, VAE and Ladder Net suitable for noisy data, used as classification layer for RNN to enable unsupervised learning LSTM provide good performance for data with long term dependencies RBM for feature extraction, dimensionality reduction and classification problems RNN especial for time-series data	Fault detection and predictions IoT environments Real-time and stream processing with different kinds of RNNs

[8] Song, et al., 2016	LSTM, RNN	LMST for data containing long term dependencies; time-series and IoT data Streams; LSTM adds labelling and predictive functionality in combination with RNN RNN good when sequential data and data streams	IoT, Transport, Mobility
[9] Xie, et al., 2017	LMST, RNN	LMST and RNN suitable for time-series and IoT data Streams	Predictions because of long-term dependencies in data RNN for short-term IoT applications like condition monitoring
[10] Mocanu, et al., 2016	RBM, CRBM, FCRBM	RBM for feature extraction, dimensionality reduction, classification CRBM extends RBM with long-term predictions by adding a conditional history layer FCRBM improves performance by reducing the number of possible compositions of each output layer in a stacked (C)BRM	Predictive IoT applications e.g. for smart cities or smart energy grids
[11] Gensler, et al., 2016	DBN, Auto-LSTM	DBN perform good for predictions on time-series data Auto-LSTM for predictions on time-series data, combination of AE and LSTM	Predictive IoT applications like power generation forecasts
[12] Shao, et al., 2017	AE	Good for feature extraction, unsupervised learning, noise reduction and compression (relevant feature detection), often used as pre-processing layer for complexity reduction, short-term dependencies only, not good for predictions	IoT applications like fault diagnosis
[15] Liang, et al., 2016	RNN	Adopted RNNs used for data streams and weight-sharing, as well as co-training in parallel	Applications running parallel RNNs with shared layers Cloud-based stream processing
[16] Ciresan, et al., 2012	CNN	Image recognition in real-time in combination with max-pooling layers, good for short-term dependencies, not good for predictions	Real-time and parallel processing IoT applications like traffic sign recognition
[17] Lim, et al., 2017	CNN	Image recognition in real-time in combination with max-pooling layers, good for short-term dependencies, not good for predictions	Real-time and parallel processing IoT applications like traffic sign recognition
[18] Ibrahim, et al., 2016	CNN, LSTM	CNN for Image recognition LSTM for predictions considering long-term dependencies; hierarchical LMST model for individuals and group behaviours	Recognition of individuals and groups e.g. to determine current behaviour or dynamics

Table 1 gives an overview of the reviewed papers with the DL-Methods mentioned. For each paper the characteristics (or strength and weaknesses) as well as the recommended application areas (like predictions) of the DL-Methods mentioned in the corresponding paper are summarized. Table 1 makes no statement regarding the validity of results in a quantitative way. The categorisation of the different DL models is only made in a qualitative way. This is because among all reviewed papers only in [19] concrete measured values are defined. All other papers solely provide qualitative statements. How to measure and evaluate the validity and quality of results of different DL methods is an open question [20]. So far, few approaches for measuring, evaluating and benchmarking have been developed. Moreover, those approaches are usually not verifiable as generally valid. For instance, in the case of classifications the use of accuracy estimation techniques, such as the "holdout method" or "n-fold cross-validation", can be used to evaluate performance, predictive ability and model accuracy [20]. As such, mentioned techniques divide a training set via varying approaches into data areas for learning and validation. For most models no measuring, evaluating and benchmarking concept has yet been defined. In general, the evaluation is done here by expert opinions [20]. The paper [20] points out that there is a demand for improved measuring and benchmark methods. Proven measurement methods to generate representative benchmarks are needed in order to be able to assess DL models.

The papers [1] to [5], [7], [13], [14] and [19] to [23] are not part of Table 1 because they are used as reference regarding basic statements and explanations made in this paper. These papers were not on the topic of DL methods and techniques.

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Low cost high resolution ampere meter for automated power tests for constrained devices

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Abstract. In recent years, there has been a trend for operating systems to replace more and more conventional baremetal applications, even in constrained class 1 and 2 devices. This leads to new challenges for battery-powered IoT devices, where the battery should not be recharged or replaced regularly. The energy consumption of software must be considered throughout the development. For software that is encapsulated by an operating system and runs on multiple different hardware platforms, this means that power consumption must be determined for each of them. This paper proposes a measuring unit to enable automated regression testing for a variety of different hardware platforms with individual range and resolution requirements. A prototype was created and evaluated in which multiple different shunt resistor measurement modules are switched out by an analog multiplexer, controlled by a HIL platform. The results show that the approach is feasible and offers the possibility of a cheap, scalable, easily customizable measuring unit for the usage in automated power tests.

Keywords: Current measurement · Automatic testing · IoT

1 Introduction

Driven by the exponential growth of the Internet of Things (IoT) it can be observed that a large ratio of these interconnected things are constrained devices [1]. Wearables, smart homes, smart cities and the Industrial IoT introduce embedded devices not only limited in terms of CPU power, but restricted by the available energy. This trend is reflected by terms like "Set-and-forget"- devices [2] equipped with non-replaceable batteries for "lifetime-energy-limited" usage, and by "period-energy-limited" applications replacing batteries periodically [1]. Currently, such devices achieve lifetimes of 5 till 10 years with a typical coin cell battery (like CR2032). Most of the time such devices reside in energy efficient deep sleep modes resulting in an energy consumption less than a factor 10^{-6} compared to active modes. Different to earlier generations of constrained devices, it is no longer common practice deploying hardware specific baremetal applications. With the spread of operation systems (OS) for class 1 and class 2

constrained devices, large parts of the software consists of hardware independent code running on multiple different hardware platforms. To manage the resulting complexity and allow for a safe maintainability of all feasible platforms, it becomes necessary to introduce automated testing, especially in the form of regressions.

For verifying "lifetime energy-limited" devices, tests should not be restricted to finding functional defects only. Test cases should also aim for discovering abnormal energy consumption which needs to be classified as a non-functional defect of a devices behavior. Beyond finding such defects, an automated test infrastructure allows monitoring the code down to individual code changes which may trigger changes of power usage resulting in savings or increases. To determine the energy consumption of a given piece of code, it is either necessary to measure the execution on the target hardware with a power analyzer providing a large enough range and resolution, or to have a sufficient accurate energy model of the target platform. Both approaches are problematic in regards to the scale of the resulting test environment. With the usage of operating systems supporting dozens or hundreds of boards, it becomes necessary to test applications on every OS supported board. As a result, the energy consumption also needs to be predicted for every one of those boards.

This paper proposes a low cost, easily obtainable energy measuring setup for monitoring changes in energy consumption for performing automated regression testing on constrained devices. Furthermore, an evaluation is performed whether the proposed measuring unit is suitable for practical usage in automated testing environments.

2 Related Work

In order to create a model of a devices energy consumption, it is necessary to determine CPU power usage driven by individual instructions as well as the power consumed by peripheral hardware components like transceivers. The first model on instruction level was proposed in [3]. The average power consumption of a system is measured and multiplied by the clock period and the number of clock cycles. Later approaches focus on determining the worst-case energy consumption (WCEC) as the energy useage may vary between instructions with shorter or longer runtime [4]. Strict bounds of WCEC-based analysis were shown lately, as determining data dependent dynamic power consumptions results in an NP-Hard problem, where an approximation cannot be made to an usable degree [5]. Former studies often found the variation in the data dependent dynamic power consumption to be not significant. So it is accounted as a constant value [3,4,6,7]. However, in class 2 constrained devices examined in [5], the variation of the data dependent power consumption amounts to up to 42% of a cores power dissipation. Another study shows cases with even up to 50% [8]. As a result, current approaches focus on predicting the WCEC by methods using statistical analysis or genetic algorithms instead [9].

The energy model for different hardware components and the respective power modes often consists of a finite state machine. The target hardware is modeled as different power states and their connecting transitions. For all identified states and transitions, the power consumption is measured. The parameters influencing the power consumption of a state, as well as their behavior, need to be identified. This can be achieved by utilizing regression analysis to create approximation functions for the parameter dependent energy consumption [10]. The first approach to create such a mode used the utilization of a peripheral hardware module as a trigger for a transition [11]. Later work instead correlated power bursts to individual system calls, as the power states of peripheral hardware often do not line up with their utilization in software [12]. A transceiver for example does not immediately go back to its sleep state after sending the data, but will continue to consume power for a short while after [12]. Automatically finding these states and refining the state machines is still an open research question. In practice the creation of state machines for energy models require a lot of repetitive manual interactions [13].

Different to energy models which enable static code analysis, it is also possible to run each test on the target hardware, measure the resulting power consumption and correlate it to the source code. The most common and cheap approach is to measure the voltage drop over a shunt resistor by utilizing an analog digital converter(ADC). Additionally, an Operational Amplifier(OpAmp) is used to amplify the voltage drop [14–16]. Other authors proposed the usage of multiple different shunt resistors or measuring units to reach a higher range and resolution. For the "Nemo" [17] a microcontroller is switching out five different stages of shunt resistors. In [18] a second shunt resistor OpAmp combination can get added to the circuit, feeding into the same ADC. In the "Rocketlogger" [19] two additional complete measuring units can be added, with the resulting voltage drop in the circuit being compensated by a differential amplifier.

3 Design Considerations

As it is necessary to determine the power consumption of code being executed on different hardware platforms, the use of power models as well as commercially available measuring units are not practical solutions due to the cost incurred with each hardware target, as well as manufacturer specific interoperability issues. While singular shunt ADC measuring units can generally not provide the needed range and resolution, there are solutions in the field of large scale wireless sensor network (WSN) verification environments (or testbeds), which achieve the necessary range by switching out shunts or adding complete measuring units. However, the solutions are designed to measure the same range and resolution for each identical hardware platform in a testbed.

The presented approach is designed to switch out multiple measuring modules, taking advantage of the availability of breakout boards for low cost power monitor ICs. By doing so, measurement modules can be fitted with different shunt resistors to match individual hardware platforms and their respective en-

ergy modes. This way, the proposed measuring setup can be fitted for different ranges and resolutions, but be designed as a mass-producible cheap adapter board. With the ability to calibrate individual measurement modules, a switch occurs as soon as the target hardware changes from any of the multiple sleep modes to active processing. This allows to detect differences in the resulting power consumption of functionalities in different power modes requiring different resolution ranges. Should inaccuracies occur as a result of the switch and mask spikes in power consumption, it is possible to repeat tests without automated range switching, once for each measurement module.

A common approach for automated tests on constrained devices is the use of a hardware-in-the-loop (HIL) platform that flashes a new executable onto the target and sends the results to an automation server. The proposed measuring setup is connected to the HIL platform, a Raspberry Pi, which is triggered by a Jenkins Server to flash the target platform and return the output. For automated power tests, measurements are tagged with timestamps for being correlated with the targets output. This is realized by matching the given time stamp of the measuring unit with one of the target platform. In this way, the measurements are timestamped in a real-time system (RTS) and processed on the more powerful HIL platform

4 Measurement Unit

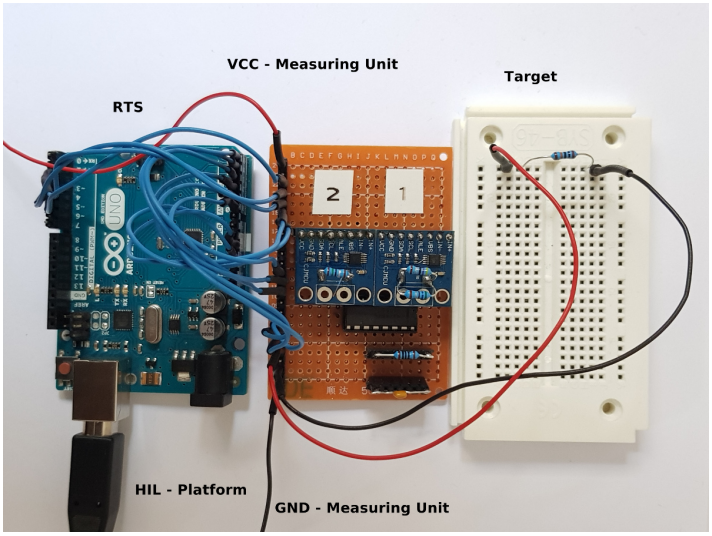

Fig. 1. Measuring Unit

Each measurement module uses a Texas Instruments INA226 power and current monitor IC. Here, the IC is used as a high side current sense amplifier, in which the voltage drop over an external shunt resistor is read by a 16 bit ADC. The shunt is connected in series with the load to be measured, so that the voltage

drop can be used to calculate the current through the entire circuit. The module is connected over an I^2C bus also providing internal calibration and the option to read only the average over a series of measurements to correct individual measurement errors.

The INA226 is capable of measuring a voltage drop between -81.9175 mV and 81.92 mV resulting in a resolution of 2.5 µV per bit step of the ADC. So for example, a shunt resistor of 1.5Ω leads to a range of up to 54.61 mA with a resolution of $1.\overline{6}$ µA. Two INA226 breakout boards from CJMCU fitted with different sized shunt resistors are connected in parallel to each other and via an MAX4619 analog CMOS multiplexer in series to the load. To change the measuring range, the multiplexer switches one of the two measurement modules into the circuit. At a supply voltage of 3.3V, the MAX4619 switching process takes a maximum of 25 ns according to its data sheet. A capacitor with series resistor is connected in parallel to guarantee the power supply to the load during the switching process.

The measurement modules and the multiplexer are controlled by an RTS, in this case an Arduino Uno. The INA226 are configured for the shortest conversion time of 140 µs per sample. Each INA226 notifies the RTS about newly available samples via a PIN interrupt. The measured data of the active unit is then read via a dedicated I^2C bus. Once a measurement matches a predefined threshold, the RTS switches the measuring ranges and modules by activating the multiplexer.

The measured values are timestamped and transmitted to the HIL platform via a serial interface. The average function of the INA226 is not used for preserving all raw data as evaluation input.

5 Evaluation

In order to achieve a resolution of the measured current of at least 1 µA, the first module is equipped with two 1% resistors connected in parallel. Both together lead to a resistance of about 2.56 Ω. According to Ohms Law, the circuit offers a resolution of around 0.98 µA. The second measurement module is equipped with a 1.5 Ω resistor for measuring currents of up to 54.61 mA. The capacitor (4,7 nF with a 66 Ω series resistor) is dimensioned to recharge within the ADC conversion time and to not drop below 3V during a switching process in order to measure a SAM R21 Xplained Pro Board without modifications [20]. This allows for a module to switch after each measurement. Before the first measurement takes place the capacitor has to be charged for 31.02 µs.

The time resolution between two new samples currently averages only 4.35 ms at the HIL platform. This is caused by the decision to use an Arduino Uno as RTS. The serial connection from RTS to HIL platform as well as the I^2C connection between INA226 and RTS are both bottlenecks in the current setup. The transmission of unoptimized log text takes a minimum of 3.906 ms including the measured value and the timestamp at 45 byte using a baud rate of 115200 bd. The chosen software I^2C library supports multiple I^2C interfaces where the I^2C bus speed is only 65 kHz. With the standard I^2C library the sample rate

is around 470 µs at 400kHz bus speed for requesting and receiving two byte of measurement data. Looking at a logic trace, the transmission of two byte of data at 400 kHz takes around 70 µs. An I^2C command to read from a specific register takes an expected transmission of 5 byte data requiring 190 µs. The library however reads an additional configuration register.

The accuracy of the measured values was performed using resistors with a tolerance of 1 %. For the lower end of the measuring range with a 470 kΩ and in the upper end with a 100 Ω resistor. The expected measured value for the lower measuring range at 3.3 V is between 6.95 µA and 7.09 µA, due to the tolerance of the resistors. The actual measured value varies between 5.01 µA and 8.93 µA. The average of several measurements results in a value of 6.94 µA. Thus the relative error is only 0.2%. For the upper measuring range, the expected value is between 32.67 mA and $33.\overline{3}$ mA. The actual measured current fluctuated between 30.50 mA and 30.51 mA. The mean value is 30.50 µA, the relative error 6.5%.

Both measurement modules operate continuously. Since only one measurement module in the circuit is flown by a current at a time, the other one can not measure a voltage drop at the shunt. Switching the multiplexer to the other measurement module during a running measurement results in an erroneous measurement. For preventing the creation of measurement values, the first sample after a changeover is ignored by the RTS. The first valid sample after this switching process is delivered after a maximal two times of the time resolution.

6 Conclusion and future work

A cheap, scaleable, easily customizable and digitally controllable measuring unit was developed to enable automated power test for a wide array of constrained devices. While the choice of RTS did act as a bottleneck for the sample rate and, as a result, the switching delay, it can be fixed by replacing the RTS. With the INA226 supporting I^2C high-speed mode and the option to connect the RTS to the HIL platform via JTAG, measurements at a sample rate of close to the 140µs conversion time of the INA226 should be feasible. Measuring inaccuracies of the INA226 in the setup are largely limited to one resolution step, with only around 2% of the measured values for the 470k resistor being off by more then one step. This can be adjusted by choosing a shunt resistor resulting in double the resolution and half the range. Such tradeoff would be reasonable for measuring the sleep modes. However, moving from a breadboard prototype with 1% resistors as a shunt to a PBC and a lower tolerance shunt resistor should further improve the measurements accuracy.

To cover the error class of extremely short wake-ups from sleep modes, the use of an analog multiplexer allows more modules to be added and selected on a per test basis. So for example an additional module with a high sample rate ADC and a low range shunt resistor could be added.

A future version of the measuring unit is planned using a RTS supporting high-speed I^2C communication as well as a JTAG interface. Such improvement

allows a higher sample throughput and automated firmware changes for the measuring units. For example a ATSAMD21 based RTS can support multiple high-speed I^2C interfaces via their SERCOM architecture.

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Recommendations for developing safety-related systems with graphical languages

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Abstract. The present paper deals with the development of recommendations for the application of graphical programming languages in safety-related system developments.

The basis for this development is the analysis of existing safety-related systems and the way in which these systems implemented in text-based programming environments meet the applicable norms and standards.

Based on that a present research project analyzes how graphical programming environments can meet these requirements.

The core of the project is the development and validation of recommendations for graphical programming languages to meet these applicable norms and standards, including certification bodies, professional associations, manufacturers and users. The elaboration is limited to concepts and suggestions regarding software aspects.

Finally, these recommendations should be implemented and verified in the specific development environment LabVIEW.

Keywords: functional Safety · safety-related Systems · LabVIEWsafety.

1 Background

1.1 Graphical programming languages

Graphical programming languages show a way in which algorithms and system behavior of programs can be implemented by graphical elements and their arrangement [36]. This paper presents these relationships mainly using the programming language G of the development environment LabVIEW. It is a programming environment of the manufacturer National Instruments, which started more than 30 years ago. The language G describes a flow-controlled model [7], similar to the usual graphic modeling using block diagrams in UML. LabVIEW programs are called Virtual Instruments, or VIs for short. These essentially consist of two components, the front panel containing the user interface and the

block diagram with the graphical program code [8]. This doesn't translate into other programming languages, but the graphical code is compiled directly into machine language [9].
G combines the strengths of the theoretical data flow model with the practice-oriented principles of structured and modular programming, revealing key features of traditional higher-level programming languages [37]. These are simple and compound data types, static typing with strict type checking, hierarchical and polymorphic operations, branches, case distinctions, sequences and loops [37].

1.2 Safety-related systems

Safety-related systems consist of two different parts. On the one hand, a functional hardware control to be monitored and, on the other, safety functions that monitor the correct functioning of the overall system and initiate risk-reducing measures [11]. Safety-instrumented functions as a link between software and hardware represent software code that can enhance the functional safety of hardware components by performing a risk assessment, for example, using the risk graph method according to DIN EN ISO 12100 or ISO 61508-5 [19]. High demands are placed on all hardware and software components [26]. A so far very successful concept for the realization of such safety-related monitoring systems represent programmable logic controllers which are used in the largest industrial sectors of process, automotive, aviation and medical industry. They work internal processes with a cyclic process-driven behavior and can be implemented in a user interface consisting of text-based and graphical-based elements. In addition, there are also purely text-based programming languages and corresponding development environments, such as C, C ++ or Pascal, with which safety-related systems can be developed [35].

1.3 Present procedure

The procedure for implementing applications in computer science is primarily not standardized. Developers can choose from a variety of schematic approaches, implementation methods, and programming languages. Assuming text-based programming, this ultimately consists of a large amount of lines of code that are difficult to use even in smaller projects with multiple programming library accesses [2]. Large projects, with mainly several developers, increasingly restrict the structural quality in terms of maintainability, modularity and extensibility, if no other application description or handling exist [2].
Textual descriptions such as text-based program code are thus a relatively poor working basis for an efficient handling of software applications. There is a lack of abstracting intermediate models that allow people with technical understanding to understand the various abstraction levels and perspectives of the software, thus allowing a gradual approximation to the application [2].

Other industrial sectors, such as mechanical engineering, have already adapted to the complexity of present and future machines [2]. Using CAD, the computer-aided design, two- and three-dimensional constructions could be constructed digitally for the first time in the 50s and 60s of the last century, allowing them to move, adapt and expand freely. Initial programs still worked with digital drawing tables and pen output, later the accuracy of output improved due to higher-resolution screens and printers [5]. As a result of this digital graphical modeling, great development time savings have been made, along with higher value solutions and lower development costs. Reasons for this can be found in the significantly better controllability of complexity in a digital graphical framework [2].

A similar approach can be applied to software development. For example, UML, the Unified Modeling Language, can be considered as the first step in graphical software modeling [2]. UML uses block diagrams to describe the architecture, the design and the implementation of a software. Through this visual modeling, it is possible to produce universally valid structural and behavioral models of the software. The result is a promotion of the intelligibility of the implemented structures solely through the graphical representation [4].

In view of the development in current machines, digitization, communication and flexibility of individual components are in the foreground. Static processes without adaptive manufacturing processes, resources and subscribers should be a thing of the past very soon [6]. Technologically, the industry speaks from the fourth industrial revolution. In order to network the entire corporate structure of companies, automation systems should be no longer controlled in individual processes but independently exchange information between different operating areas and coordinate entire work processes [21]. Possibilities for this can be found in the constant development of communication via the Internet, using microcomputers. This development is also called IoT, which is the acronym for the term Internet of Things. However, the implementation of systems mentioned for industrial environment applications requires the use of abstracting but still structuring programming languages [26].

However, many Internet of Things applications and many Industrie 4.0 applications and implementations must also meet safety-critical requirements, so that application standards for precisely these programming languages have become indispensable in the safety-critical environment such as medical technology, automation systems, the automotive industry and aerospace engineering. The research of future electrical, electronic and programmable electronic automation systems generally depends on the IEC 61508, which is described as the basic standard, which is presented as the basis of all others. [1]. It covers requirements for the entire safety lifecycle, from the concept phase through system development and production start-up to the decommissioning of safety-related products

[11].

The standard distinguishes between hardware and software conception, as well as the management of a project, with all its components. An integral part of the concept and development phases is the software architecture for safety-critical systems. A development environment should be used to adequately support this process by having pre-certified structures or providing guidelines [11].

Management regulations are mostly used for quality assurance, project overview and traceability regarding tests and security features of systems and project constellations [11]. Software rules, including programming language rules, define how to properly handle and comply with policy values in order to create only secure source code, and which will cause harmless consequences only [11]. In addition to various methods for determining the safety integrity and risk analysis of component groups, hardware regulations also specify maximum permissible limits for developed systems [11]. Depending on the field of application, such a system requires different limits and problem approaches, but all of them follow the same basic designs [11]. This is the reason for the norm and guideline development of different industries according to their own requirements in accordance with the legal regulations of European committees. These are european standards, so-called EN, which set the legal requirements. These technical standards may be inaccurate, incomplete, interpretable or even obsolete, but at the legal level represent the state of the art [39].

Programming languages established in the safety-critical environment are the text-based languages C in the area of embedded systems and IL list for programmable logic controllers [35]. It's about these text-based languages in a strongly and weakly typed environment that is aligned to the norms [11]. Strongly and weakly typed programming languages compile a large number of tests that define the use of data types, variables, and other syntax, such as data access or procedure calls, to ensure maximum system safety [11].
Programming guidelines, such as the MISRA-C, additionally support developers in complying with the specifications expected of certification bodies [14]. Other environments are not allowed or used, including graphical implementation.

For the development of functionally safe software code in graphical programming languages like G, various individual criteria can be set up, which are divided into four consecutive categories.
The first step is to check the syntax in a programming language. Each programming language has its own language set and possibilities to connect different elements or commands. If these language limitations are not met, it would not be possible to compile into the machine language, making verification the basic element of any programming language. Most development environments for C or C ++ can query for syntax compliance before a program is transferred. In graphical languages, such as G, this query can be done at every syntactic change.

It therefore has equivalence to text-based languages, such as C [40].

The second step involves compliance with guidelines that represent the proven structures for safety-related systems in various industries. Similar to the first step it is a static code analysis. Advanced rules, such as those defined in policies such as MISRA-C, can be used to review structural constraints. Such programming languages are limited to a smaller language scope [40]. This is limited to a verifiable level of complexity that precludes, for example, the use of pointers to produce only clear traceable code. Such a set of rules in the form of recommendations for a policy is part of the work. For this purpose, the already proven MISRA-C Guideline was roughly compared with the LabVIEW Development Guideline provided by the software manufacturer National Instruments [30]. However, a direct comparison of the two is difficult, because the structure is based on a guide to designing and implementing a project in LabVIEW, not listed rules. VI Analyzer, a LabVIEW's tool, can validate the design suggestions that are made there, making it possible to analyze MISRA-C against LabVIEW compliance. In addition, the VI Analyzer offers the possibility to develop own tests for the static verification of the code [16]. It was noticeable that some rules are already included in the LabVIEW Development Guideline and VI Analyser tests [15]. Others do not need a definition, because LabVIEW has no other way than being compliant due to the building block principle. All yellow marked rules should be included in a new policy and should be checked for compliance [30]. Overall, the MISRA-C defines 141 rules, of which only 121 are required. By means of the color code, the rules to be implemented can thus be reduced to just under one third. The remaining 40 required rules still to be implemented are basically the pure definition of the correct LabVIEW application [30] [17].

The third step is basically to prove that the software code is running properly. This must be ensured by assigning software code to functional requirements, but also requires a test environment to check runtime errors and timing [40]. What software verification can look like from conceptual design to the testing of safety-related systems in graphical programming languages is currently being developed. Using the example of G, the tools NI RequirementsGateway and NI UnitTestFramework could be used.

The third step closes the link between static code verification, dynamic run-time testing and quality management to the fourth step regulatory compliance. This is only possible if design regulations, such as modularity or diversified design, depending on the applicable standards, can be checked. The tools mentioned in the previous paragraph are expected to provide a more general approach due to the iteratively building complexity [40]. A comparison of individual criteria of the standards for possible realization in graphical languages is currently being developed.

2 Future relevance

If you consider UML instead of a modeling language as a own programming language, it fulfills almost all requirements of graphical development. The vocabulary of the language would consist of graphical elements which, by their wording, describe the functionality [2]. Relations and relationships between functions and classes could easily be analyzed and surveyed by their slightly abstracting level of development [2]. However, this is just as the problem in the implementation. Due to the general abstracting approach of UML it is not suitable for the concrete implementation of complex systems even in the extended versions UML 2.0. There is a lack of a specific vocabulary or syntax [2]. Often, UML is also run as an additional layer in parallel with the text-based project, which means that at least two languages are spoken in a project. The problem of such system breaks often lies in the greater complexity in project organization. If any defects occur, this can partially or completely nullify the benefits of graphical modeling [2]. In 2004, Martina Maier already stated that a complete expressive graphical description language would free us from the breaking with languages and thus advance a big step towards to controllability of complexity in software development [3].

In 2015, a research initiative launched by the CAS in Darmstadt with the company National Instruments and other Alliance partners. This is where the term 'LabVIEWsafety' emerged, which should serve as a defining element in the use of graphical languages for programming in high-assurance system development [10].
Through cooperation with various alliance partners and certification authorities, the possibility of a safety-related system development in this and other graphic development environments is likely to emerge in the future.

Even at the beginning of the research initiative it was noticeable that a visualization of the program execution could considerably improve the understanding of complex processes in some points. By means of graphical notation, software can also be understood by non-software specialists, as it maps the function similar to a block diagram. Such a universal and solution-neutral approach is particularly helpful as a communication tool in the team or during prototyping with the customer. The data flow model used here can thus be used flexibly, starting with the design, the modeling and the simulation, over the implementation, up to the test and the validation of the system. Difficult concepts of traditional programming such as dynamic data structures or variables are largely eliminated. Program execution can be done in parallel, without much effort by using special instructions for developers. A structured programming approach is facilitated by clear interface definition [23].

3 Problem description

In the research and development of technical automation systems, there is a trend to design and develop more and more complex systems with a decrease of development times and more complex legal basic conditions. This progressive approach of companies is mainly due to increasing demand and competitive pressure from the continuous automation and autonomization of industrial fields and private environmental influences. An ever increasing subarea of such automation systems are the safety-related systems, which are set to a much higher legal framework than conventional systems [11]. Text-based programming languages are considered established in the context of implementing functional safety. Evidence that graphical languages can not live up to these conditions does not exist. Thus, a responsibility issue arises in relation to a possible further development of safety-related software development [26].

The task of the research thus also represents an comparison, based on the standardization, between these different languages in order to create clear structures, in terms of aptitudes in the safety-related environment, and to ensure a strict typing of the programming language [11].

Since a high degree of clarity in management and thus often long training periods are necessary to develop complex systems in a safety-conscious way, in text-based languages this often only allows a small group of developers. This limits the know-how required for task and solution finding as well as potentials for early error detection [25]. A graphical development environment can bring significant benefits here [25].
In their basic structure, conventional programming languages , whether text-based or graphical, have few prerequisites to control such complex structures in the Internet of Things in a clear way. Software code must always be checked for errors and should have a well-proven compiler. [23]. There is an enormous development effort to create a necessary modular environment for a safety-related system [24]. A similar development effort is evident in graphic programming languages, but according to previous analyzes better clarity and less potential for errors should arise [23].

In addition to the industrial development, programming languages continue to evolve. In 4th generation languages, a high level of abstraction can be achieved through modular design and easy-to-use tools, which can be quickly understood by inexperienced developers and checked for accuracy or extensibility [22]. The principle of a strong abstraction in complex working modules basically enables all people with technical understanding to have access to the programmatic development of programmable electronic systems, especially in the graphical framework [23]. Part of the research work will be the exploration and development of such a higher abstraction level for the safety-related environment in graphical programming languages using the example of LabVIEW.

For very specific safety-critical systems, such as those required for medical devices or individual process plants, reliable, fast and inexpensive design methods are still lacking. There are already products that have been largely realized with programmable logic controllers. However, these are very expensive in small quantities, since there is little combination with components of other manufacturer product ranges. There is a lack of a viable alternative for custom machine design in the industry that could be created through a modular iterative approach [27]. Findings from previous drafts in the text-based and graphical environment should serve to build higher levels of abstraction for graphical system modeling and implementation.

Safety functions provide a link between software and hardware. According to DIN EN ISO 12100, the central standard for risk assessment in the safety-related area, a safety functions is a function of a machine whose failure can directly increase the risk. They represent software code that can increase the functional safety of hardware components by means of a risk assessment. The extent to which the use of a safety function actually minimizes the risk can be determined by means of the risk graph method according to DIN EN ISO 12100 or according to ISO 61508-5 [19] [11]. Such certification for risk assessment for graphical program code does not exist yet, without evidence of inability.

A means of program verification of software code is a formal method. It helps to ensure compliance with legal standards by verifying the accuracy of the algorithms and not just subordinating them to testing. Examples of formal methods can be found in symbolic program execution, as well as the method of pre- and post-conditions according to Hoare [38]. The extent to which these methods can be used in graphic development has not been examined yet. It must be developed a program verification for graphical program code.

4 Objective

The project is dedicated to the topic of using graphical programming languages for safety-related system development for various reasons. On the one hand, the increasingly complex safety-critical system structures of systems to be automated create the need for further development of development environments and programming languages for the application of current, but also new structures for module-based clear systems in the IoT and Industry 4.0 [11]. The work does not pretend to solve current problems immediately, but plans new approaches for graphical system architectures to create comparisons to current approaches. This may be useful for demonstrating operational reliability, as sub-architectures from earlier safety-related constructs could be used.
On the other hand, some approaches of the current industry and its standards are already outdated and thus increasingly difficult to reconcile with the latest developments in the direction of IoT. Some do not provide a graphical devel-

opment approach or can be difficult to apply to graphical languages such as LabVIEW. Although such guidelines and standards are updated in committees every few years, they still rely on the same approaches in current releases [11] [18] [14]. Graphical, well-structured programming tools, could take away an essential level of complexity and thus allow the creation of more complex projects, sometimes with the help of inexperienced developers. In addition, a graphical approach also helps to avoid program code errors, such as misspelling or forgetting to include libraries, as these are simply not possible [24].
By demonstrating and restricting various approaches in a new graphical programming language policy, using LabVIEW as an example, and certifying it, graphic software and hardware manufacturers can legally secure themselves in relation to the various provisions in the standards and provide an additional incentive for researchers and developers of safety-critical systems for the selection of graphical development environments for implementation [27]. A complete new guideline development also creates the opportunity for a better orientation towards future-oriented technology and architectural designs. The aim of this research is to develop recommendations for such a directive, as actual implementation is only possible through close cooperation between manufacturers, certification bodies and the various industrial sectors.

5 Summary

Guidelines, such as the MISRA-C and C ++, consist of a list of rules for safe and consistent programming in the programming languages. The purpose is the simple verifiability of certification bodies. Projects created under this policy thus comply with all legal regulations of the software, by strictly typing the programming algorithms [14]. In order to guarantee a scientific gain of knowledge, the guidelines of Design Science Research (DSR) will be used as a methodological framework for the processing of the presented research questions [32]. In general, already established, fundamental theories and practices are applied, adapted, abstracted or combined in order to generate concepts for solving existing application-related knowledge gaps [31] [33]. The research is not intended to develop a completely new technology and approach for safety-related systems, but also to examine the existing approaches with regard to their applicability in future machine structures, in order to make optimal use of the potentials of previous architectures for future visionary automation applications. The usability of the developed solution concept and the scientifically grounded approach to the preservation of this concept is thereby secured by the iterative research process provided by the DSR [33]. In addition, the already existing approaches are adapted to the efficient development of the overall architecture. The procedure for splitting the problem into subproblems in order to be able to break down the complexity is called Method Engineering [34].

A next step is a further examination of the existing standards from the given

areas and a comparative analysis between graphical and text-based code, as well as various graphical programming languages. In addition to the software architecture, special emphasis must be placed on the hardware, which must be fundamentally divided into different artifacts. Further steps include recommendations for developing current and exploration of new standards and guidelines for graphical programming languages, which could include the creation of proprietary software architectures, security libraries, qualification tools and code analysis tools.

Basically, the total cost of creating safety-related software is divided into two subcategories that are interdependent. These are the joint creation of guidelines by graphical software and hardware manufacturers and our research institute, which will later help guarantee easy certification with graphical languages created safety-related software. The basic prerequisite for this is, first of all, the certification of the development environment in order to prove that all the necessary requirements are met. Beginnings of the analysis can be found in chapter Present procedure.
In order to presuppose on the legal level that all specifications are adhered to in the current development environment, a pre-certification of existing functionalities is an option. Special emphasis should be placed on the basic level of such languages, which usually contain all components of more complex functionalities [15]. Thus, referring to the research aspect, it is derived from a presentation of these towards certification bodies, for concrete analysis.
The observation and reworking of concrete methods and methods for assessing the adaptation of graphical programming structures is an essential part of the data collection to be created in the first steps. For example, expert interviews with persons involved in the certification selection process represent a further survey method in order to gain an overview of the requirements of individual devices with regard to the certification bodies. Document and content analyzes of the industry-specific standards to be investigated in the course of research projects are to be used to find solutions for a wide range of safety-related, electronically programmable devices.
High standards of clarity and traceability are also set for the programming technology. Some of these are already very detailed in the LabVIEW Development Guideline on the example of LabVIEW [15]. However, there are some limitations to interrupts and recursions, exclusion criteria for using dynamic variables, and static verification methods needed in the safety-related part of programming [14].

There is a lack of framework conditions for the use of graphical programming languages for the development of safety-related electronically programmable systems. This creates a need to evolve safety-critical code into the graphical environment [28]. So far, there are neither legal nor systemic requirements to fulfill this goal.

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Evaluation of hardware requirements for device management of constrained nodes based on the LWM2M standard

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Abstract. Nowadays, resource constrained devices are seen as one of the main components for building the Internet of Things (IoT). Typical constraints of such devices are given by the size of the built-in memory, a non-continuous power supply, and limited computing power. A categorization for such constraints into classes is given in RFC7228. The exponential growth of the number of end devices demand for a centralized, automated, and secure device management to handle the complexity of the upcoming IoT. The emerging open standard Lightweight Machine to Machine (LWM2M) is one of the first approaches to meet the requirements for managing constrained devices. A growing variety of implementations of the LWM2M protocol stack became available in the past years. This paper aims to define useful metrics for measuring device management capabilities on constrained nodes. Two relevant open source implementations are compared by their memory usage. The results show that LWM2M is feasible on Class 2 devices.

Keywords: IoT · Device Management · LWM2M

1 Introduction

According to Gartner and other analysts the amount of IoT devices in consumer and business environments doubles each two years. Such an increase of interconnected devices forming complex systems with broader attack surfaces demands for an appropriate security level of communication protocols and firmware for IoT devices. These new requirements ask for a new infrastructure for managing devices in an automated and centralized manner. This approach is well known for interconnected devices like personal computers, mobile phones, printers, etc. In the field of constrained devices such as small sensor nodes for measuring temperature, humidity, pressure etc. or actuators like thermostats or light switches, device management is not yet widespread [1]. Microcontroller for such applications are available since a few years providing hardware accelerations for cryptography as well. Furthermore, wireless connectivity for sensor nodes is developing towards a standardized interoperability like given by the IEEE 802.15.4 standard. In a wireless sensor network (WSN) devices often interact directly

with their environment. This leads to new risks especially in safety-critical applications like smoke detectors. So with introducing interconnectivity such small devices must become maintainable with Firmware Over-the-Air (FOTA). In addition, for detecting misbehaviour a WSN requires monitoring capabilities and should provide remote parameter configuration. This paper focuses on functionality for security purposes in particular. The LWM2M protocol developed by the Open Mobile Alliance (OMA) is an example for how to standardize open device management [2]. With its focus on constrained devices LWM2M provides a variety of services besides device management and is build on top of IP. In the last years several open implementations for LWM2M clients came up. They differ in a large variety in their memory consumption and implemented functionality. So for selecting an appropriate implementation an upfront analysis is necessary whether functional requirements are met and hardware requirements can be fulfilled by a given hardware device.

2 Device management and its implementation

Before personal computers got interconnected through a network, management functionality was rarely required. Each user had to manage its personal device manually and physical access to the device was required. By interconnecting such devices, large enterprises introduced a centralized device management enabling remote control over a continuously growing number of computers. In general, such management consists of configuration, monitoring and administration of managed entities. Managed entities could be network elements, applications, system resources or services [3]. In the 1990s, management was divided into three categories: system management, network management and application management. With the emergence of smart devices the new domain "device management" appeared. Device management consists of functions from all three categories. Furthermore, it is not only used in a business context, but for private purposes by individual users as well [3].

Comparing common management protocols, the way of managing entities is very similar [4]. Managed entities are named resources or objects. They consist of a name and a corresponding value representing a unique ID. Resources and objects are often sorted into logical groups (e.g. a group named "temperature sensor" with two objects: battery level and temperature). Similar types of operations exist that can be performed on objects. Primarily those are: *GET* the value of the object or resource, *SET* the value of the object or resource, *EXECUTE* a specific function provided by the object or resource, *NOTIFY* a central management point about events being observed by a specific object or resource.

LWM2M implementations: As of today, the LWM2M standard has a very low market penetration. For now there are a couple of open implementations already available. Some of them are part of IoT operating systems like MBED, RIOT, Contiki or Zephyr. Others are maintained by companies [5, 6]. LWM2M uses a client-server architecture while this paper investigates clients only. An

LWM2M server requires a more powerful machine where resource constraints should not be an obstacle.

Related Work: The literature provides already some work on evaluating device management on constrained nodes. Z. Sheng et al. presented an efficient way minimizing packet size with Constrained Application Protocol (CoAP) [7]. Others implemented their own LWM2M client for evaluation patterns of memory usage and network load [8, 9]. D. Tracey et al. used Contiki for expanding LWM2M by new objects for a comparison with the Common Information Model (CIM) as a standard being used in enterprise-wide management solutions [10]. The results show that LWM2M manages data in a more efficient way. Furthermore there had been attempts to connect Bluetooth Low Energy (BLE) networks to LWM2M via a Gateway mapping the BLE service onto LWM2M objects [11]. According to the authors, this approach was taken because IP isn't still suitable on all constrained devices. A very similar approach was taken by [12] who integrated LWM2M into the Continua architecture for medical remote patient services. This was also realised by a Gateway mapping medical data (e.g. blood pressure, smart watch) to LWM2M Objects. To run LWM2M on more constrained devices directly without the needs for a gateway in between A. Karaagac et al. presented several optimizations in the LWM2M communication flow [13]. Improving security and power supply on constrained devices is an active field of research [14–17]. In the future IoT a centralized interoperable device management is key [18].

3 Evaluation criteria and methodology

Devices for large IoT environments bring their own non-functional requirements. When the number of devices grows, manual workload for changing batteries after one or a few years drive operational cost becoming a strong inhibitor for new business models based on such large IoT environments. Hence their energy consumption should allow periods of 5, 10, or even more years of running time. Another criteria is on limiting the required size of memory to a minimum for using the cheapest hardware configuration of microcontroller variants. Both energy consumption and memory size depend on the hardware architecture and a modest resource footprint of the used software. The following list of non-functional requirements should be used for assessing the eligibility of network protocols and their implementations in resource constrained environments.

Memory usage: Several software components like an operating system, IP stack, etc. build the software stack running on constrained devices. Device management adds further components to the stack. Its code is stored in ROM/Flash where the size can be determined after compilation time. The size of the data segments define the size of required RAM. It is used for variables, buffers etc. where only the size of the static part of memory can be determined after compilation time exactly. During runtime the size of dynamically allocated memory like a heap needs to be added. For constrained devices, an implementation should achieve that only a minimal part of RAM is being used dynamically.

Energy usage: For a very low energy consumption constrained devices should be in a power saving or sleeping mode most of the time. Both optimizing the software stack behaviour for maximizing the deep sleep time and measuring the energy consumption per software function is an active research area [19].

Protocol overhead: Reducing the overhead of communication protocols for constrained node networks (CNN) can be achieved by minimizing the size of messages and the number of messages to be sent. Readable formats like XML or JSON use much more bytes as a consequence compared to binary formats. Corresponding metrics allow measuring the efficiency of the complete network stack or layers of it.

Encryption: Public key infrastructures (PKI) are hardly implementable even for class 2 devices. Current open approaches are based on DTLS with PSK or raw public keys. If weaker encryption is sufficient there are a few lightweight cipher suites choosable [20]. Furthermore, hardware accelerated cryptography primitives can be used. However, for FOTA, secure multicasting would be desirable [21].

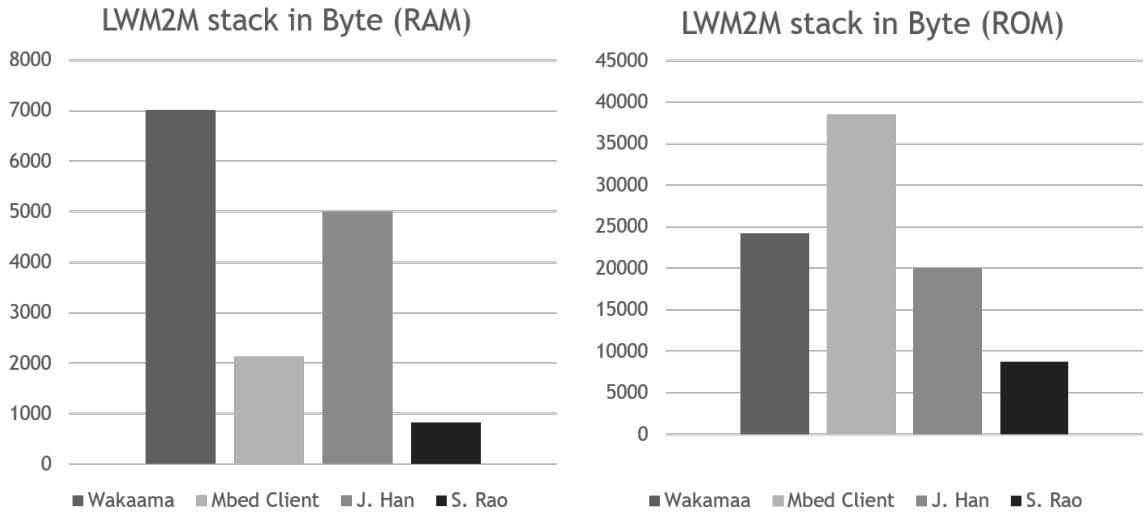
Modularity: For maintaining a software stack over a long lifetime, the implementation should be modularized. Configurability allows providing only the required code parts within the shipped firmware.

As the following results were gained in an ongoing project this paper presents first results investigating memory usage. For determining the memory footprint a tool from G. Mukundan [22] was used. It analyses firmware in executable format from the *Map* and *ELF* file. For the investigation, sample firmware applications were created where a Nordic nRF52-DK board was chosen for the evaluation as a typical hardware used for constrained nodes.

4 Results

In total, four LWM2M implementations were selected for this examination. Data for two of them were already provided by Han et al. [8] and Rao et al. [9]. For investigating the other two, according components were extracted from the Mbed stack (named *mbed client*) and RIOT OS (named *wakaama*). They were ported and integrated as a sample firmware for chosen hardware board. Figure 1 presents a comparison of the memory usage for both RAM and ROM. S. Rao's implementation results in very low consumption of 820 Byte RAM and 8764 Byte ROM without the mandatory LWM2M objects and DTLS. The mbed client results in an exceptionally high ROM usage of 38450 Byte. One reason seems to be the overhead generated by using a highly object oriented C++ design with a large code base while the other three are implemented in C. The mbed client provides all LWM2M capabilities. For porting it to another software stack easily a platform abstraction layer is provided also resulting in ROM overhead. The mbed client is designed to connect to the ARM's native cloud platform only. A few changes in the code were necessary for allowing connections to an open source LWM2M server like *Leshan*. The RAM consumption of the mbed client is modest with only about 2130 Byte. Wakaama was developed by the Eclipse Foundation.

The implementation requires a lot of dynamic memory. Such RAM usage is not recommended for embedded programming. Nevertheless, the code was ported to RIOT OS. The ROM usage results in 24250 Byte which is closer to the size cited by Han. Wakaama provides DTLS security with PSK and raw public key, certificates are not implemented. Depending on the used DTLS library and its modularity, security adds around 4-8 KB in RAM and 25-60 KB in ROM. The RAM and ROM size also depends on which LWM2M capabilities are already provided by an implementation. This may differ to a small extend between the presented implementations. The RAM usage of Wakaama with 7010 Byte is still beyond design objectives for class 2 devices.



(a) RAM (b) ROM

Fig. 1. LWM2M implementations in Byte

As a sort of hacky workaround for the port, around 5 KB of memory are allocated statically for simulating the previous dynamic memory design on the heap. This results in memory leaks by assigning static blocks bigger than the containing data. The memory actually been used by the wakaama code is less than the reserved memory. To fix this issue it would be advisable to allocate only the utilized memory for the used objects and identify the parts where dynamic memory is needed. Furthermore, on RIOT the occupied stack size on the nRF52-DK could be measured. It was about 1,2 KB.

Additional Results: LWM2M suggests the use of *TLS_PSK_WITH_AES_128_CCM_8* or *TLS_EC-DHE_PSK_WITH_AES_128_CCM_8* as cipher suites. These should suffice security needs of interconnected constraint devices according to RFC 7925 [20]. For LWM2M connections via the internet containing sensitive data an 8 Byte MAC is probably too weak. Comparing modularity, Wakaama provides only very limited configuration options for selecting code parts to be shipped. In contrast, the mbed client can be customized by a configuration file

for choosing modules to be contained within the firmware e.g. cipher suites, IPv4/IPv6, LWM2M bootstrapping etc.

5 Conclusion and Future Work

For using IoT networks including large numbers of constrained devices manageability of all components becomes a strong requirement. Therefore, device management on constrained nodes needs to be seen as essential for building secure and mature IoT solutions soon. As hardware resources on these nodes are limited, appropiate software components for implementing device management need to fulfil non-functional requirements on memory and CPU consumption as well. LWM2M is an emerging standard in the IoT for managing constrained devices. Because these devices are restricted, there are special requirements for software and hardware. The important metrics are memory usage, energy usage, protocol overhead, encryption and modularity. The presented implementations vary especially on there memory usage and functionality. Although it has a big ROM capacity, the mbed client contains all standard functionality and has a well rounded C++ API. Wakaama on RIOT can still be optimized in its RAM usage compared to other implementations. Both libraries are maintained actively. The amount of memory usage justifies the feasibility on Class 2 devices.

For future work it would be worth considering on how to validate the presented requirements for an application protocol. This paper presents first results of evaluating the memory footprint as part of a research project. Furthermore, questions need to be answered how to optimize functional coverage versus memory footprint, how RAM usage can be minimized, and energy consumption can be reduced during runtime. Another drawback of current implementations is that LWM2M clients have to wait for server requests actively. Constrained nodes are usually active for sending sensor data only while sleeping most of their time. Keeping the radio module on for receiving requests leads to unnecessary power consumption. So adding a timing schema with active slots for managing nodes will be another optimization.

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Scene-Adaptive Optimization Scheme for Depth Sensor Networks

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Abstract. In this work a scheme for scene-adaptive depth sensor network optimization is presented. We propose to fuse the knowledge inferred by the sensor network into a common world model while at the same time exploiting this knowledge to improve the perception and post processing algorithms themselves. Moreover, we show how our optimization scheme can be applied to improve the use cases of disparity estimation as well as people detection with multiple depth sensors.

Keywords: depth sensor networks · context aware · knowledge based optimization · scene-adaptive · optimization

1 Introduction

Low cost commodity depth sensors are an emerging technology and are applied to a broad field of applications such as people detection and tracking, 3D reconstruction or emergency detection in an ambient assisted living context. However, depth sensor networks as well as modern vision algorithms have many parameters and require fine-tuned, scene-specific configurations to achieve optimal performance. Due to strongly varying scenes and changing conditions at run time it is very challenging to fine-tune those parameters manually in real world applications. To overcome the problem of scene-specific manual (re)configuration of depth sensor networks, we propose a scene-adaptive scheme which exploits the scene knowledge to improve perception and post processing vision algorithms. Our objective is not only to tune the given parameters but also to improve the vision algorithms, such as stereo block matching, detection or tracking by explicit exploitation of the scene knowledge, e.g. by building scene-specific object models. Therefore, we fuse the knowledge inferred from the sensor network into a common world model, representing our current context knowledge. This knowledge is then fed back to optimize sensor parameters and algorithms to improve the performance of a sensor network at run time.

2 Related work

The configuration of video sensor networks in the context of video surveillance has been widely studied in the literature. In [13] a general overview of the different aspects of sensor network reconfiguration is given. Rinner et al. [12] focus on the aspect of configuration of smart camera networks in the context of video surveillance. They review the configuration for a specific analysis task and evaluate different configuration methods. In [8] a flexible uncertainty model is presented to reconfigure the sensor network with the objective to optimize the detection performance. Fischer et al. [4] give an overview of intelligent surveillance systems, analyzing the information flow between sensors, world model and inference algorithms. In [14] an overview to visual sensor networks is given. However, prior work focuses on monocular camera networks and employs parameter reconfiguration. In contrast, our work deals with depth sensor networks and proposes a scheme for explicit exploitation of the given scene knowledge. This includes conventional parameter reconfiguration methods as well as methods that construct and use sophisticated world models to improve the integrated algorithms of sensor networks at run time.

3 Scene-adaptive sensor network optimization

In this section we present a scheme for scene-adaptive sensor network optimization. The general information flow in a depth sensor network is depicted in Fig. 1 and separated into five different abstraction layers. The **sensing** layer

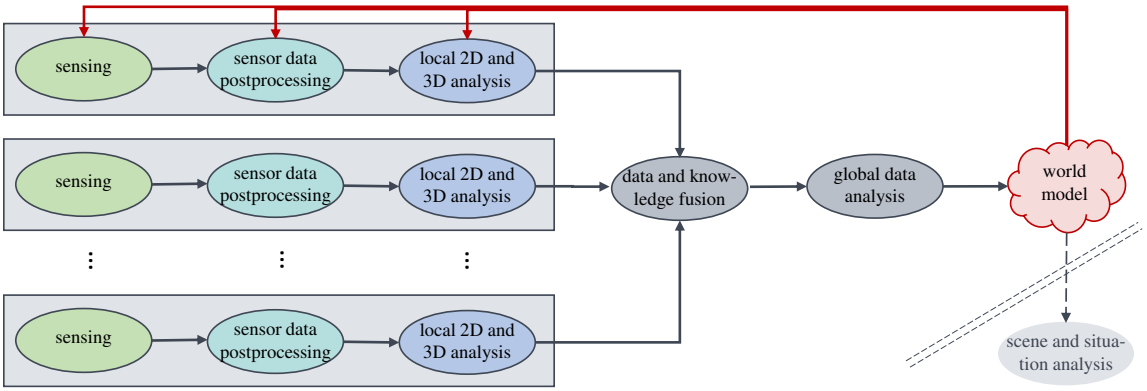

Fig. 1. Information flow in a depth sensor network with scene-adapative optimization strategy.

contains low-level methods related to the raw sensor measurement such as synchronization, calibration and image acquisition. In the **sensor data post processing** layer depth estimation algorithms (e.g. stereo block matching), filtering and low-level feature extractors are included. **Local data analysis** covers high level vision algorithms which take the RGB-D data as input such as segmentation, recognition, object detection, local 3D object and scene reconstruction or

tracking of objects. Based on the results of the **data and knowledge fusion**, the **global data analysis** layer includes methods which make use of the fused information of multiple sensors of the network. Examples are 3D scene reconstruction, 3D object localization and global tracking. The sensor network infers information about the scene across abstraction levels. Over time, information is fused into a common world model which represents the current scene knowledge. While a world model can be used to do e.g. scene and situation analysis, we use it to optimize the parameters of each individual sensor online and support the data analysis methods e.g. by building scene-specific object models gradually.

3.1 Knowledge representation

The employed knowledge representation within the world model has to be expressive to solve the high-level task of the sensor network and the optimization of the sensor network itself. The fusion layer might provide sensor data as well as locally derived high-level knowledge and the world model therefore might need to cover low-level data up to high level information. Taking these aspects into account, several existing approaches for knowledge representations are qualified to serve as world model. For most tasks and networks, a world model consisting of geometric and semantic scene descriptions will be suitable. Geometric scene knowledge thereby encompasses information about the objects contained in the scene and their properties. This includes the object class (e.g. humans, furnature, floor plan), the object location and orientation in a global world coordinate system, dynamic properties e.g. a motion model, shape, material. Examples for such a world model are object oriented world models [2, 5]. In order to enhance the quality of the world model, a knowledge base consisting of preprocessed information or prior knowledge can be used. This includes morphable shape models [3] for different object classes as well as common recognition, detection and segmentation models [18] which are applied on image and 3D data, e.g. RGB-D data, point clouds, voxels or triangulated surfaces [1]. In terms of semantic knowledge Fuzzy Metric Temporal Logic and Situation Graph Trees [11] or ontologies [10] can be incorporated. The semantic description might be data driven, e.g. Hartz and Neumann [6] use a scene interpretation system [7] and learn ontological concept descriptions from data.

3.2 Optimization possibilities

Depth sensor networks involve multiple algorithms which leads to a large amount of parameters. In this section we give an overview of parameters and methods which are suitable for automatic scene-adaptive sensor optimization. We assume that a suitable knowledge base (see section 3.1) exists and focus on algorithm and parameter optimization. Following our layered scheme, we categorize the optimization targets into three major categories, see Fig. 2. **Sensing** parameters have a direct impact on the measurement quality. Parts of this category have already been addressed. Auto exposure is state-of-the-art for decades in consumer cameras, but sophisticated scene models [17] can improve the result

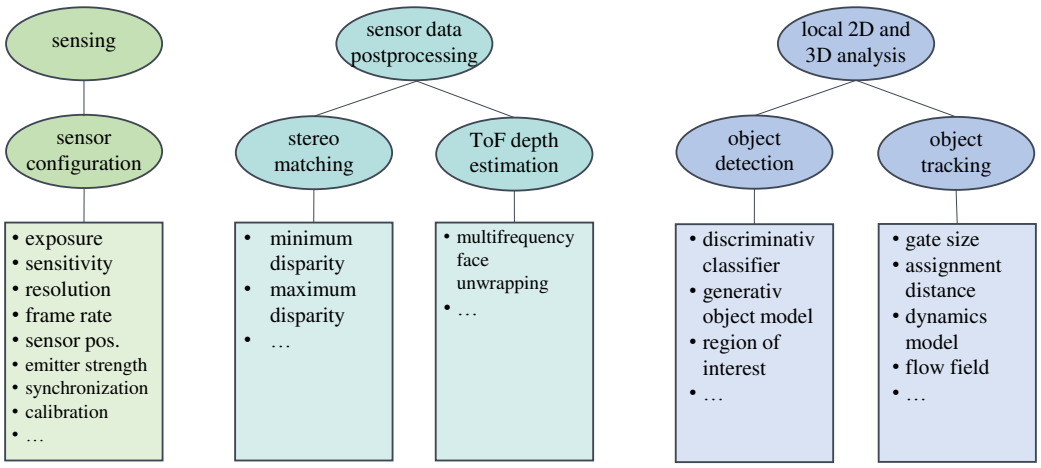

Fig. 2. Non-exhaustive taxonomy of building blocks within a depth sensor network which are suitable for scene-specific optimization.

e.g. by taking only the pixel intensities near regions of interest into account. **Sensor data post processing** methods vary highly between different depth sensing technologies. The depth estimation of a stereo sensor can be improved by setting the minimum and maximum observable disparity based on geometric scene knowledge. In section 4.1 a approach for the task of scene-adaptive disparity estimation is presented with an exemplary knowledge representation. Many scene-adapative **local data analysis** methods have already been published. Yang et al. [16] learn global appearance and motion models to improve multiple target tracking. Masksai et al. [9] propose a context-aware optimization strategy for multi object tracking. They learn the most likely trajectory patterns with respect to a given scene layout to reduce incorrect assignments between detections and tracks. In 4.2 we show how the task of people detection can be optimized in a scene-specific fashion.

4 Application

In this section we show the applicability of our scheme on two exemplary use cases.

4.1 3D model based disparity estimation

Our knowledge representation contains sensor knowledge in the form of a camera model and existing camera calibration parameters π, scene geometry using a ground plane assumption $P(h) \subset \mathbb{R}^3$ and a 3D morphable human surface model parameterized by β. Scene semantics are represented as segmentations of a single human s_h and the ground plane s_g in the image. Let $D_\pi(u)$ be a depth image computed using the estimated disparity values u from the image pair (I_1, I_2). Classical stereo algorithms estimate the disparity values u minimizing a cost function

$$E(u) = E_{\text{photometric}}(u; I_1, I_2) + E_{\text{reg}}(u) \ , \tag{1}$$

where $E_{\text{photometric}}$ is the photometric error penalizing intensity deviation in the local neighborhood given u and E_{reg} regularizes the problem penalizing unlikely disparity values based on simple scene assumptions. We propose to employ a scene-adaptive optimization scheme reformulating (1) with

$$E_{\text{adaptive}}(u) = E_{\text{photometric}}(u; I_1, I_2) + E_{\text{model}}(u[s_h], u[s_g]; \beta, h) \ , \qquad (2)$$

where E_{model} uses our provided scene representation to measure the deviation from the estimated depth at the segmented pixel locations $u[s_h]$ and $u[s_g]$ to the explicit geometric scene representation consisting of the ground plane at height h and the human shape model parameterized by β. Scene-adaptive disparity estimation is then performed by estimating $\hat{u} = \arg\min_u E_{\text{adaptive}}(u)$. Eq.(2) can be extended in various ways, which proves the generality of the proposed approach by e.g. introducing a human motion model to enforce temporal consistency constraints.

4.2 People detection with multiple depth sensors

The sensors have a top view on the scene and a significant overlap to each other. Additionally, we assume that the sensors are intrinsically and extrinsically calibrated in advance and that the common ground plane is known. We model the presence of a person on the ground floor as a discrete grid of Bernoulli random variables $\boldsymbol{X} = (x_1, .., x_n)$, $x_i \in \{0, 1\}$ where each x_i maps to one specific ground plane grid location $\boldsymbol{g}_i \in \mathbb{R}^2$. Our goal is to infer the likelihood of a scene configuration $\boldsymbol{X}$ given current depth observations $\boldsymbol{O} = (O_1, \ldots, O_C)$ from C depth sensors. Applying Bayes' theorem and assuming that the prior factorizes as $p(\boldsymbol{X}) = \prod_{i=1}^{n} p(x_i)$ we get the posterior distribution

$$p(\boldsymbol{X}|\boldsymbol{O}) \propto p(\boldsymbol{O}|\boldsymbol{X}) \prod_{i=1}^{n} p(x_i). \qquad (3)$$

For this application we assume that the likelihood $p(\boldsymbol{O}|\boldsymbol{X})$ is given (see [15] for details on the construction of the likelihood) and only focus on the scene-adaptive choice of the prior $p(\boldsymbol{X})$. We start with an uninformative prior to make the detection of people at every location equally likely. In many real world scenes this is a crude assumption due to obstacles or preferred walking tracks which can be present in the scene. Thus, we propose to accumulate the detections over time to get the relative frequencies $\boldsymbol{H} = (h_1, \ldots, h_n)$ of the presence of people for every ground plane grid location $\boldsymbol{g}_i$ and fuse those information into the world model. This scene-specific knowledge can be used in the feedback step to continuously update the prior beliefs $p(x_i)$ accordingly to $\boldsymbol{H}$ on regular time intervals.

5 Conclusion

In the present work we have proposed a scheme for scene-adaptive optimization of depth sensor networks. We have given an analysis of relevant knowledge representations and categorized identified optimization targets. Moreover, we have

exemplarily applied our scheme on the use cases of disparity estimation as well as people detection with multiple depth sensors. Future work will include the investigation of more use cases as well as proof of concept implementations.

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Chapter 3

Visual Computing

Immersive Shopping
Presentation of Goods in Virtual Reality

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Abstract. Mixed Reality is gaining popularity in more and more areas. One of such application, which has gained recent interest, is the enhancement of shopping experiences by presenting virtual goods in a real or virtual surrounding. While product representation (e.g. quantity, placement, size, surrounding) in brick-and-mortar retail stores is naturally constrained, e-commerce is liberated. But instead of using those possibilities the best practice to represent products in the web is to show a single whole object on a white background. Contextual information is therefore removed and from the shown image alone it is unclear if the product is available, in what quantity, its size, or how valuable it is in comparison to other products. In retail stores, however, those incentives have a well understood influence on customer behavior and are used to actively steer the buying habit. But if those incentives can also have a positive effect in immersive virtual environment has, to the best of our knowledge, not been investigated.
Our results show that basic findings on the presentation of goods do not behave significantly differently in virtual in comparison to real environments. The virtual surrounding in which the product was presented had a significant impact on the product evaluation.

Keywords: Immersive Virtual Reality · Virtual Shopping · Customer Experience

1 Introduction

Although the beginnings of *virtual reality* (VR) glasses date back to the 1960s, it was only in the last few years that the technology could be made accessible to a broad mass of people. As a result of constant further development, VR is being used in more and more areas, the hardware of *head-mounted displays* (HMD) is improving and enthusiasm for and interest in this rather new end-user technology is growing. Virtual representations of goods are expected to gain relevance in e-commerce applications. But how to present goods with immersive technologies is not well understood. Can learnings from brick-and-mortar retail stores simply be transferred into the digital domain? Or should we follow standards

and guidelines from the mobile and web sectors regardless of the differences and characteristics to VR? Probably not! See for instance Speicher et al. [13]

It has been experimentally demonstrated that there is a difference between the perception of space in physical and virtual environments. Saleeb [10] showed that the perception of size lies in a perceived reduction of height by 4% to 9%, width by 9% to 31% and depth by 18% to 32%. These values apply to the static state. Through movement, the values decrease, so that the changed perception of space corresponds somewhat better to reality, but still shows differences. Experiments by Rojas et al. showed that rendered 3D objects with medium quality alter consumer perception in comparison to real objects. [9]

So how could immersive shopping look like in the future? Besides simply resembling well known shopping spaces, the question arises, if and how the liberation from physical constraints can be combined to good effect. To answer the raised question we first review how goods are presented in different environments (see Section 2) before we present our test setup where we change the position, quantity and size of the products on the one hand and the influence of different environments on the other (see Section 3). Thereafter we present our findings (see Section 4) and conclusion (see Section 5).

2 Presentation of Goods

In this section we present a brief overview on how products or goods are presented in different media. A full discussion of this topic is beyond the scope of this publication.

2.1 Store

The presentation of goods is seen as part of the shop design and includes the distribution, arrangement and decoration of the goods in the room. It influences the behavior of the customer and his/her emotional and cognitive processes. [4] Therefore, a lot of attention has been put into the investigation in how to distribute and arrange goods. In retail goods are presented in the four zones: stretch level, eye level, touch level and stoop level following particular rules for the vertical and horizontal arrangement; e.g. items that are promoted should be placed in the eye level, cheap items belong down and sensitive items are placed high. The eye level receives the most attention and everything above and below is not perceived to the same extent. A product in the eye level sells between 50% and 80% more frequently than a product in the stoop level. [5] In the horizontal positioning the center of a shelf achieves the most sales, followed by the right side of the shelf. The left side of the shelf forms the area with the weakest sales. [11] This can be explained by the fact that customers not only walk in the right direction, but also reach to the right. [15] Research has shown that customers think they have more choice when shelves are filled with few, but well presented, items. The sales could be increased by 10% despite a reduction of items by about 30%. [5]

2.2 Web

In recent years, online trading has been able to expand through platforms such as eBay or Amazon and is gaining more and more importance. Food is a significant part of the global retail market, but it is still not strongly represented in e-commerce. On websites food is presented using 2D images, text description and white background, which do not create a real shopping experience, see for instance left image in Figure 1. [4] Usually the product is also shown as a single product and presented by photographs and additional text descriptions. [6] The decision to buy food in a store is mainly influenced by the haptic experience. It is important for consumers to know the appearance of the goods and to be able to judge the quality derived from it themselves which, of course, is not possible with a digital sales channel. Only the sense of vision is able to check and assess product quality independently of product characteristics. Visual representations or text descriptions of the product on the web can partly compensate the lack of tactile information. [7]

Fig. 1. Typical representations of goods (left image) in a web store where the products are presented without background (with white space) and augmented-reality application (right image) where the real environment is augmented with virtual content.

Both text and visual product information may not be presented in a structured and organized way on the Internet. However, the arrangement of products and the placement of information about product characteristics are important in order to influence the behavior of users. As discussed in Section 2.1 relative shelf position is affecting consumer choices. Breugelmans et al. show that product placement can also have an effect on the consumer choices in the context of online grocery. [2]

Previous research by Alba et al. has shown that users can more easily capture and process information if it is clearly presented. [1] A plain background will bring focus to the product and allows the user to take a better look at it.

Details of the product can get lost with a contextual background. Efficient visual presentation helps the buyer to process the product information and gain a realistic understanding of the product. The challenge is to present products through images and text that all important information is given and a real product experience can be replaced. [6]

2.3 Augmented Reality

The use of *augmented reality* (AR) in retail is twofold: It can be either used

- to augment products at the point of sale or
- to present a product in any given environment such as home.

While the former is focused on the presentation of product-related information the latter shows the product itself in a given environment. A typical AR retail application is depicted in the right image in Figure 1. Spreer and Kallweit have revealed that AR has the potential to improve the assessment of information and that, to ensure the users' acceptance, it needs to offer a clear customer benefit and enjoyment-related elements. [14]

2.4 Virtual Reality

The use of VR department stores is not commonplace yet. This can be contributed to the availability of VR, the VR experience itself and the lack of VR shops. The world's first VR department store was 'opened' in collaboration with eBay and the Australian company Myer. With a smartphone and a customized version of the Google Cardboard, the user can enter the personalized department store and view 3D models of certain products from all possible perspectives in VR. Chinese e-commerce Alibaba also uses buy+ to show what a virtual shop can look like. [8] At the Taobaoer Maker Festival, users could buy a cardboard, insert their smartphone and walk through the virtual shop. The focus was on buying experiences from foreign shops that do not have a location in China. Unlike the VR department store from eBay and Myer, buy+ not only offers 3D models and 360° views of the products, but also a virtual environment of real shops. This should enable users to have a realistic and improved shopping experience. There was a lot of interest in the beginning, but no further updates and news were released, although nearly 8 million users tried buy+ during the Taobaoer Maker Festival. Possible reasons could be that the users had no added value because the virtual shopping experience was not very immersive due to the cardboard. Another reason could be that there wasn't much to see since only six retailers were available. [8]

3 Test Setup

As we have seen in Chapter 2 there exists different approaches between real and virtual shopping which come with different advantages and disadvantages.

While real and web-based commerce is well understood, immersive shopping is not. The aim of our study, therefore, is to figure out if customer behavior is influenced by the same parameters in an immersive virtual environment as in a physical environment. The test setup concentrated on four purchasing decision parameters (the first two are optimized in retail, the third investigates perceptual differences and the last one can probably profit the most from the possibilities of immersive virtual environments), namely:

- **placement**: Does product placement in VR has the same influence as the four shelf zones in brick-and-mortar retail?
- **quantity**: Is the scarcity effect transferable to VR even though it does not really make sense in e-commerce?
- **size compared to reality**: Are there any differences in the perception of size of a product between real and virtual? And how is the displayed size of a product influencing the buying decision?
- **environment**: How can the surrounding influence the perception of the product according to the attributes ecological, healthy, regional, sustainable, fair, valuable?

We decided to use two goods, a milk package as a representation of a daily commodity and a wine bottle as a luxury commodity, and to place them into five different environments as depicted in Figures 6 until 9.

The software for the study was developed by us using the game engine Unity and was particular designed to fit to the requirements of the test. The hardware setup consisted of a PC with i7 CPU and 1080i GPU running Windows 10, HTC Vive + Lighthouses and a Leap Motion mounted on the head mounted display.

3.1 Procedure

The entire experiment consists of a total of 16 different environments, of which 8 environments with the milk or wine variant are shown to the test person. Whether the subject sees the milk or wine variant is decided by chance. The test lasted 15 to 20 minutes and had the following structure:

1. participant enters the room and is welcomed and instructed by the test leader
2. participant fills in the demographic information
3. participant puts on VR glasses and adjusts them accordingly
4. the test leader starts the next randomly selected environment
5. participant has time to look around, interact in this environment and to fulfill the given task
6. questions about this environment are asked and entered into the form by the test leader
7. steps 4. until 6. are repeated until the last environment is tested
8. the experiment is finished and the participant can write comments or other suggestions into the form
9. the test leader thanks the participant and the subject leaves the room

3.2 Participants

The study included a total of 70 subjects (24 females, 46 male) at an age between 20 and 76 years. 51 participants have already experienced VR before the test. A total of 57% of participants shop online every month and 25.7% shop weekly. 70% of the participants have never bought food online.

4 Results

In this section we present the results from the experiments described in the previous section. If not stated otherwise the results are given as Likert scales from 1 (fully disagree) to 5 (fully agree). Figure 2 presents the three free variables placement, quantity and size while Figures 6 until 9 show the different tested environments. All differences considered relevant ($p<0.05$) according to ANOVA are marked with an asterisk *, those considered highly relevant ($p<0.005$) are marked with two asterisks **.

Fig. 2. A wine bottle in different places, in different quantities and in different sizes.

4.1 Placement

Based on the results in Figure 3 where the difference between the four shelf levels is presented, it can be stated that the participants have chosen the products nearly exclusively from the eye level (a much higher *buying interest*** as well as *grasping*** for the product). In comparison to the physical environment this effect seems to be even more pronounced in VR. Comparing, in Figure 3, the perceived *effort* ($p\approx0.49$) we see that there is not a large variation. A tendency to higher effort is in the stretch level, the least effort is located in the touch level.

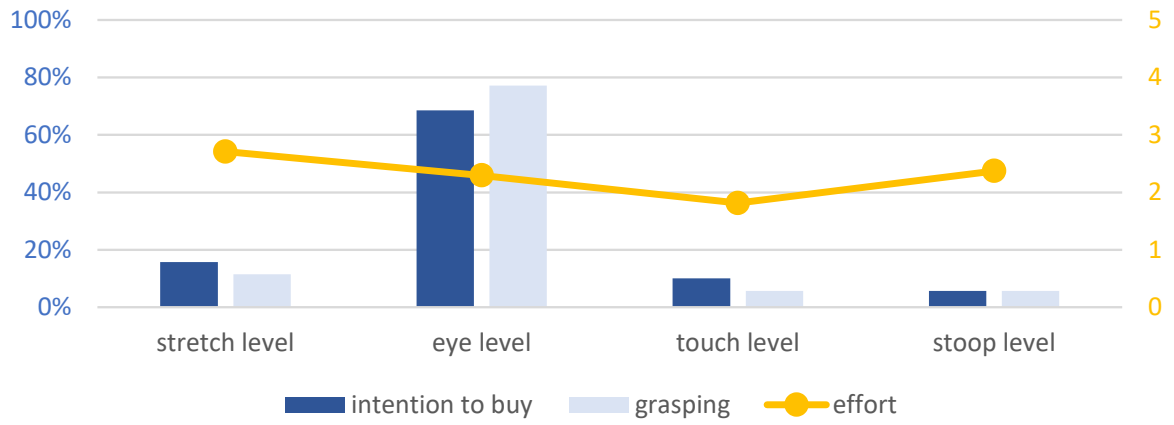

Fig. 3. Comparison of the intention to buy, grasping and the felt effort in relation to the four different levels.

4.2 Quantity

Artificial scarcity is part of an innovative brand strategy. This strategy means the artificial reduction of products, in order to increase the attractiveness for the customer and to positively influence the purchase decision to influence the shelf space. For instance, retailers only fill half of their shelves, to artificially illustrate the strong demand for certain products. Or they limit their product offerings in time to keep customers under pressure to buy the products already before expiration. Due to scarcity, the value of a product and its perceived quality can vary. [3]

The intention to buy and the felt value are shown in Figure 4. In contrast to online shopping where only a single product is shown in our experiments the *intention to buy** was higher if a couple or many products of the same type have been shown. The *value* ($p \approx 0.15$) attributed to a product is only slightly reduced if shown in a large quantity.

4.3 Relative Size

Figure 5 shows that the participants chose an object which was scaled by 10% as the best fit to the original or *real size**. This is consistent to the findings by Saleeb which, as already discussed in the introduction, has demonstrated that there is a perceived reduction in size which is being compensated in our experiments by deciding for a larger version of the original size. This choice towards larger than real size directly translated to the product with the highest *intention to buy**. It is interesting to note that the intention to buy was shifted even further to larger product sizes. This suggests that products should be presented in exaggerated sizes.

4.4 Surrounding

Figures 10 and 11 give the influence of the different surrounding, as given in Figures 6 until 9, on the perception of the two products, milk pack and wine

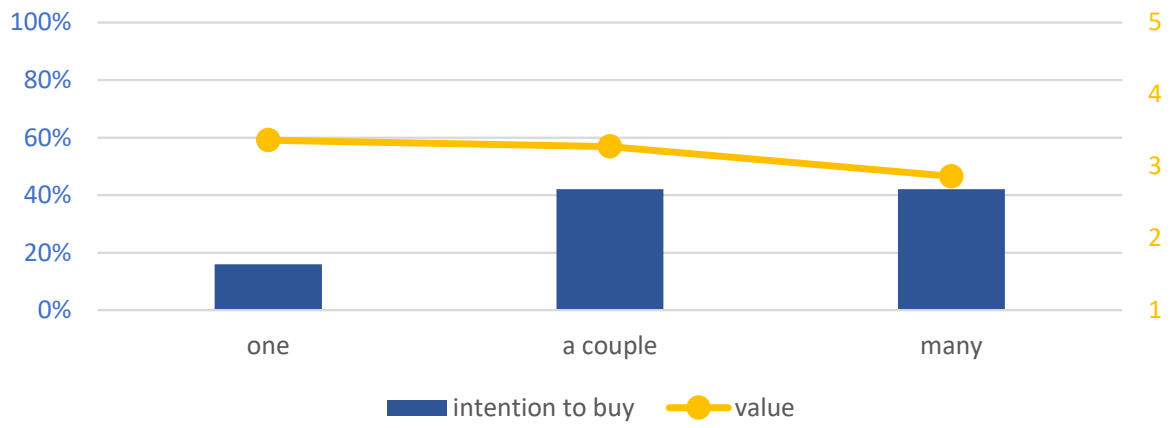

Fig. 4. Comparison of the intention to buy and the felt value in comparison to the presented amount.

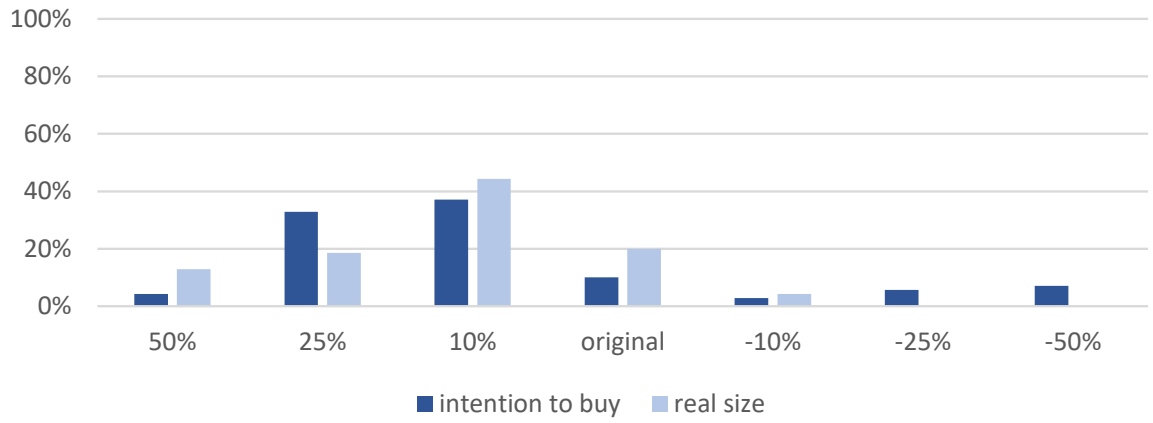

Fig. 5. Comparison of the intention to buy and the estimated size in comparison to various scales of the object.

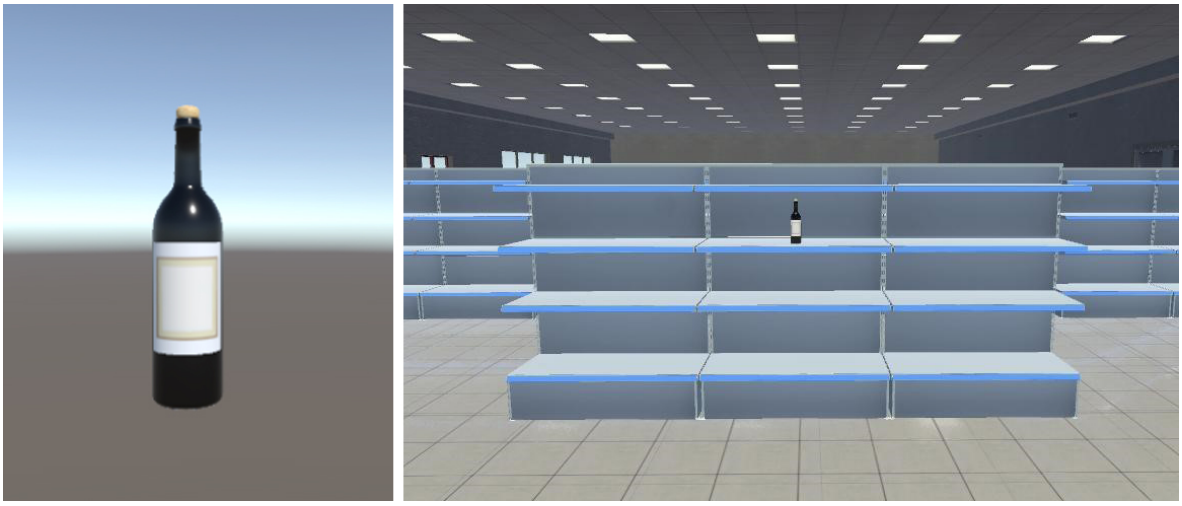

Fig. 6. A wine bottle in an empty and store environment.

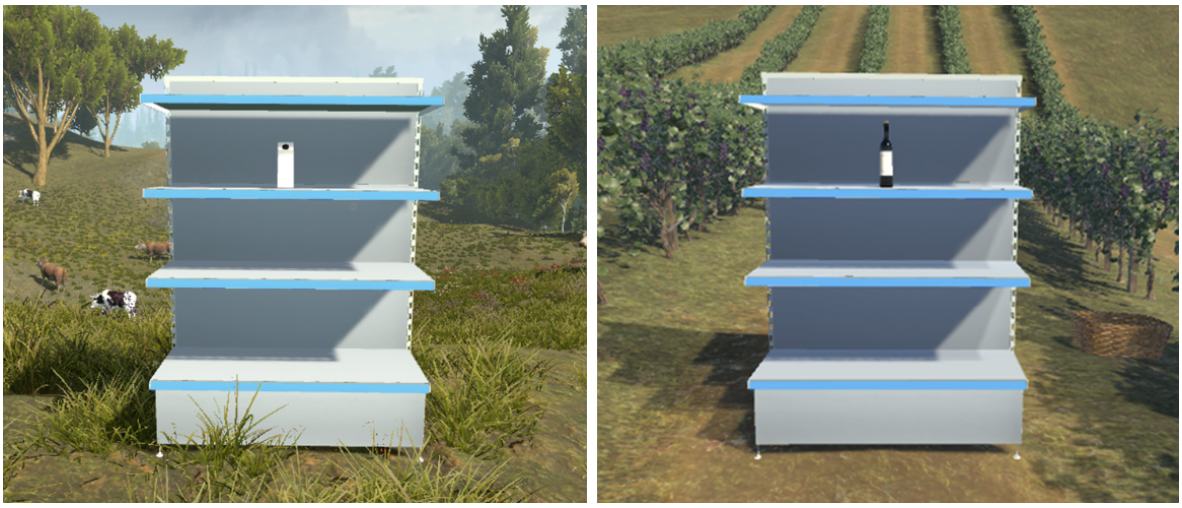

Fig. 7. A milk or a wine bottle standing in a shelf in accordingly adjusted environments.

Fig. 8. A milk or a wine bottle in accordingly adjusted environments.

Fig. 9. A milk or a wine bottle in environments which are not good matches.

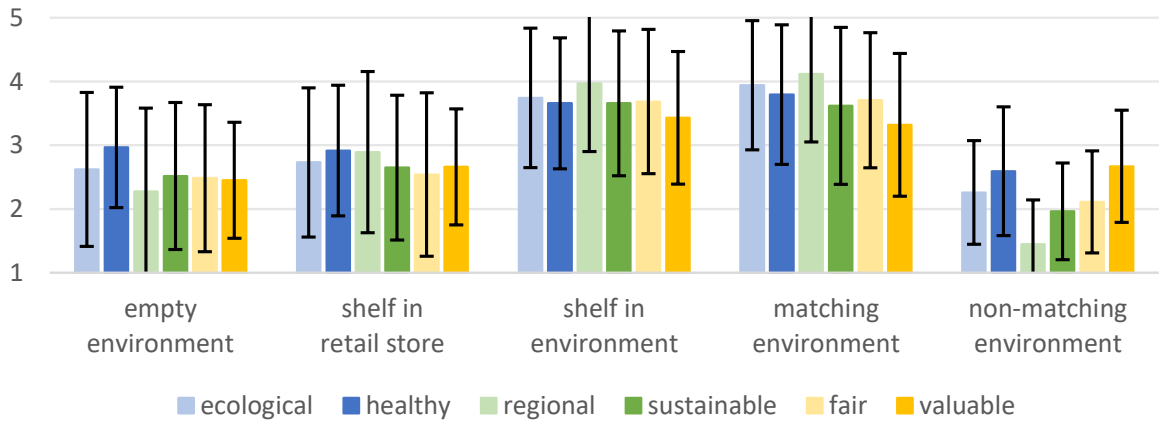

Fig. 10. Different attributes according to a *milk package* in different environments.

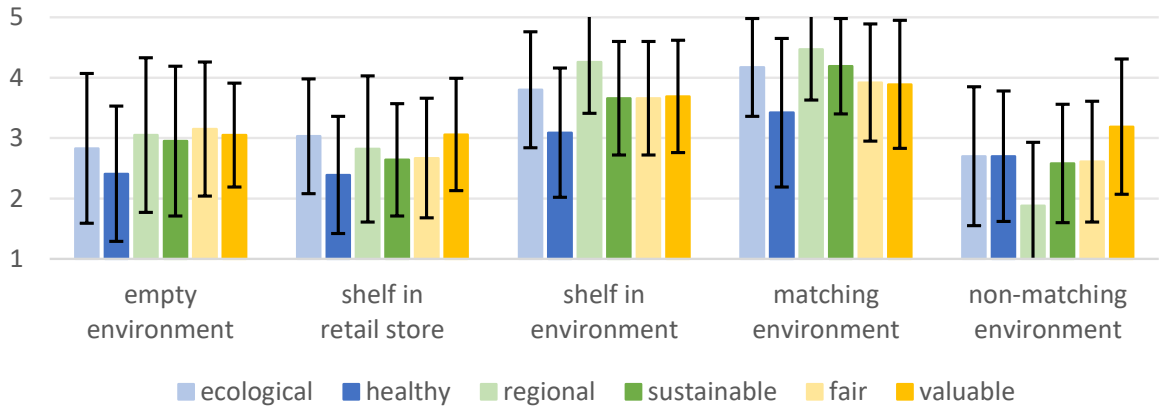

Fig. 11. Different attributes according to a *wine bottle* in different environments.

bottle, according to the attributes ecological, healthy, regional, sustainable, fair, valuable.

It can be observed that the surroundings have a similar effect on both products and a clear chronological order exists: the least average score over all attributes and products is the 'non-matching environment' (2,39), followed by 'empty environment' (2,73) and 'shelf in retail store' (2,75) which are rated equally, and last but not least the final group 'shelf in environment' (3,69) and 'matching environment' (3,88). It can, therefore, be concluded that an environment which fits to the presented product can promote the product. This is similar to the effect that more French wine is sold in a retail store if French chansons are played.

By comparing the individual attributes between the two presented products it becomes obvious that some preassumptions about the products are applied; e.g. wine is rated less healthy than milk while it is rated more valuable. Some attributes are influenced heavily according to the surrounding; e.g. ecological (max. difference between the environments 2,63) while others are more stable such as valuable (0,67).

Due to the relatively small sample size for sub-groups the results presented in this paragraph need to be verified in further research. We want to share our insights nevertheless because we think they might be at least helpful to show tendencies: The participants without VR experiences (n=19) felt more uncomfortable compared to participants with previous experience. The ones with VR experiences assessed the environments more realistically and rated the interactions as more natural than the test persons without experience. This is in line with results we have previously published. [12] If the test persons felt comfortable in the environment, they usually rated the characteristics of the products better and valued the price level higher. If the environment was evaluated realistic and visually appealing it also had a positive influence on the evaluation of the products regarding their characteristics. If the user did not feel as part of the virtual environment, the product characteristics tended to be rated worse. This confirms that the presence can have a positive as well as a negative influence on the product rating.

5 Conclusion and Outlook

We have investigated the presentation of goods in virtual reality. We found that the assigned values to the different shelf zones can be taken over to immersive shopping environments. Products should not be presented individually as is common today on web-pages, but rather should be presented in a group that is not too large and not too small. The shifted perception of size, independent of the product, should be particularly taken into account in order to be able to guarantee the customer a realistic image of the product.

On the web customers receive only 2D content, while in a virtual environment they can view the products 3D from all perspectives and thus get a better impression of the size and shape of the respective product. The quality of the food can be better derived from a realistic visualization of the products and their characteristics than from images or text.

Immersive virtual retail has the potential to overcome some of the drawbacks associated with e-commerce or brick-and-mortar retail stores. It offers shopping experiences which can go far beyond known path in particularly if one is not relying on common shop layouts which are usually restricted in many ways: space, expenses, number of visitors, physical laws, etc.

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What do serious games developers search online? A study of GameDev StackExchange

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Abstract. The interest in serious games (SG) has grown very fast in the last decade. Yet the research community rarely studies SG and the challenges SG developers are facing while creating games that should educate, train, and inform players. In this research, we use Latent Dirichlet Allocation (LDA) topic model to analyze a popular Q&A site (Game Dev StackExchange) in order to understand the thoughts and needs of SG developers. We analyze the most active and popular topics about SG development. Our study reveals that SG developers' needs are very diverse, ranging widely from simple script code to simulate 3D learning environments, over best practices to design educational games for specific target groups, to features that can increase the player's motivation and learning outcomes.

Keywords: Serious Games Development, Q&A sites; Latent Dirichlet Allocation, Topic Models, Software Search, Software Reuse

1 Introduction

Serious Games (SGs) are video games intended to educate the players instead of pure entertainment (David R. and Sandra L. 2005). The interest in SGs and their application in education and businesses areas has increased very fast in the last decade (Vasudevamurt and Uskov 2015). SGs provide an engaging and self-reinforcing context in which the player is motivated and instructed towards non-game events or processes, including business operations, training, marketing, well-being and advertisement (David R. and Sandra L. 2005). Thus, it is not surprising that many global companies (like Microsoft, IBM, SAP, Adobe, Cisco, Google etc.) have started integrating SGs and gamification techniques in their main business functions, processes, and activities (Anderson and Rainie 2010). However, the creation of effective SGs is a difficult and complicated process which requires an appropriate balance between game design and instructional design, including an in-depth understanding of learning, cognition, emotion, and play (Brent and Bill 2014). But the efforts, time and costs of serious games development can be reduced if existing software assets and other pedagogical components available on the market can be effectively reused and integrated into

the development process (Wim V et al. 2016). However, this requires to understand what SG developers search, and which factors can influence how they locate and select software (Hucka and Graham 2018). Existing research has mainly studied the needs of developers for traditional software engineering, ignoring the challenges of SG developers. But, SG development is different from other traditional software engineering disciplines because of its specific challenges related to the theoretical understanding of learning, cognition, emotion and play (Bellotti et al. 2010). But, to date very little is known about the development and maintenance challenges of SG developers. Therefore, we conducted a study by analyzing discussion threads on Game StackExchange (GDX) site[1] with the aim of understanding search behaviours and practices of (serious) games developers.
We used LDA topic model to identify major topics and areas of interests in SG developers searched for. We discover our topics by using SG terms and the most popular tags used in SG related posts. We rank our topics based on the number of documents. Finally, we analyzed the most popular and active topics by considering the number of documents assigned to each topic and their views. We conduct our study by using the following research questions: **RQ1**: What issues do serious games developers search online? **RQ2**: What are the most popular topics about serious games development?

This paper is organized as follow: We review related works (section 2), highlight our research questions and describe our methodology to detect SG-related posts (section 3). Then, we present and discuss our findings (section 4) and conclude (section 5).

2 Related works

The research most closely related to our work are those investigating SG development and software search.

Serious Games Development. Nowadays, we observe a growing number of software engineers and researchers focusing on SG development (Brent and Bill 2014; David R. and Sandra L. 2005; Mestadi et al. 2018; Petridis et al. 2012; Söbke and Seicher 2016; van der Vegt et al. 2016). Also, established business companies like Google, IBM, SAP are motivated to design, develop, and implement full-scale SGs in their business functions and processes because of the following advantages: SGs have the ability to 1) solve complex problems collaboratively, 2) improve the efficiency of business processes, 3) support predictive modelling and real-time visualization, 4) increase ROI[2] from processes, time, and resources, and 5) provide more retention of knowledge compared to traditional methods (Vasudevamurt and Uskov 2015). The creation of SGs is also a complex process of game design, programming, content production, and testing (Westera et al. 2016). And its success significantly depends on the quality of external technical gamification platforms, dedicated software architecture (Wim V et al. 2016), reusable SG engines, and advanced technology components (software assets) (Wim V

[1] GDX is a popular Q&A site used by thousands of (serious) game developers from all around the world to post questions and discuss issues about game development.

[2] ROI (Return on Investment) - https://www-01.ibm.com/software/rational/rsar/roi/

et al. 2016). However, there is a lack of standardization, best practices, and tools (Vasudevamurt and Uskov 2015) for supporting the development of SGs and the reuse of game assets which have the ability to preserve and enhance the games' pedagogical effectiveness (Westera et al. 2016). Thus, SG developers often rely on a large set of entertainment-based features and game engines despite the inherent differences between SGs and entertainment-based games (Brent and Bill 2014; Petridis et al. 2012). But, the complexity, time, and effort for creating SGs can be reduced if existing tools and game assets available on the market can be effectively reused (Wim V et al. 2016).

Software Search is a common practice in Software Engineering that aims at discovering suitable software for a given purpose (Hucka and Graham 2018). Existing research has shown that *Software Search* is an important component of real, day-to-day software engineering (Singer et al. 2010) because it can increase work productivity (e.g. through effective reuse). Studies investigating *Software Search* in the past have tried to understand developers' search practices and challenges (Ko et al. 2006) including in mobile development (Rosen and Shihab 2016). These studies relied on techniques, such as, web survey, interview, search logs, or a combination of those (Sadowski et al. 2015), but the analysis of Q&A discussion sites like StackExchange are becoming very popular due to the increasing number of opensource tools and search engines available online (Barua et al. 2014; Rosen and Shihab 2016). However, to the best of our knowledge, there is no study that has studied SG development. Thus, in this research, we will study what SG developers search and will examine their specific needs and challenges while developing games for serious purposes.

3 Research Methodology

In this section, we describe our methodology to identify SG related posts. We present and motivate our research questions. Then we describe our data collection and analysis process which we use to answer our research questions.

3.1 Research Questions and Motivation

RQ1: What issues do serious games developers search online? – Past research on *Software Search* has mainly studied what developers seek for general purpose software engineering (Hucka and Graham 2018; Singer et al. 2010). But the analysis of SG developers' specific needs has remained almost ignored so far. Surprisingly, the literature often argues that SG development differs from general purpose software engineering (Murphy-Hill et al. 2014) because of the challenges related to the pedagogical effectiveness of games (Westera et al. 2016) which include the development of new techniques and tools for training, educating, and motivating learners (David R. and Sandra L. 2005). Therefore, we are motivated to analyze what SG developers search online and what issues they may face.

RQ2: What are the most popular topics about serious games development? – Discovering the most popular SG discussions can help the SG community to identify major areas of interest for future investigations. For instance, game companies may fine-tune various aspects of their products and SG publishers may point to areas in which

practitioners have the most challenges and interest. Also, researchers may discover new research opportunities with a high chance of having an impact on practice.

3.2 Data Extraction and Data Processing

To create our corpus, we first download the *posts.xml* file from the GameDev StackExchange data dump (last updated June 2018) which contains user-generated questions and related answers[3]. We parse the data dump which includes a total of 110,193 posts, from which 42639 are questions. For each extracted post, we maintain a record of its metadata: the post type, timestamp and the total number of views. We then process our corpus by removing all existing code snippets that are present in the posts (i.e. enclosed in <code> HTML tags), as well as common English words which do not help to create meaningful topics as demonstrated in past research (Barua et al. 2014). We then tokenized each word and remove all common English words (adverbs, pronouns, and prepositions), and punctuations using the LingPipe library (Baldwin and Dayanidhi 2014). We finally create our corpus by considering only question posts because each question provides interesting insight about what the game developers have tried. Answer posts oft discuss solutions to existing issues but do not highlight the problem itself. Thus, we extract the *title* of each question, which nicely summarizes the issue being discussed, and the related *body* which gives additional context information about how this problem was initially approached by the asker.

3.3 Identifying SG-related posts

In order to found which posts of our corpus are relevant, we need a way to filter out posts which are not really related to SG development. To achieve this goal, we examined prior work (Barua et al. 2014) and defined an initial set of SG-related keywords. We considered a list of SG synonyms as proposed by (Michael Hoffmann 2016), a set of primary markets for SG (David R. and Sandra L. 2005), and the top ten most popular SG engines (Cowan and Bill 2014) as shown in **Table 1.** Initial keywords used to find SG-related posts. However, with our initial keywords, we couldn't find enough posts that were suitable for our analysis. So, we applied *the tag threshold* $TRT\_tag = \frac{No\ of\ SG\ posts}{\text{Total no.posts}}$ to our collection algorithm (proposed by (Rosen and Shihab 2016)) to identify more SG related posts by using the most popular tags assigned to each post previously found with our initial keywords. **Fig. 1** shows the top 30 most popular tags used in SG-related discussions ranked by their popularity (the number of posts to which a tag is assigned). We experimented different *TRT_tag* values and found that 35% was suitable for our analysis. With this value, we were able to identify 18% more SG-related posts from our corpus. As shown in **Table 2**, our SG-related corpus contains in total 18902 posts. We believe that the list in our corpus contains the most popular posts about serious games which we define here as *SG-related posts*.

SG Synonyms	Applied Game – Applied Gaming – Serious Game – Serious Gaming – Gamification – Games for Change – Games for Good
SG Markets	Military – Government - Education – Corporate-Games – Healthcare – Politics – Religion – Art

[3] To be found at: https://archive.org/download/stackexchange

SG Engines	Unity – Flash – Second life – E-adventure – Unreal – Torque3d – Cocos – Xna

Table 1. Initial keywords used to find SG-related posts

All posts	42639
SG posts found with initial keywords	11262
SG posts found with TRT>=35%	18902
All tags assigned to SG posts	941
Tags relevant to SG posts	337

Table 2. SG related posts and SG related tags

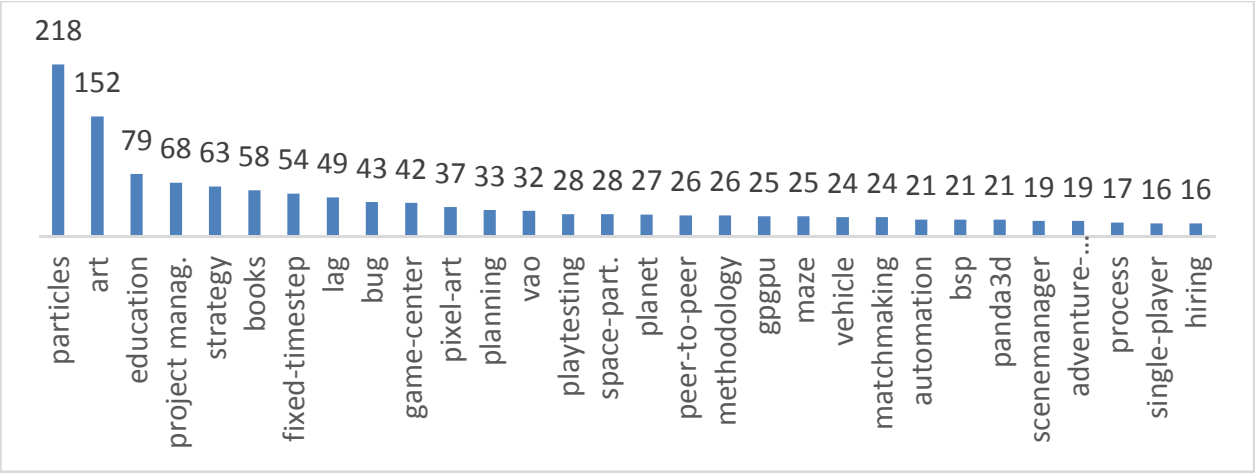

Fig. 1. The 30 most popular SG-related tags

3.4 Identifying the most popular SG-related topics

To discover the most popular SG topics, two metrics were introduced. First, the *topic relevance metric* $R(t) = \frac{Dist(d)}{\max(Dist(d_i))}$ represents the distance of a topic distribution assigned by LDA to a document to the highest distribution assigned to that same document. We use this metric as a threshold to consider only topics with the highest distribution values as the most relevant ones. Usually, a document will have 1 to 5 most dominant topics assigned to it with a distribution of 0,10 or higher (Barua et al. 2014). However, due to the probabilistic nature of LDA, we found some topics with a very small document distribution (e.g. 0.01) which introduced noises in our analysis. By using an R(t) of *35* as our distribution cutoff, we were able to eliminate existing noises in our analysis and could detect only relevant topics to our documents. Second, *the average number of views* $\mathrm{Av(t)} = \frac{SumDocumenstViews(t)}{TotalTopicDocuments(t)}$ was introduced to analyze the popularity of each topic t. *TotalTopicDocuments* is the number of documents assigned to a topic t and *SumDocumentsViews* is the sum of views of all topic documents. Existing research has shown that most of the online discussions are visited by passing (not registered) users (Mamykina et al. 2011) and that the number of views assigned to each

post may indicate the importance of a topic (Rosen and Shihab 2016). By using the above-described measurements, each topic can be analyzed using two different dimensions: the number of documents assigned to a topic indicating how active a topic is, and the number of views of topic documents indicating the popularity of each topic in the SG community.

3.5 Topic Modeling using LDA

Topic Modeling is a document clustering technique that uses statistical methods for identifying abstract topics within a document collection. Several topic modelling techniques have been developed and evaluated (such as *Probabilistic Latent Semantic Indexing*, *Non-negative Matrix Factorization*) (Ding et al. 2008). In this research, we use Latent Dirichlet Allocation (LDA) topic model as it was routinely applied to millions of software engineering web documents (Barua et al. 2014; Rosen and Shihab 2016). LDA uses the frequencies of words and topics (groups of words) from documents of a text corpus to discover patterns and build a model based on related words and topics (Rosen and Shihab 2016). The number of topics (K) is defined by the user to control the granularity of discovered topics and there is no standard value of K that can fit every situation and dataset (Grant and Cordy 2010; Wallach et al. 2009). We experimented different K values and found out that 30 yields good results without being too restrictive. We also optimized our Dirichlet hyperparameters by using $\alpha = 0.5$ and $\beta=0.1$ to control how much fuzziness is allowed in the topics' distributions across words and topics respectively. It was shown that optimizing these the facto standard heuristics parameters can dramatically improve the consistency in topic usage as the number of topics increase (Rosen and Shihab 2016). To better classify the issues found in our corpus, we add their dominant topic as determined by the LDA topic model. We labelled our topics manually by considering the top words found in each topic and by examining a sample of posts assigned to each topic.

4 Results

In this section, we present the results of applying our research methodology to answer our research questions. We first examine the percentage of SG-related posts to all existing posts in our corpus. Then, we describe each discovered topic and finally discuss each topic qualitatively.

4.1 Exploring the importance of serious games related posts

Before delving into our research questions, we would like to understand the importance of SG-related posts in our corpus. Thus, after extracting and processing our corpus, we can now examine (as shown in **Fig. 2**) the number of SG-related posts (red line) and their percentage (blue line) to all existing posts per month. Our analysis shows that at least 36% of all existing posts are related to SG development. There is an increase of SG-related posts from August 2010 to March 2013 reaching a maximal value of 300

SG-posts (50%) in July 2012. Then, there is a small decline leading into November 2014 which finally gets stabilized over the following years till 2018 with an average of 27%. Thus, we conclude that the number of SG-related posts is growing and that discussions about SG development are relevant in the game development community.

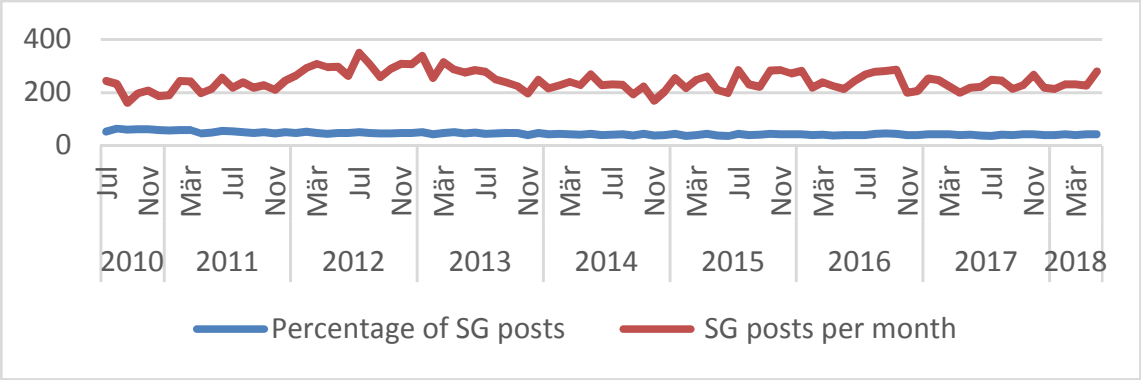

Fig. 2. Percentage and Evolution of SG posts on GameDev StackExchange per Month

4.2 RQ1: What issues do serious games developers search online?

Table 3 shows 14 out of the 30 topics discovered by our LDA methodology from which we merged some topics because of their semantical similarity. For instance, the topics *Collision Detection* and *Pathfinding* are related to *Game Physics* and thus were merged together. We arranged these topics in descending order according to their *share metric* as proposed by (Barua et al. 2014). as proposed in (Rosen and Shihab 2016). In general, we found that SG posts fall into one of the following topics: *Game Design &* Learning Design, *(3D)Modeling/Rendering, Physics, Scripting,* and *Networking*.

Topic	*Top keywords*
Graphics Engine	game java graphics creating render lwjgl library don function simple math framework multiple engines question opengl threads testing people web
Game Physics/Collision Detection/Path Finding	movement physics boxd speed libgdx simulation body path finding velocity projectile bullet gravity distance ball collision detection network
Networking	server multiplayer game client side players network mmo online player networking architecture rts sync prediction browser udp prevent communication clients
Mesh	unity mesh rendering order error performance problem device correct triangle water android dynamic problems udk collider vertices triangles text gui
File&Format	xna file project monogame custom files content culling frustum format screen loading static write running pipeline possible read asset creation
Scripting	unity working script gameobject add properly audio object playing method new level doesn issue editor scaling set child gameobjects isn
Data structure	game data code structure objects implement build libgdx visual studio board designing font node cocosd rts platforms ways gamemaker style
Platform	time canvas game html real games play javascript app google mobile step mode delta devices application run simple services program
Game Design	game games design good pattern idea creating practice making bad management gameplay effects mobile common adventure patterns story book examples
Component	system based component entity turn components systems entities particle architecture event ecs handling design strategy combat battle oriented events types
Learning Design	learning design games learning api starting programming start platform card resources indie software programmer computer developer started language development
Camera	camera screen position object mouse move moving libgdx set target issue coordinate person click shooter transform touch follow environment full
3D Modeling/ Rendering	multiple model models blender textures mesh single sprites objects parts unity rendering meshes building support fbx separate techniques dealing combine
Movement	object point vector rotation direction rotate camera sphere rotating move calculate specific calculating plane axis angle points quaternion find tower
Animation	animation character sprite unity create unityd animations skeletal states behavior flash jump controller bone animate max android trees start animated
Game Engine	game engine open code source legal issues based engines design racing window assets browser small music develop console put projects

Table 3. SG-related topics discovered with our LDA

To get a better insight about our discovered topics, we show a subset of examples related to each group of topics along with some context information (like title, body, tags, #postId) whenever needed, and will discuss their impact on SG Development.

Game Design. We found one topic about game design. Our study reveals that SG developers seek best practices and experts' opinions for taking important design decisions, like choosing a proper design pattern (#32093) or selecting an appropriate platform to create educational games (#8359).

*Title: Design Pattern for **Social Game Mission Mechanics** Body: When we want to **design a mission sub-system** like in the The Ville or Sims Social, **what kind of design pattern / idea** would fit the best? There may be relation between missions (first do this then this etc...) or not. **What do you think sims social or the ville or any other social games is using for this? I'm looking for a best-practise method to contruct a mission framework** for tha game. How the well-known game do this stuff for large scale social facebook games? [Topic: Game Design, **Tags**: game-design,flash, social. PostId: #32093]*

*Title: What makes a good educational game? – Body: I'm currently creating a game framework/engine for educational games. My hope is that this can be used in elementary schools. **What makes a good educational game? Which platforms should I target?** [Topic: Game Design, Tags: serious-games cross-platform educational-games.. PostId: #8359]*

Also, SG developers seek techniques to implement AI for tracking the progression of the player (#129492), assess the player's learning outcomes (#94079) and interest (#8925), and increase his engagement in learning (#149096, #28540).

*Title: Machine learning to improve strategy game AI - Body:I am currently working on a simple strategy game as a hobby and I am starting to think about designing an AI to add opponents ….My idea was **to record the player's activity every X amount of time** as well as the current state of some game variables. Then I would use some machine learning algo (as a black box) to find a relationship between game variables and actions to make. I would also record the final score at the end of each game so that the **AI learns more from successful games than unsuccessful ones** (or even better set a score threshold above which to send the data to the AI)…*
***Any thoughts or directions towards interesting resources /tutorials would be very welcome [Topic**: Level Design, Tags: game-design ai strategy reinforcement-learning, PostId: #129492]*

*Title: How can I ensure the player learns all skills in a single open level? Body: I am making a game that only has a single level. It is a survival game. … I can have the player learn new skills gradually. For example, level one requires jumping, level 2 requires climbing, level 3 requires both. **Is there a common strategy to force the player to learn all the necessary skills** to succeed? Currently I have 4 directions which the player can travel from the starting point. Each of which…[Topic: Learning Design, Tags: level-design tutorials reinforcement-learning, PostId: #94079]*

*Title: Things that make a **game more interesting for kids –** Body: What makes a game more interesting or fun to play… Does the age of consumer play an important role in his/her interest of game?What can I put in a game to make it more fun, educational, and interesting to play? – Topic: Game Design PostId: #8925 Tags: game-design serious games*

*Title: How to calculate players engagement?- Body: **What metrics could be used to know what certain people think** about the game and **how much they liked it**? [Topic: Game Design, PostId: #149096 Tags: game-design -design metrics]*

*Title:What are the downsides of only explicitly informing the player of *success*? – Body: I working on **educational software** and **trying to increase engagement** ("fun") [Topic: Game Design, Tags: game-design, PostId: #28540]*

There are two emerging research fields that focus on tracking and analyzing players' interactions. First, *Game Analytics (GA)* (A. All et al. 2016) focuses on developing techniques to automatically follow users' interactions and increase their engagement (maximizing the time a player stays in the "flow"). Second, *Learning Analytics (LA) (Loh et al. 2015)* aims at analyzing and measuring players' learning outcomes, for purpose of understanding and optimizing an environment in which it occurs. But, there is a lack of standard formats to represent players' interactions (Cooper 2013) and facilitate the processing and analysis of their learning progress (Ángel et al. 2017).

3D Modeling/Rendering. Our study reveals that SG developers seek instructions and efficient tools or programs for creating and rendering (nice-looking) 3D objects even with limited knowledge, skills, and time (#121634, #44168).

Title: Creating a large amount of sprites and animations. Body: For my AP U.S. **Government and Politics class**, I am making a **spinoff of Mortal Kombat**. Because of time constraints, I'm using an open source version of the game and want to **create new characters**. I have about two weeks to do the project.. **I want it to look as nice… What**

*Title: Software rendering 3d triangles in the proper order - Body: **I'm implementing a basic 3d rendering engine in software (for education purposes**, please don't mention to use an API). When I project a triangle from 3d to 2d coordinates, I draw the triangle. If I'm sorting all the objects, this is n*log(n). **Is this***

programs or techniques would be best…? – [Topic: 3D Modeling/Rendering, Tags: sprites animation, PostId: #121634]

the most efficient way to do this? [Topic: 3D Modeling/Rendering, Tags: 3D, rendering, software-rendering PostId**:** #44168]

3D Modeling is the process of using software to generate a representation of 3D characters and objects for use in a game (Dorribo-Camba et al. 2013; Jackson and Buxton 2007), and *Rendering* refers to the process of creating an image from 2D or 3D model (McShaffrey 2005). *Rendering* covers every aspect ranging from texture creation, lighting and shadow to materials, scene graph management (Millington and Funge 2009). Well-designed SGs that can engage and affect learners require vivid characters, realistic models and environment to be able to demonstrate behaviours with specific learning lesson(s) (Kelly et al. 2007). Although existing research has revealed the reuse of existing 3D models can reduce design time by 30% (Dorribo-Camba et al. 2013; Jackson and Buxton 2007), there is still little work in the reuse of existing 3D models. Existing techniques rely on indexing mechanisms to extract metadata (semi-automatically) from models and support reuse (Ioan Marius Bilasco et al. 2006), however, substantial efforts are still required to maintain the extracted metadata.

Physics. Game physics (known as Physics) refers to the process of introducing classical laws of mechanics in games (Millington 2007). Physics introduces the realistic feel to the game and can stimulate real world objects (e.g. lighting, collision detection, water, cloth physics, weather, etc.) (Vasudevamurt and Uskov 2015). Physics engines support the modelling of virtual world objects by means of configuration to avoid manual programming (Söbke and Seicher 2016). But physics calculations are often computationally demanding and thus need to be appropriately integrated into game design concepts in order not to distract the player, but promote immersive and engaging games (Söbke and Seicher 2016). We found that SG developers seek help to create and/or optimize their algorithms for collision detection (#75109) or pathfinding (#108338), and how to generate special characters (like living beings) and to integrate them in specific virtual environments (like world politics) (#53137).

*Title: How to **simulate early politics? –** Body: I'm making a historically accurate game where the player can interact with past times and shape the future. The entire game is scientifically generated with math and **real physics**…**The player can build anything they want** and it will **use physics to simulate each creation based on the materials it's made of.** I was considering just modeling our political system and then applying mathematical regression to the algorithm to regress it 100 million years. However, I'm worried about the limitations of floating point numbers and I think that errors will compound.…P.S. **I'm mostly talking about American dinosaurs, because they had the most impact on world politics**. [Topic: Physics, Tags: mathematics procedural-generation simulations, PostId: #53137]*

Existing game engines provide a variety of features and algorithms for AI, rendering, and simulation that can be used right away by developers (Söbke and Seicher 2016). Facilitating the detection of such features can lead to efficient SG development because developers will only focus on developing domain-specific features instead of writing low-level algorithms from scratch (David R. and Sandra L. 2005).

Scripting. Our study reveals that SG developers seek specific code (like unityscript) to control the behaviour of their games and do animation (#161824, #163929). The literature refers to three levels of coding (Blow 2004): **script code** (for controlling the overall content, rules, and high-level behaviour of games), **gameplay code** (for graphics simulation, physics), **engine code** representing special algorithms for 2D/3D animation, rendering, and programming networking. Coding plays a significant role in the development of SGs and should be completely integrated into existing SG engines in order to optimize the game's efficiency in terms of performance and memory usage (Vasudevamurt and Uskov 2015).

Networking. We found that SG developers seek help to create games that allow multiple users to play together over greater distance and on a distributed environment like the Web (#157707). Networking technologies are responsible for the scalability and security of games and also deal with issues related to bandwidth and latency (Vasudevamurt and Uskov 2015).

Title: Optimization for end-to-end multiplayer pong-like game – Body: I've developing a small pong-like ***game for educational purposes*** *and I've reached the point where I'm looking at implementing network gameplay. I was looking into what optimizations are usually performed for a smooth experience since latency can cause jitterry movements if not handled properly….*
I know that client-side prediction is used and read up on it but it seems to me that this is applies in client-server types of multiplayer. Is this true, and if yes why?
Topic: Networking, Tags: networking, multplayer, optimization, pong PostId: #157707

4.3 RQ2: What are the most popular topics about SG development?

Fig. 3 displays the top 10 most popular SG-related issues on GDX along with the average number of views assigned to each topic. We see that while *Rendering* and *Game Design* are the *most active* topics about SG (those having the largest number of posts), while topics such as *Game Physics, Animation* belongs to *the most popular* topics (having the highest number of views).

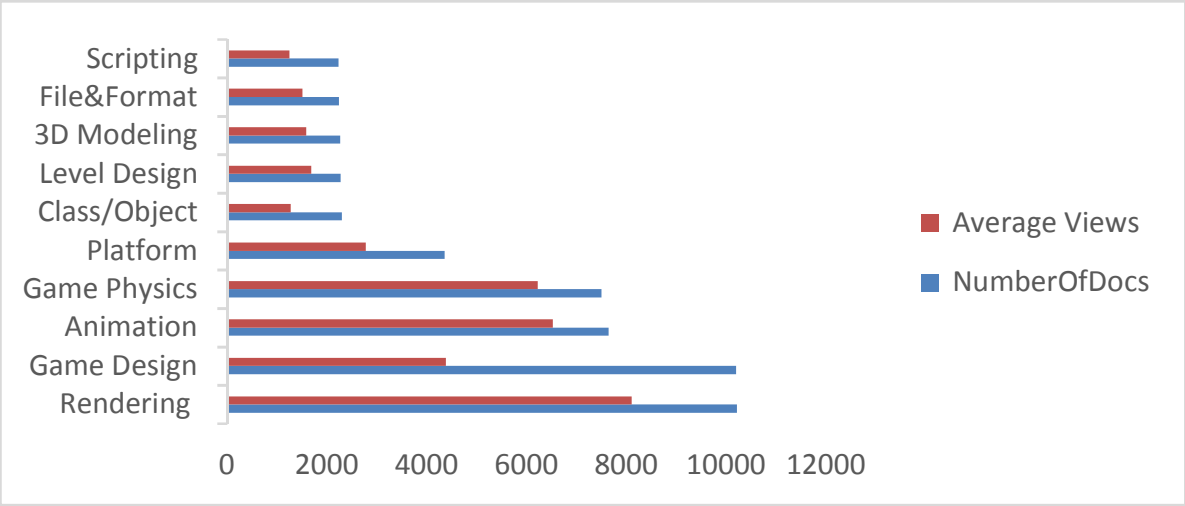

Fig. 3. Top 10 most popular SG-related topics

5 Conclusion & Future Work

In this paper, we have used the LDA topic model on GameDev StackExchange corpus to quantitatively detect and classify the main topics SG developers usually search. For instance, we have found out that *Rendering* and *Game Design* are very ***active topics*** (suggesting that SG developers are seeking best practices and common strategies to do one thing), while discussions about *Physics* and *Animation* belong to the most ***popular topics***, which suggests that they are seeking help to fix their issues. Our study also reveals that SG developers seek different things, ranging from simple scripts for stimulating 3D learning environments, over best practices to design educational games, to specific algorithms for increasing the player's motivation and learning outcomes.
We believe that future research in SG should focus more on standardizing common practices (like design patterns, design concepts) and tools to facilitate the development of specific game genres and the reuse of common features that add a good balance of

learning and pedagogical objectives to games. This will motivate developers and gaming companies to easily and efficiently design, develop, and deliver full-scale SGs while being able to reduce the time to market. For this to be successful, a good understanding of SG filed and theories (game design, learning theories, and domain content) is needed.

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Improving Network Configurations by the Analysis of Bipartite Geometric Network Structures in the Euclidean Vector Spaces $\mathbb{R}^2$ and $\mathbb{R}^3$

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Abstract. This paper summarizes the analyses of specific bipartite geometric structures regarding the improvement of network and measurement configurations in the $\mathbb{R}^2$ and $\mathbb{R}^3$. The purposes are enhancements of methods to increase and to optimize the geometric stability and statistical reliability of bipartite geometric networks.

Bipartite geometric structures - here the bipartite frameworks in the $\mathbb{R}^n$ and bipartite directional networks in the $\mathbb{R}^2$ - show an outstanding characteristic concerning the quadrics: Quadrics function as critical location for these geometric structures. The question comes up if there is also a negative effect or deteriorating influence regarding combined bipartite geometric structures especially in the $\mathbb{R}^2$ and $\mathbb{R}^3$ caused by the quadrics. Synchrotrons like the SIS18 at the GSI and the future SIS100 for FAIR offer the possibility to research specific configurations related to the quadrics and other geometric properties.

Bipartite distantial networks in the $\mathbb{R}^3$ - e.g. used for calibration of measuring machines - presumably show characteristics that the target points are insufficiently controlled together depending on the amount of the stations. This can cause negative effects on the geometric stability and statistical reliability. The question arises, which range such a geometric instability can reach and which configuration of stations increases the geometric stability.

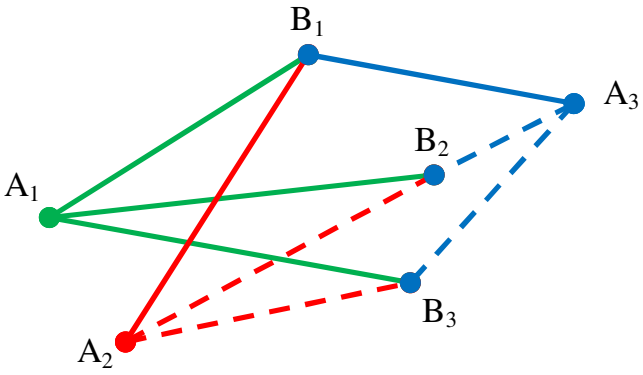
As a main method to analyze the described problems the homogeneous Plücker-Grassmann-coordinates for simulated and measured networks will be used. They are related to latent restrictions derived from the Jacobian matrix of partial derivatives. Further they are related to the partial redundancies, elements of the variance-covariance-matrix of the residuals.

Keywords: Bipartite geometric structures, bipartite distantial and directional networks, laser tracker networks, quadrics, critical locations, latent restrictions, geometry of particle accelerators, optimization, ideal figures, network adjustment.

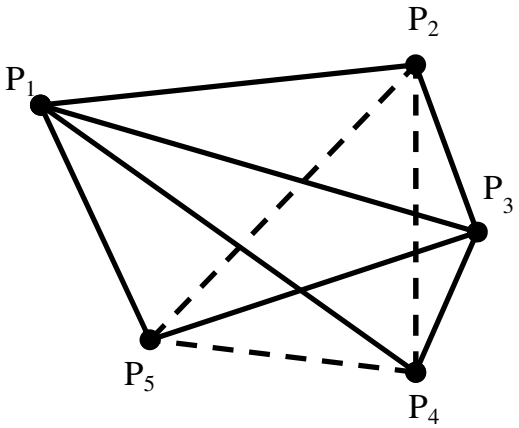
1 Introduction

The progressive influence of tasks and principles from mechanical engineering in the fields of geodesy and industrial measurements leads to a rethinking concerning evolved structures in the classical geodesy and therefore geometry. This influence of mechanical engineering can be shown by the use of high precise measuring instruments like the laser tracker with accuracies of some micrometers. Laser trackers enable the possibility to determine objects and structures in three-dimensional space. These objects, which can have a dimension of some decimeters up to some kilometers long particle accelerators, are determined by using small, medium and large network structures, whereupon now non-triangular geometric structures have been employed. These non-triangular structures uniquely correspond to the bipartite graphs known from graph theory. Due to this their naming will be modified to “bipartite geometric structures/networks” respectively “bipartite geodetic networks”.

The main characteristic regarding this bipartite geometric structure is the existing of two disjoint point groups A and B, where the vertices of group A are only connected with the vertices of group B. The group A can be considered as the stations of the instruments. The group B consists of the target points, observed by the instrument. To comprehend the structure of bipartite networks in comparison to the well-known triangular networks a contrasting juxtaposition of both types is shown in the following figure.



A complete bipartite network with 6 points (vertices) and 9 edges (e.g. distances). This special form with distances as edges describes the minimal distantial figure in the $\mathbb{R}^2$. The minimal closed path/closed polygon in the structure is a tetragon (dashed lines).



A complete triangular network with 5 points (vertices) and 10 edges (e.g. distances). Here the minimal closed polygon is the triangle (dashed lines).

Fig. 1. The comparison between bipartite and triangular networks

GSI Helmholtz Centre for Heavy Ion Research in Darmstadt, Germany, operates a unique large-scale accelerator for heavy ions. GSI maintains several particle accelerators. Presently, a large future project, the Facility for Antiproton and Ion Research (FAIR), is under construction which is intended to provide particle beams with a high intensity and quality. Many accelerators have a simple geometric size, like straight lines – the linacs – or circular respectively elliptic machines – the synchrotrons. The accuracy to align such complete coherent machines upon their construction often requires tolerance ranges of less than 0.1 millimeters. Therefore laser trackers and bipartite geodetic networks, with their nonreciprocal observations and with their specific geometric properties, come into play. Thereby, recent on-site work revealed that this methodology leads to unexpected effects regarding the adjustment and statistical analyses, which seem to influence and even interfere with the geometric stability and reliability of the measurements obtained.

1.1 Problem description

The bipartitedness of geometric networks, further the possible influences of their network substructures and the negative role of the quadrics was recognized by a test measurement in the former work for a provider for industrial measurements. During this test measurement with an instrument for calibrations of precise measuring machines – the LaserTRACER from the company ETALON AG – a major difficulty with the adjustment occurred. All distance residuals were exact 0.0000 mm, but the confidence region of all unknowns, the coordinates, had values of several centimeters! The network itself, which had no triangle in its structure, was built from distances and directions in such a specific manner, that a non-congruent and non-similar distortion occurred. Further investigations showed that this structure in an abstract sense was equivalent to the bipartite graphs from the graph theory. An investigation into the separation as a single distantial and a single directional network showed that the distantial structure was under-determined, but the directional structure over-determined. The variance-covariance-component-estimation where the a-priori standard deviations for the distances were set with a value by 0.5 micrometer – from manufacturer's data – and for the directions with several degrees – because the directions were measured to obtain approximated values and should have no influence in the adjustment – led to this described distortion. Thus, the over-determined directional network was forced into the under-determined distantial network, where its distances were restricted by the high accuracy of the observations and which itself was highly flexible. This phenomenon, developed from an erroneous and unknown consideration of this type of network geometry and its influence to the adjustment, was the trigger to analyze and research bipartite geodetic networks respectively bipartite geometric structures.

1.2 Relevance for bipartite geodetic networks in the R^3

Many bipartite geodetic networks show exactly this phenomenon that after a separation in single distantial and directional structures these substructures are not balanced regarding its rigidity. In their combination as a complete and combined network the

rigidity is given. But how this network is biased by the geometry of the bipartite sub-structures, influenced by a-priori standard deviations, influenced further by additional unknowns – the unknowns of orientation occurring at directional structures – and biased by spatial approaches – from $\mathbb{R}^3$ nearly to $\mathbb{R}^2$ – is an open question and one main part of this dissertation. The particle accelerator at the GSI Helmholtz Centre provides the frame to build such bipartite networks as paradigm like similar network structures which were established at other particle accelerators in the world and for the network determination in the field of industrial measurements.

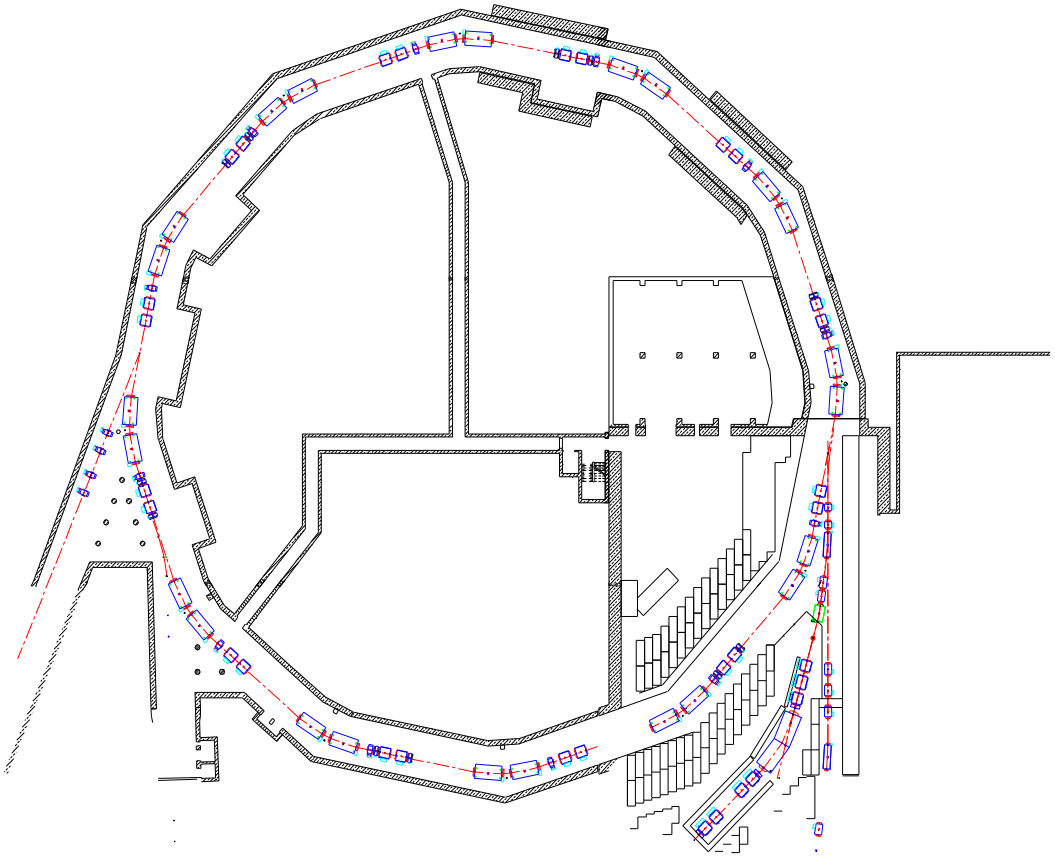


Fig. 2. The heavy ion synchrotron SIS18 at the GSI Helmholtz Centre in Darmstadt

2 Background and State of the Art

The given research outlined here combines knowledge from the fields of geodetics, geometry, algebra and graph theory.

2.1 Bipartite frameworks and bipartite directional networks in the R^2

One part of bipartite geometric structures is analyzed and known under the name of bipartite frameworks. The functional relation between the vertices is the existence of a distance or length, which can be considered as a rod, bar, strut or a measured length. The measured length can be observed electro-optical, per laser, interferometric and via sound techniques. Important criteria for these distantial structures were the assumption of complete bipartitedness and the analysis for critical locations and degenerations. Bipartite frameworks degenerate when all points, which belong to the object, are located on a quadric (Bolker und Roth 1980). In the 19th century in the fields of statics the degeneration of such bipartite frameworks in the $\mathbb{R}^2$ was observed. Their relation to the conics was assumed but not directly proven (Wunderlich 1977a). Due to the development of electro-optical distance measuring instruments in the 60s/70s of the 20th century bipartite distantial structures were investigated for the $\mathbb{R}^2$ and $\mathbb{R}^3$. Here the minimal figures, the complete bipartite structures $K_{3,3}$ and $K_{4,6}$ were analyzed geometrically, especially for the quadric problematic (Wunderlich 1977a, 1977b; Rinner et al. 1969). In the 70s of the 20th century geometric structures corresponding to the bipartite frameworks were analyzed in the field of satellite geodetics, where the ground stations and the satellites function as the two disjoint point groups (Blaha 1971; Tsimis 1973; Grafarend und Sanso 1985). The rigidity of bipartite frameworks especially in the statics and for tensegrity frameworks in the $\mathbb{R}^n$ was investigated from the 80s of the 20th century. Here one important issue was the mathematical proof, that bipartite distantial structures degenerate when all vertices are located on a quadric (Bolker und Roth 1980; Whiteley 1984; Connelly und Gortler 2015).

A second part of bipartite geometric structures, the bipartite directional networks in the $\mathbb{R}^2$, were analyzed early in the 18th and 19th century. It is known as the 8-Point-Problem of Lambert and Clausen. These objects were rediscovered in the late 20th century. The main points of analyzing were the critical curves, where such structures degenerate. These curves are the quadrics too but also the circular cubic curves. The most well-known examples of such cubics are the conchoids of de Sluze, with Maclaurins trisectrix and the cissoid of Diocles as examples (Wunderlich 1976, 1978).

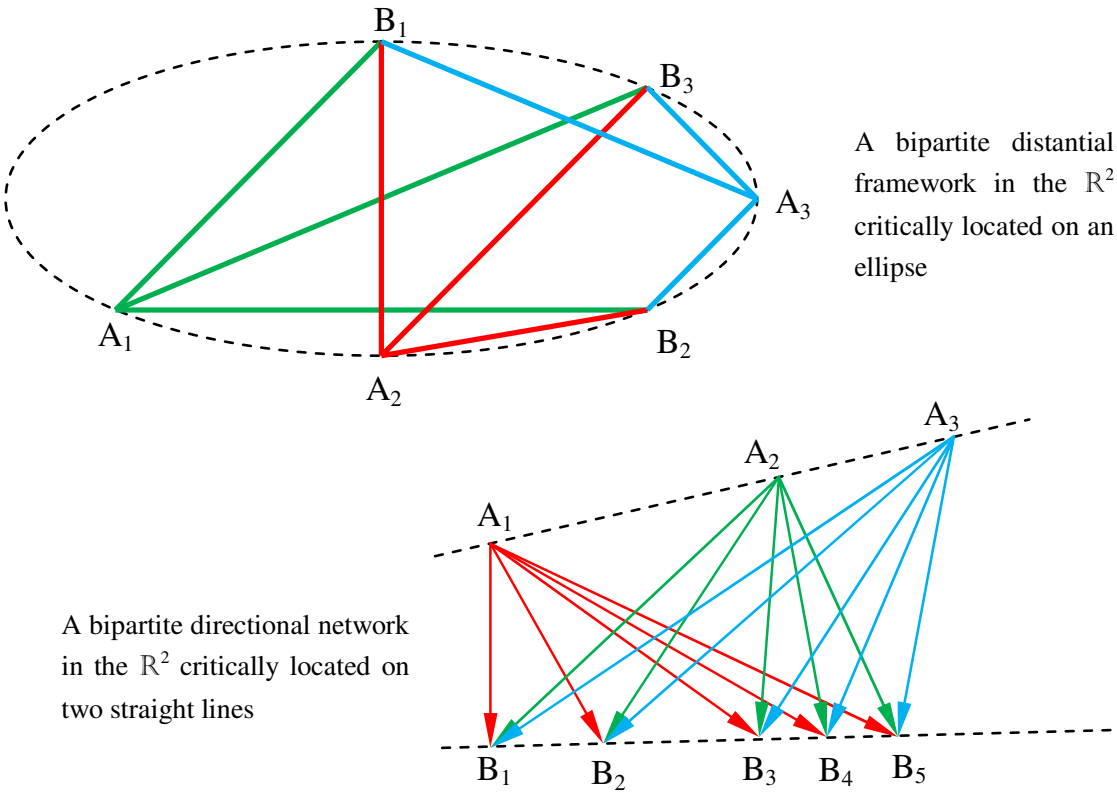


Fig. 3. The critical locations on two conics

2.2 The alternative solutions for the minimal bipartite frameworks $K_{3,3}$ in the R^2

Triangles with given side lengths can be constructed and embedded into the $\mathbb{R}^2$ in two ways, first regarding their correct respectively real location and second with its mirror image. The reason for these two possibilities results from the missing information of orientation for the triangle.

But the minimal bipartite framework $K_{3,3}$ in the $\mathbb{R}^2$ with given side lengths can offer 8 possible independent geometric figures and additional their 8 mirror images, altogether 16 figures. Presumably for the minimal bipartite frameworks in the $\mathbb{R}^n$ for $n \geq 3$ there exist also a great number of such alternative solutions, but the exact number and real examples with given side lengths are an open question. For the minimal bipartite frameworks in the $\mathbb{R}^2$ the first assumption was given by Wunderlich. Walter and Husty made a deeper investigation and confirmed Wunderlich's assumption of 8 possible alternative figures and gave some real examples (Wunderlich 1977a, 1977b; Walter and Husty 2007).

2.3 Graph theory and topology

Geodetic networks can be abstractly interpreted as graphs, whereupon the classical triangular net structures show relations to the complete graphs. Bipartite graphs itself

play an important role to establish special forms of networks used in informatics (Petri nets), in mechanical engineering, in logistics and for processes in the economy (Diestel 2012). Special topological issues are embedding bipartite graphs on surfaces like spheres, n-tori and projective planes (Mohar und Thomassen 2001).

Graph structures are often related to polytopes, surfaces, n-manifolds (Ziegler 1994). Polytopes itself can topologically be classified through the decomposition into combinatorial surfaces to get invariants like the Euler characteristic, homology groups and to see the homeomorphism to orientable and non-orientable compact 2-manifolds without any boundary (Stöcker und Zieschang 1994; Kinsey 1997; Kühnel 2008).

3 Aim of work and contributions

One main part is the geometric and statistical analysis of specific bipartite geodetic networks in general and which are designed, measured, adjusted and optimized in the surroundings of particle accelerators at the GSI Helmholtz Centre. The main types are the combined structures and pure distantial networks. A further task which is related to the network design is the research on regular, ideal and optimal configurations and on alternative solutions regarding bipartite distantial figures. Another very important point is the analysis and the classification of bipartite directional structures, which are geodetically relevant in the $\mathbb{R}^2$ and $\mathbb{R}^3$. The analysis of geometric properties (minimal resp. basic figures, degenerations, optimal figures) is here also an integral part.

The circumstance that bipartite structures can represent static unique objects leads to the question. Does there exist a superior structure analogue to the n-simplices for distantial and directional bipartite geometries? Such a generalization and the development of other forms (e.g. non-complete or partial bipartite objects) will be transferred into the mathematical frame. One further task shall be the disclosure of possible relations between triangular structures (n-simplices) and bipartite structures, the possible bipartite equivalents. A first topological approach is the investigation and definition of polygonal manifolds respectively combinatorial surfaces with their embedding into orientable and non-orientable compact 2-manifolds.

In the course of the research several findings are expected:

1. Geometrical issues in general

- The analysis and classification of bipartite directional structures (minimal and basic figures, possible degenerations, regularities in the $\mathbb{R}^n$ for $n \geq 2$) → and the comparison to triangular directional structures
- The analysis and classification of combined bipartite geometric structures → distantial and directional type in the $\mathbb{R}^2$ and $\mathbb{R}^3$ with an outlook to the $\mathbb{R}^n$ for $n \geq 4$
- The investigation and deeper analysis of ideal, optimal and regular figures and concomitant curves for bipartite distantial structures especially for figures in the $\mathbb{R}^2$ and further $\mathbb{R}^3$ and $\mathbb{R}^4$
- The investigation of rigid partial bipartite structures of the distantial type
- The development of a consistent nomenclature for bipartite geometric structures of all types and elements connected with the bipartite structures

2. Issues regarding the optimization and network adjustment

- The extension of design models for geodetic networks
- The deeper analysis of the inner geometry of over-determined bipartite geometric structures with the help of latent restrictions, the associated normal form of a matrix and Plücker coordinates, which are related to the partial redundancies of the variance-covariance-matrix of the deviations. The normal form of a matrix correlates to the Grassmannian of a differentiable manifold, which consists the homogeneous Plücker-Grassmann-coordinates (Jurisch and Kampmann 1999, 2002)
- The deeper analysis of the interdependence between the stations and target points at over-determined bipartite distantial networks and its significant effect on the geometric stability and statistical reliability
- The continuation of analysis and the extension of further alternative solutions for bipartite frameworks in the $\mathbb{R}^2$ in general and especially for the over-determined case. This also leads to different pseudoinverse matrices and partial redundancies for one set of given distances and therefore to an extension of considerations for the network adjustments in general

3. Topological issues

- The topological classification of complete bipartite geometric figures by their decomposition into combinatorial surfaces and their embedding into compact orientable and non-orientable 2-manifolds without any boundary

4 Methodology

The GSI Helmholtz Centre with its existing particle accelerator and the planned machine for FAIR provides the possibility to measure and to analyze bipartite geodetic networks in a manifold way. Networks built from distances, directions and their combinations and spatial approaches (from $\mathbb{R}^3$ nearly to $\mathbb{R}^2$) are objects of inquiry. The analysis of possible effects caused by the quadrics and the substructures on the adjustment of actual measured bipartite geodetic networks especially in the $\mathbb{R}^3$ will be the main part of this dissertation. The results of the examination of actual measured and adjusted bipartite geodetic networks provide the basis of theoretical examination and optimization in general and concerning similar parts for FAIR like the SIS100 and other complex areas.

The geometry of the machines itself (circular, linear, elliptic forms) and the evaluation of networks with different instruments (mainly the laser tracker and further the theodolite and tachymeter) also provides the frame to examine and investigate regular and special situations how such a network can be built. The distinctiveness of the machines (synchrotrons, linacs, storage rings and so on) is mirrored directly in the geometry and the adjustment of bipartite geodetic networks. The adjustment of bipartite geodetic networks with all of their characteristics, its distinctiveness, the influence of the quadrics and the statistical analysis will be an essential part of the entire disser-

tation. Networks which are built to determine large facilities provide the basis as object of investigation.

The methodology can be categorized with the following tasks:

- Measurement and analysis concerning the influence of the quadrics and the substructures of simulated and real measured combined networks in the surroundings of the existing particle accelerator at the GSI (e.g. the SIS18), for the future machine FAIR (e.g. the SIS100) and with experimental networks in general; preferentially measured with the laser tracker
- Evaluation and analysis of measured and simulated distantial networks (bipartite frameworks) to improve conditions regarding geometric stability
- Analysis of simulated combined networks in the whole $\mathbb{R}^n$ to show geometric properties
- Analysis of bipartite directional networks in the $\mathbb{R}^n$ for $n \geq 3$, their classification, the depiction of their geometric resistance comparing the quadrics
- The development of a logic taxonomy and therefore a consistent nomenclature for bipartite geometric structures of any known type
- The search for ideal figures of bipartite distantial structures and the comparison to ideal triangular figures

The findings of the analyses regarding latent restrictions will be implemented in the network design and optimization issues. This also comprises the analyses on possible ideal configurations and results from the variance-covariance-component estimation at combined geodetic networks. And further the research on the consolidation of the reciprocal control of the target points via the stations will help to ensure the geometric stability and statistical reliability.

These described results shall also help to understand and comprehend the difficult nature of bipartite geometric structures in comparison to their well-known and well-analyzed triangular counterparts.

5 State of investigations and next steps

Several preliminary studies regarding bipartite geometric structures were carried out. This comprised detailed analyses of small bipartite distantial structures in the whole $\mathbb{R}^n$ and the discovery of rigid partial bipartite frameworks in the $\mathbb{R}^3$. A first approach regarding the research on ideal figures was done with bipartite frameworks in the $\mathbb{R}^2$ – especially analyzing the minimal figure $K_{3,3}$ – and with bipartite frameworks in the $\mathbb{R}^3$ and $\mathbb{R}^4$. A future work regarding bipartite frameworks will be an extended investigation on the alternative solutions for the minimal figure $K_{3,3}$ in the $\mathbb{R}^2$, taking in account further the over-determined case and the attempt to find alternative solutions in the $\mathbb{R}^3$.

Bipartite directional networks were analyzed especially in the $\mathbb{R}^2$ and $\mathbb{R}^3$ but also in the $\mathbb{R}^4$ and higher dimensions. Regarding this an important characteristic can be stated:

Hypothesis 1: *Bipartite directional networks in the $\mathbb{R}^n$ for $n \geq 3$ show a geometric resistance comparing to the quadrics. They don't degenerate, when all network points are located on the corresponding quadrics in the $\mathbb{R}^n$.*

Further analyses were concerned with simple, small and regular combined bipartite networks in the $\mathbb{R}^2$. First analyses concerning the location on conics were also done with these geometric figures. As a next step these investigations will be extended on larger complete and partial bipartite structures in the $\mathbb{R}^2$ and $\mathbb{R}^3$. Therefore the conics – especially the circle and the straight lines – are the specific objects of investigation.

To facilitate the handling with naming a nomenclature for bipartite geometric structures was developed and will be developed further, for any known type of structure and for specific figures and characteristics.

Future works will concentrate on the simulation and evaluation of experimental networks, which later will be measured with the laser tracker at the GSI. Other important campaigns will be the measurement, adjustment and analysis of networks concerning synchrotrons like the SIS18 at the GSI. Here its specific circular shape and the spatial approach from $\mathbb{R}^3$ to $\mathbb{R}^2$ come into play. Considerations to analyze network measurements of large machines from other institutes in the world are also conceivable.

To analyze the geometric stability of over-determined bipartite frameworks in the $\mathbb{R}^3$ the next steps are the simulation and geometric analysis of such networks. Later the theoretical examination will be substantiated with distantial networks measured with laser trackers or the LaserTRACER.

6 Research Background

Working in the fields of automotive and aircraft industries, the engineering itself and especially in the field of particle accelerators I came in contact with small and large bipartite geodetic networks, their measurements, design and evaluation. The main tools were instruments like different types of laser trackers, the LaserTRACER – where the bipartite geometry was first recognized – and classical instruments like the theodolite and tachymeter which were embedded in bipartite network considerations.

At the GSI Helmholtz Centre I am responsible, among other things, for planning, operating and evaluating of different measurement campaigns for the machine areas and also for the geometric determination of normal and superconducting magnets. All these measurements – for small and large facilities – show as a network frame exactly such bipartite structures.

In the year 2014 I enrolled at the Graduate School at the Darmstadt University of Applied Sciences to prepare my doctorate. My first supervisor in Darmstadt at this time was Professor Dr Torsten-Karl Strempel from the faculty of mathematics and natural sciences, who advised me especially in the fields of geometry, topology and combinatorial geometry. Since August 2018 I am supervised by Professor Dr Klaus Habermehl, who advises me in the fields of geodesy and surveying.

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Survey: Software Search in Serious Games Development

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Abstract. The interest in serious games (games that can educate, train, and motivate) has grown very fast in the last decade, yet the research community rarely studies serious game development. For instance, previous work has mainly investigated non-game developers' search practice and has proposed techniques and tools for general purpose software engineering. This paper reports on a pilot user study that was used to understand the thoughts and needs of (serious) game developers. We asked serious game developers "what", "how", and "why" they usually search online to develop their games.
Our study reveals that software search for serious games development is mostly related to finding game-specific tools, documentation, and algorithms for AI, animation, rendering, and learning analytics. Also, specific web platforms (like web tutorials, Q&A sites, and public software repositories) are very relevant for serious games development. Finally, our analysis of serious game developers' search habit informs about the need for more advanced search engines with sophisticated query and filtering facilities.

Keywords: Software Search, Search Engines, Serious Games Development.

1 Introduction

Serious Games (SGs) are video games intended to educate the players instead of pure entertainment (David R. and Sandra L. 2005). The interest in SGs and their application in education and businesses areas has increased very fast in the last decade (Vasudevamurt and Uskov 2015). SGs provide an engaging and self-reinforcing context in which the player is motivated and instructed towards non-game events or processes, including business operations, training, marketing, well-being and advertisement (David R. and Sandra L. 2005). Thus, it is not surprising that many global companies (like Microsoft, IBM, SAP, Adobe, Cisco, Google etc.) have started integrating SGs and gamification techniques in their main business functions, processes, and activities (Anderson and Rainie 2010).

But the efforts, time and costs of serious games development can be reduced if existing software assets and other pedagogical components available on the market can be effectively retrieved (or reused) and integrated into the development process (Wim V et al. 2016). However, this requires to understand what specific actors involved in the development of SGs (like researchers, developers, designers) are usually seeking software and which factors can influence the way they locate and use what they need to develop their games (Hucka and Graham 2018).
This study reports on a deeper exploration of serious games developers' search practices. It was conducted as an online survey (using Google Drive) with professionals and practitioners in SG development. The main goal of this study was to explore the search habits of SG developers in order to understand the factors that can influence the way they *search* and *reuse* software and other related information. The survey was conducted using the following research questions:

- RQ1: What software and other related information do you usually search to develop your serious games, and why?
- RQ2: What are some approaches you usually use to FIND software and related information you need to develop your serious games?
- RQ3: While searching online in the past, what are some obstacles that may have hindered your ability to FIND (RQ3.1) or REUSE (RQ3.2) what you needed to develop your serious game?
- RQ4: Please describe one or more situations when you were trying to find a specific software or any software-related information on the Web…?

Our research questions will be answered by interpreting their results. These questions will be indexed and discussed in the following chapter.

2 Background and Related Work

2.1 Serious Games Development

Nowadays, we observe a growing number of software engineers and researchers focusing on SG development (Brent and Bill 2014; David R. and Sandra L. 2005; Mestadi et al. 2018; Petridis et al. 2012; Söbke and Seicher 2016; van der Vegt et al. 2016). Also, established business companies like Google, IBM, SAP are motivated to design, develop, and implement full-scale SGs in their business functions and processes because of the following advantages: SGs have the ability to 1) solve complex problems collaboratively, 2) improve the efficiency of business processes, 3) support predictive modelling and real-time visualization, 4) increase ROI[1] from processes, time, and resources, and 5) provide more retention of knowledge compared to traditional methods (Vasudevamurt and Uskov 2015). The creation of SGs is also a complex process of game design, programming, content production, and testing (Westera et al. 2016). And its success significantly depends on the quality of external technical gamification

[1] ROI (Return on Investment) - https://www-01.ibm.com/software/rational/rsar/roi/

platforms, dedicated software architecture (Wim V et al. 2016), reusable SG engines, and advanced technology components (software assets) (Wim V et al. 2016). However, there is a lack of standardization, best practices, and tools (Vasudevamurt and Uskov 2015) for supporting the development of SGs and the reuse of game assets which have the ability to preserve and enhance the games' pedagogical effectiveness (Westera et al. 2016). Thus, SG developers often rely on a large set of entertainment-based features and game engines despite the inherent differences between SGs and entertainment-based games (Brent and Bill 2014; Petridis et al. 2012)**.** But, the complexity, time, and effort for creating SGs can be reduced if existing tools and game assets available on the market can be effectively reused (Wim V et al. 2016).

2.2 Software search and related user studies

Software Search is a very common practice in software engineering that aims at discovering suitable software for a given purpose (Hucka and Graham 2018). It has become an important component of real, day-to-day software engineering (Singer et al. 2010) because it can increase work productivity (e.g. through effective reuse). Researchers in software search have tried to understand the search practices and challenges of developers for general software engineering (Barua et al. 2014; Bauer et al. 2014; Hucka and Graham 2018; Xia et al. 2017) and mobile development (Rosen and Shihab 2016). But the study of serious games developers' search practices has remained almost ignored so far.

Techniques used to study software search include *web survey*, *interview*, *search logs*, and *analysis of Q&A sites* (Barua et al. 2014; Rosen and Shihab 2016; Sadowski et al. 2015). (Umarji et al. 2008) surveyed software engineering implementing standard software and discovered that developers were usually looking for blocks of codes (like parsers, wrappers), libraries (for date manipulation, speech processing), stand-alone tools (like an application server or an ERP package). They also discovered that developers were looking for subsystems like data structures, parsers, binary search algorithms that they could reuse in their own implementation without or less modification. (Singer et al. 2010)s' survey informed about the frequency in software search. The study revealed that developers spend 66% of their time reading software documentation, 57% fixing bugs, and 35% making enhancements to their software system. (Singer et al. 2010) observed software engineers at their workplace and discovered that searching was an activity that occurs not only during coding but also while interacting with the hardware (e.g. doing configuration tasks) or debugging. This study also informed about the criteria of selection of software, like working functionality, evaluation of online communities or local experts, and the social characteristics of the software project (like its popularity).
To understand the specific needs and challenges of serious games developers, we recently investigated a popular Q&A site (GameDev Exchange) to find out what SG developers usually search to develop their games (Tamla et al. 2019). We have found that serious games developers usually seek a different kind of help such as best practices, common design patterns, and specific algorithms to develop better serious games that can really train, educate, and motivate players (David R. and Sandra L. 2005).

This survey reports on a deeper exploration of serious games developers' search practices. It was conducted as an online survey (created with Google Drive) with professionals, researchers, and students involved in the development of (serious) games. The study reports on the motivations of serious games developers seeking specific software and related information, how they go about finding help and which challenges they usually encounter to FIND and/or REUSE what they need. The study also informs about potential improvements in next-generation search engines.

3 Pilot User Study

3.1 Method

Nowadays, there is a wide range of algorithms, tools, best practices, and frameworks available online that can be used to facilitate the development of full-scale serious games. To understand the challenges in identifying and reusing such tools and features, an online survey (developed with Google Drive) has been conducted. The main goal of this evaluation was to explore the search habits of serious games developers and to understand the factors that can affect the way they search and reuse software and other related information. So, we used our previously defined research questions RQ1-RQ4. Our research questions will be answered by interpreting their results. These questions will be indexed and discussed in the following chapter.

3.2 Participants

Different consortium partners took part in this survey. We advertised the survey to external gamification companies and educational institutions. Overall, this evaluation was attended by 40 people: 10 software developers (2 software architects, 7 programmers, 1 game designer), 6 scientists, 6 project managers (including 4 CEOs), and 18 students, all involved in the conception, design and implementation of serious games.

3.3 Evaluation Instrument

We used a web-based survey to conduct our evaluation because 1) information can be gathered very easily and quickly from a wide audience, 2) the development effort is very modest and reduced, 3) data can be analyzed quantitatively and qualitatively. The survey consisted of a combination of standardized questionnaires (including free-text and multiple-choice questions) and 1 open question about a specific search experience. We designed the instrument of our analysis iteratively after analyzing previous surveys targeting software search in computing (Rosen and Shihab 2016; Xia et al. 2017). We especially paid attention to the following points:

- *Simplicity*: we created simple and clear questions. We also added explanatory text to some questions that may lead to some ambiguity.

- User experience: we considered only questions that we assumed were within the experiences of our audience
- *Relevance to user's experiences*: we constructed our questions by referring to specific software components and information that we believe are relevant to (serious) game users today.
- *Ethics*: We removed all questions that seemed to be too personal or about proprietary policies (at participants' place of work)

Overall, we defined 3 main categories to collect data on the evaluation:

- *Demographics*: In this section, we collected (prior work (Böhm et al. 2013)) general information about the age, education, and role of the participants.
- *(Serious) Game Development Experience*: This section explores the experience of the participants with the development of (serious) games for specific game genres and target audiences. We also asked questions about general programming experience like experience with programming languages and development paradigms.
- *Search Experience*: Questions in this category were derived from existing research that studied software search in general (Hucka and Graham 2018). We explored (serious) games developers' search habits and tried to explore the problems they may encounter to FIND and REUSE software and other related information. We also defined one open question to ask respondents about their experience with software search.

3.4 Procedure

The evaluation was carried out from August to October 2018. We solicited responses using convenience sampling by sending an invitation to experts, researchers, and students from higher educational, all involved in the development of serious games.

Especially, we advertised the survey via e-mail distribution lists addressing different members of different members of the consortium. RAGE project partners (i.e. UCM, INESC, OUNL, UU, UPB, TUGRAZ). Applied gaming research and development actors: serious-games-solutions.de (The Gamification Expert), oztron.com (Serious Games and Simulations for Education Technology), kastanie-eins.de (Games and Learning), bible.com/kids (Apps and Games to teach the Bible to kids). Educational institutions: the German Institute for Games (Hochschule der Medien Stuttgart (HDM), ifg.hdm-stuttgart.de) and the Institute of computer science of the New York Institute of Technology (NYIT, nyit.edu).

The survey itself was conducted using the online survey platform Google Form. While more users trialled the system, in total 40 participants took part in this evaluation and provided their feedback via the online survey.

3.5 Results

Demographics. The participants aged between 18 and 64. We asked participants about their experience in serious games development: 56% had less than one year, 24%

had between 1 and 3 years of experience, and 20% had between 6 and 20 years of experience. We also asked participants about their roles in their last serious games projects: 46.7% worked as Software Developer, 43% worked as Software Architect (Team Lead), 30% worked as Game Designer, and 10% worked as Test Analyst. The number of years in programming and the roles of participants were routinely used in past research to estimate the experience of developers (Feigenspan et al. 2012).
Additionally, we asked for the highest academic degree: 28.2% of the respondents hold a Bachelor's Degree (or equivalent), 33% a Master's Degree (or equivalent), and 15% a Doctor's Degree (or equivalent). The remaining 20.8% were students before their first academic degree.
Participants were also asked to self-rate their search experience (Böhm et al. 2013). On a five-point Liker scale, 37.8% rated themselves as experts, 32.4% as experienced, 13.5% as moderately experienced, and 2.7% as inexperienced. Results show that in addition to the high level of familiarity in search practices, the group of respondents is characterized by a high degree of education, research and (serious) games development experience.

Search Motivation. To understand *why* serious games developers search specific software and related information, we asked: "What software and other related information do you usually search to develop your serious games, and why?". The question contains a multiple choice box, allowing respondents to complete the list (Other). Other included "Research papers". Figure 1 summarizes the results to this question.

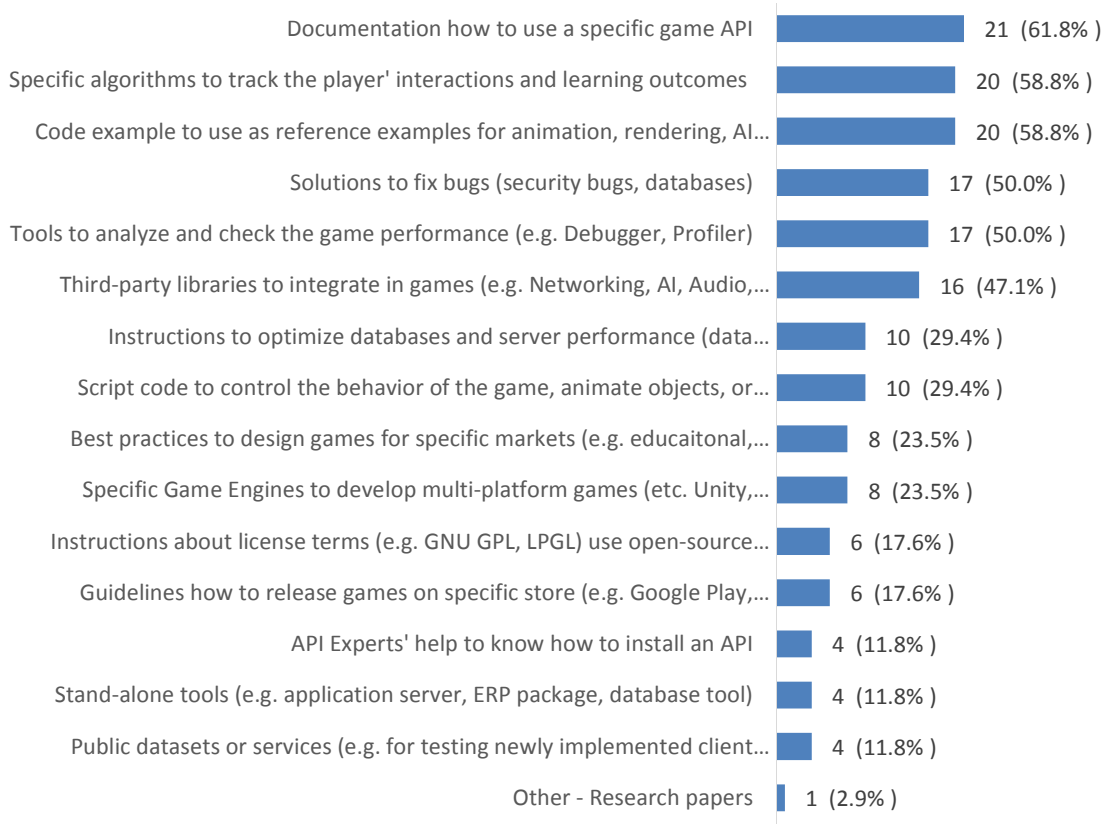

Figure 1: Responses to the question "What software and other related information do you usually search to develop your serious games?". *This question offered an additional slot for free text under "Other". Answer choices were nonexclusive. A total of 34 respondents answered this question.*

We found that looking for *documentation how to use specific game APIs* (61.8% of respondents), *specific algorithms* (to assess players' learning outcomes, increase their motivation, etc.) (58.8%), and *code snippets to use as references examples* (58.8%) were the most common motivations. Followed by *solutions to fix bugs* (50%), *tools for analyzing and checking the performance of games* (50%), and third-party libraries (50%).

Search Approach. To explore *how* serious games developers go about finding help, we asked respondents about the approaches they frequently use to find search software and related information, e.g. asking colleagues. Answer options were nonexclusive multiple choices, including "Other" option with a field for free-text input. Figure 2 provides a summary of our findings. 31 participants answered this question. The result shows that *asking colleagues or fellow students* (67.7% of participants), *using general-purpose search engines* (64.5%), *visiting standard web pages* (54.8%), and s*earching public software repositories* (45.2%) were the most common approach used by the respondents. Others included social network resources (Youtube Tutorials) and specific web site (Asset Store). Figure 3 summarizes the most popular online web pages consulted by 33 respondents. Other include "developers.google.com/games". In total 5 online sites have been named by the respondents, whereby GitHub (69% of respondents) and Stack Overflow (69%) are the most popular, followed by Asset Store sites (for unity and unreal

game engines) (33%). This result shows evidence about the importance of social networks and online communities for serious games development.

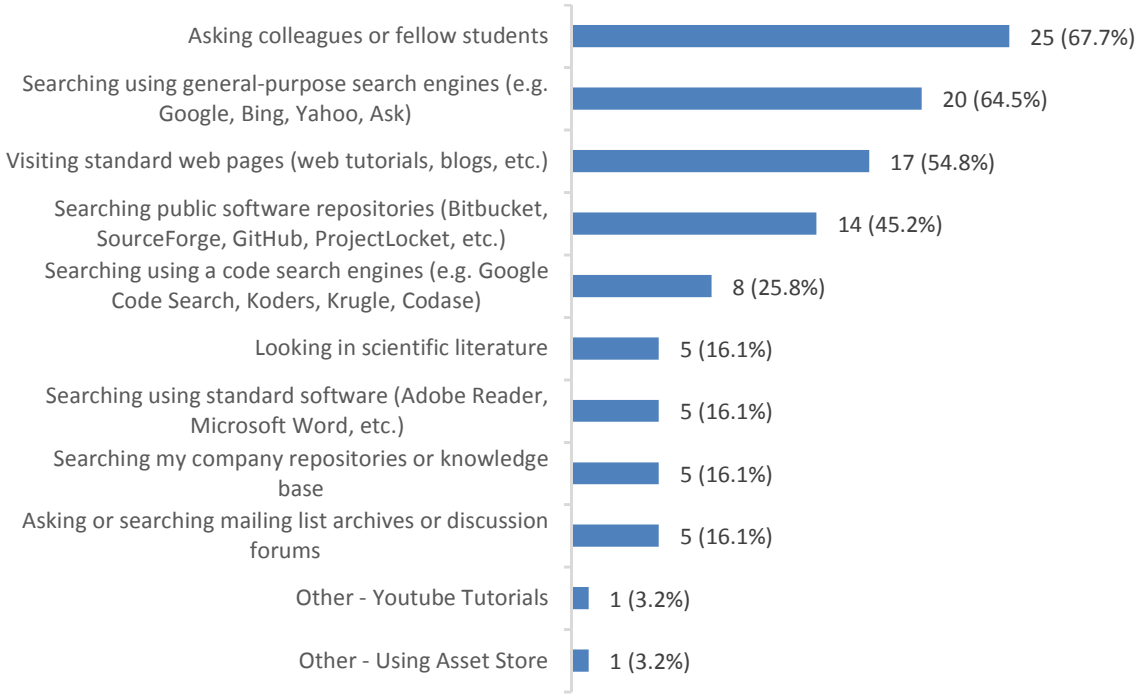

Figure 2: Responses to the question "**What are some approaches you usually use to find software and related information you need to develop your games?**" This question offered an additional slot for free text under "Other". Answer choices were nonexclusive. A total of 31 respondents answered this question.

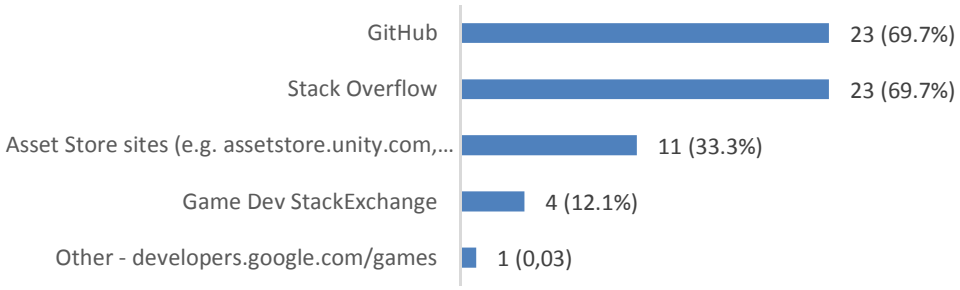

Figure 3: Responses to the question "**Do you also search specific web pages? If yes, please select the ones that match and/or complete the list**". This question offered an additional slot for free text under "Other". Answer choices were nonexclusive. A total of 33 respondents answered this question.

Challenges in Software Search. To understand the different challenges while seeking software and related information, we asked respondents what can prevent them to *find* (Figure 4) and *reuse* (Figure 5) what they found on the Internet. Respondents could select challenges in a multiple-choice box or extend the list with the "Other" option. Figure 4 reveals that 65.6% of our respondents had difficulty to *find* help online because of the following problems: *requirement was too unique* (65.6%) (which

suggest that, in some special context, they might not know what exactly to search for), *unable to locate close match* (code snippet) to use as reference example (40.6%), *wrong search queries formulated* (37.5%), and *too many alternative solutions to choose from* (31.3%). Our survey also reveals that "*poor formatted source code*" (18.8%) could not prevent serious games developers to find software although this may affect the detection of reference examples (close match). Figure 5 summarizes the results about the challenges while seeking software for *reuse*. Incomplete functionality (59.4% of respondents), poor documentation (56.3%) were the most difficult challenges to software reuse. Followed by *too much effort to integrate third-party libraries* (43.8%), *lack of testing instructions* (40.6%), and *incompatibility with the target system* (40.6%).

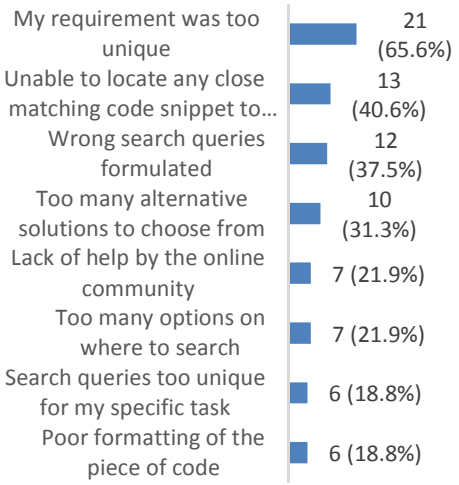

Figure 4: Responses to the question **"While searching online in the past, what are some obstacles that may have hindered your ability to FIND what you needed to develop your game?"** This question offered a multiple choice box with an additional slot for free text under "Other". Answer choices were nonexclusive. A total of 32 survey respondents answered this question. A total of 32 survey respondents answered this question.

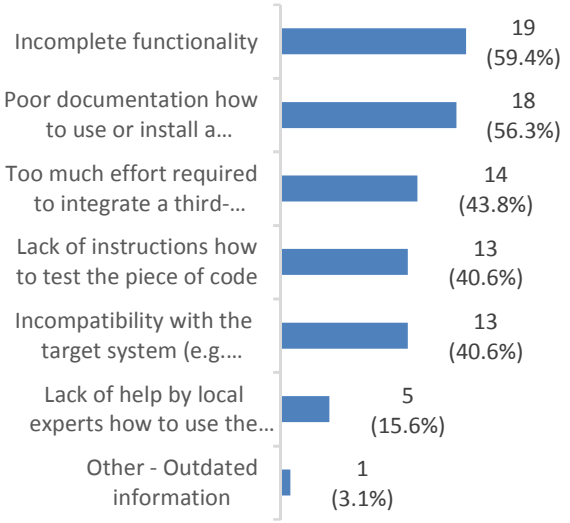

Figure 5: Responses to the question "**What are some obstacles you may have faced in the past to REUSE the software or other related information you found on the Internet**". This question offered a multiple choice box with an additional slot for free text under "Other". Answer choices were nonexclusive. A total of 32 survey respondents answered this question**.** A total of 32 survey respondents answered this question..

Search Case Experience. We wanted to learn more about how respondents seek software, so we sought examples of participants' past experiences. We asked the following questions: "**Please describe one or more situations when you were trying to find a specific software or any software-related information on the Web. What were you trying to find? How did you formulate your search queries? What approaches did you use? What problems did you have to find and/or reuse what you found? And how useful was the search result?"**

The survey form provided a text editing field where participants could write their responses in free-form text. We received a total of 12 responses, of which 8 contained substantial details about past search experience. Table 1 provides three examples taken from among those 8 responses. The analysis of these examples provides evidence that

serious games developers are trying to overcome the permanent *information overload* found in existing search engines (like Google). They seek advanced search features such as filtering by a specific programming language (#User1), or how to optimize search queries by describing the search context with keywords (#User3).

*#User1 – Unity supports multiple script languages (js, C#) and ui options to do one thing. Often this is a problem with normal search engines like google because **you can't filter for a specific language** and **get a lot of code snippets you can't use**. For example when you want to add an gravityfield to an object in c# and search for "unity add gravityfield" you find a good answer in the unity forum for js but nothing for c#.*
*#User 2 – I start with 2 /3 words. If no significant result i add another word . Problem: **too many sponsored responses within the top results***
*#User3 – Once I searched for a tool that could generate JavaScript code for a node server. My main search terms where "swagger", "node", "code gen". Unfortunately **the search engine just returned a lot of bullshit** like a small project called "swagger-node-codegen" (written in JavaScript). Nothing really helpful for me and my purpose. After several days of investigation, I found a code generation tool, written in Java, which also produces/generates JavaScript (NodeJS-Server) code.* *I think, the main problem was, that the search terms I used where to "generic" for this specific search request and even in different conjunction there are too much "possibilities" about what I could have needed. In other words - I was not able to describe my requirements in a unique and distinct search request. What I missed was **the possibility to describe my context**! For example, that **I need the resulted code to be JavaScript**, **not that the generator is written in JavaScript**.*

Table 1. Answers to the open-ended question "Please describe one or more situations when you were trying to find a specific software or related information on the Web (What were you trying to find? How did you formulate your search queries? What problems did you have

Information Desire about Software. To help inform the development of advanced search tools, we sought to determine what kind of features our respondents would like to see implemented in future search systems. We posed the following question to all participants "***What issue(s) do you think needs to be addressed in existing search mechanisms and/or tools to support serious game development?*"** (Figure 6). The question was in form of a multiple choice box with an "Other" option as free text. As shown in Figure 6 "Outdated exclusion" and "Content context-sensitive search" were added to the Other option. The analysis of responses to this question reveals that there is a need for more sophisticated filtering and query features that are well integrated with existing search engines, are easy to use and can optimize search results based on the user's context more efficiently.

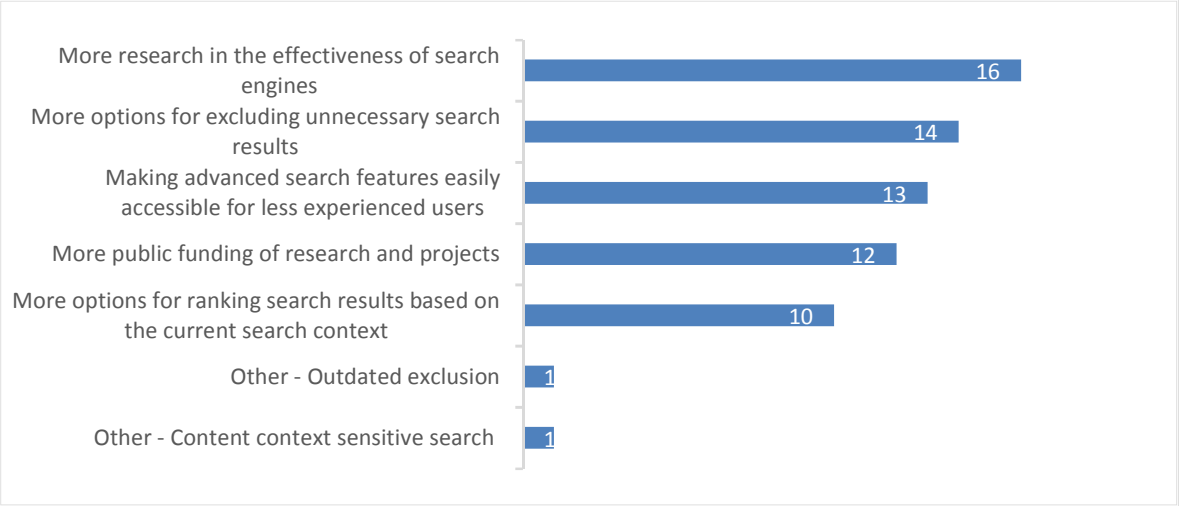

Figure 6: Response to question "**What issue(s) do you think needs to be addressed in existing search mechanisms and/or tools to support serious game development?**" This question offered a multiple choice box with an additional slot for free text under "Other". Answer choices were nonexclusive. A total of 32 survey respondents answered this question.

4 Discussion and Conclusion

Overall, the feedback gathered in this study shows that specific online tools (like search engines, public software repositories, and Q&A sites) are relevant for (serious) games development, because they can provide different kind of help (instructions, algorithms, and tools) that can facilitate and accelerate the development of serious games. Also, this survey provides evidence about the need for more advanced search engines with sophisticated query and filtering facilities.

Acknowledgement

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Modular Novelty Detection System for Driving Scenarios

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Abstract. Unsupervised novelty detection has many applications in various fields of current research. This work proposes a new combination of commonly used novelty detection techniques applied on an automotive dataset. The goal is to differentiate between known and novel driving scenarios. The presented method is unsupervised and combines a convolutional autoencoder, a principal component analysis and a nonlinear one-class support vector machine. The strength of the presented approach is its modularity. Visualization and interpretation of lower dimensional features ensure transparency about what the model learns. A module can be derived from an existing function (e.g. a previous classification task) or specifically be designed for the application domain. Additionally, it can be replaced when the context changes. The approach is also implemented with respect to limited compute capabilities, allowing its application in an autonomous vehicle. The achieved results are satisfying, especially when compared to a similar supervised approach and the visualization complies to the intuitive expectations.

Keywords: novelty detection · convolutional autoencoder · principal component analysis · one-class support vector machine.

1 Introduction

Many supervised machine learning techniques require large labeled data sets. Novelty detection can reduce the amount of data that needs expensive hand-labeling by performing a binary classification into normal and novel data. Normal data belongs to classes that are known by a model and can therefore be automatically labeled. Novel data belongs to classes that this model has never seen during its training and therefore needs hand-labeling. This classification is also valuable for the retraining of a model: It already performs sufficiently well on normal data and thus only has to be adapted (retrained) to the novel samples. Both presented applications suggest a one class classification as solution approach: The model knows the normal data to such an extend that when presented a novel data sample, the output is significantly different to the output of normal inputs. This significant deviation can be measured as novelty score and a threshold determines the classification. For novelty detection, a high true positive

rate (every novelty is detected) and a low false positive rate (not many normal samples are missclassified) are desired. Working with novelties poses multiple challenges. We assume that novelties are rare, resulting in heavily unbalanced data sets. Additionally, due to the curse of dimensionality, every data sample can be characterized as novel when enough dimensions are used for the detection. This also means that if an algorithm is trained on various kinds of novelties, most likely there will be another kind of novelty that the algorithm misclassifies. The following section gives an overview of related approaches. Section 3 describes the proposed approach in detail. Section 4 presents the experiments and Section 5 their results and discussion. Section 6 concludes.

2 Related Work

Novelty detection is related to anomaly, outlier and corner case detection and subject to research in various fields of studies like medicine [10, 8], robot systems [13] and image recognition [6]. The survey by Pimental [7] groups novelty detection approaches into probabilistic, distance based, reconstruction based and domain based approaches. The latter find a boundary around the known domain data and detect every sample outside this boundary as novelty. One-class support vector machines (1CSVMs), introduced by Schoelkopf et al. [9] for novelty detection, are an example of such an approach.

Marsland [5] presents different novelty detection approaches in learning systems, like neural networks. Generative adversarial networks (GANs) are a new type of neural networks that also find application for novelty detection [8]. GANs consist of a generator and a discriminator part that compete in the training process to improve the final result. Seeboeck et al. [10] combine three autoencoders with a linear 1CSVM for outlier detection to a modular novelty detection approach. Erfani et al. [2] combine a linear 1CSVM with a deep belief network. Utkin et al. [13] combine autoencoders and a siamese network to a siamese autoencoder for anomaly detection in multi robot systems. Nguyen and Vien [6] use an end-to-end approach including a convolutional autoencoder (ConvAE) and Fourier features where the training of each part is directly dependent of the other modules.

In safety critical applications like autonomous driving, it is important to know what a learning system actually learns. Saliency maps [12] are an often used technique to get an understanding of the intermediate steps in neural networks. They show which neurons in each layer are activated for a given input.

The approach presented in this work focuses on the advantages of a modular approach to include visualizations of intermediate results: A ConvAE extracts features from the input data, a principal component analysis (PCA) [4] reduces the dimension of resulting features which are then visualized. A nonlinear 1CSVM detects the novelties based on these low-dimensional features. Due to the similarity of the input data, both in content and image sizes, the ConvAE used for feature extraction in this approach is inspired by Hasan et al. [3], who use the ConvAE to learn temporal regularities in videos.

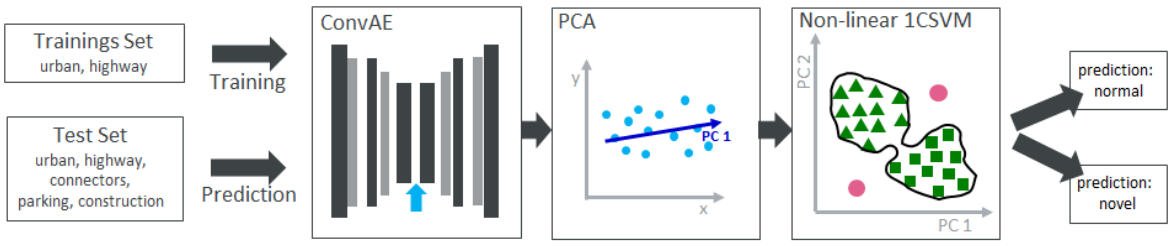

Fig. 1. Overview of the three modules that are combined.

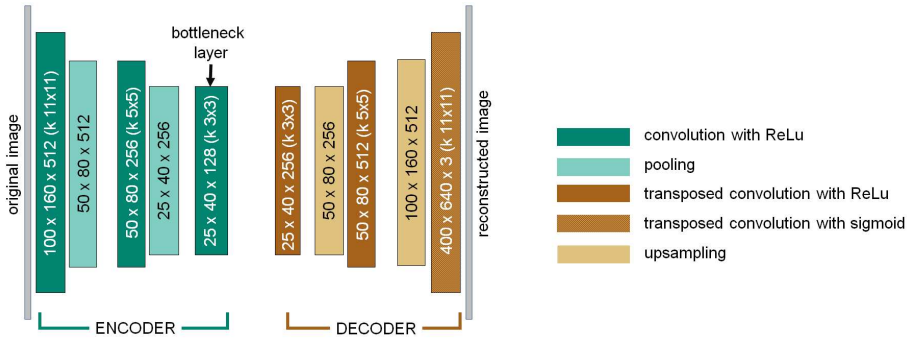

Fig. 2. The ConvAE is symmetric and consists of three convolution, two pooling, three transposed convolution and two upsampling layers.

3 System Overview

Three modules constitute the proposed novelty detection system: a ConvAE, a PCA and a 1CSVM, see Fig. 1. A ConvAE is a kind of neural network that consists of an encoding and a decoding part. The encoder extracts condensed high-level features from the input image. The decoder then reconstructs the image based on these features. The ConvAE is trained unsupervised, minimizing the reconstruction error (difference) between input and reconstructed image, the exact architecture is depicted in Fig. 2. Deep neural networks like ConvAEs tend to disentangle manifolds. Thus, the resulting feature space becomes more linear [1]. The PCA is a linear transformation that finds the directions with the highest variance in the data, the so-called principal components (PCs). The PCA is applied to reduce the dimensions of the features: They can be visualized more easily and the following 1CSVM is more efficient on lower input dimensions. A 1CSVM finds a hyperplane, defined by support vectors, that surrounds its training data [9]: data that is not similar to the training data lays outside of this hyperplane and is classified as novel. The features that characterize the novelties are expected to be highly non-linear, therefore a non-linear 1CSVM with a radial basis function (rbf) kernel is implemented. The computation of the 1CSVM requires the parameters ν and γ: ν is the lower bound on the fraction of support vectors, meaning that at least the ratio of ν samples of the training data are used as the support vectors. ν is also the upper bound on the fraction of outliers in the training data, meaning that a maximum of the ratio of ν samples of the training data lie outside the 1CSVM. γ is the kernel parameter of the rbf

kernel, which uses a gaussian distribution to compute the similarity between two samples. γ can be interpreted as the inverse of the standard deviation. A high γ means that the samples need to be close together to be treated as similar, whereas a low γ means that they can be far away and still be treated as similar. If not otherwise specified, writing 1CSVM refers to the non-linear 1CSVM.

The major computation of all three modules takes place during training. The inference is very efficient since the input image is solely parsed through the network and the resulted features are inserted in the computed equations.

4 Experiments

The RGB images in the dataset have a size of 640x400 pixels. The images were taken by a front camera in a car and labeled according to five classes: urban street and highway images are normal classes. Connector (ramp on and off the highway), parking (open parking lot) and (urban) construction zones are novelties. The training dataset consists of 2028 urban and 2029 highway images. The test dataset consists of 688 urban, 512 highway, 204 parking, 43 construction and 736 connector images, see examples in Fig.3. The loss function of the ConvAE is the mean squared error. As the first layers of the ConvAE contain the simple features such as edges and the high-level features are desired to detect novelties, the bottleneck layer (3rd convolution layer) is the input to the PCA. The 1CSVM is computed on the PCs of the train images. 1CSVMs with different input dimensions and γ values are compared. Experiments showed, that varying the ν value has no noteworthy impact on the results.

Fig. 3. Examples of the dataset, from left to right: The normal classes urban and highway, the novel classes parking, construction and connectors.

5 Results and Discussion

Fig. 4 shows the first two PCs of the extracted features of each test sample. The normal classes are not separable in this plot. This is expected, due to the way the ConvAE is trained: it is not discriminative and not using any information about the underlying class structure of the dataset. Highway and urban roads both have features in common that are significant for reconstruction. Fig. 4 also shows that parking and construction samples are not clearly separable from the normal data, but separable from each other. The PCA is only suitable for novelty detection, when the variation in the features that characterize the novelties

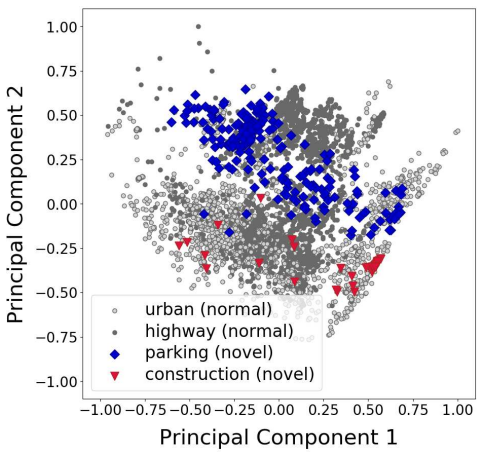

Fig. 4. The first two PCs of test images.

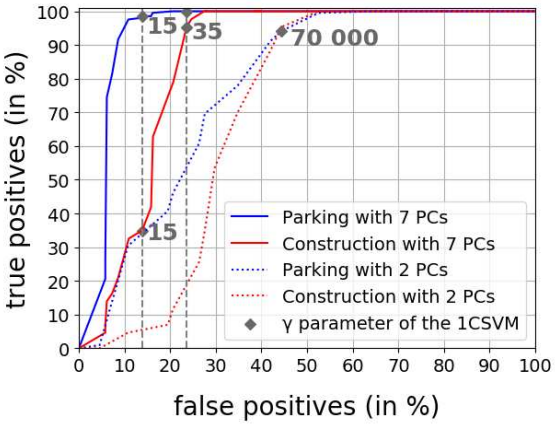

Fig. 5. ROC curves of the 1CSVM with varying γs and $\nu = 0.05$.

is not lost by computing the PCA. Shuy et al. [11] propose an approach using the first and the last PCs for novelty detection. Fig. 5 shows the Receiver Operator Characteristics (ROC) curves of the results of 1CSVMs. The 1CSVMs using seven input dimensions are better in detecting both types of novelties. The PCs are sorted in descending order of their variance on the training data. The results show, that adding the next PC to the input of the 1CSVM improves the final result. But the size of the improvement decreases per additional PC. Using more dimensions results in higher computing time, both at training and at inference. This poses a trade-off between the best results and a feasible time complexity. To achieve a good true positive rate the γ value has to be higher for construction than for parking. This means that the construction novelties are harder to separate from the normal data, compared to the parking data. This is in agreement with the results from the PCA, plotted in Fig. 4. Table 1 shows the exact detection results. It also shows the results using a supervised convolutional neural network (CNN) instead of the unsupervised ConvAE for feature extraction. The CNN was trained on the classification into urban and highway. It performs slightly better, but also needs labeled training data.

Table 1. Results of the unsupervised and supervised approach with different γs. All 1CSVMs are non-linear and use seven PCs.

	ConvAE + 1CSVM (unsup.)			CNN + 1CSVM (sup.)		
	tp (%)	fp (%)	γ	tp (%)	fp (%)	γ
parking	98,5	15,8	15	99	7	3.5
	100	24,7	35	100	23	35
construction	41,9	15,8	15	40	7	3.5
	97,7	24,7	35	99	23	35

The features of the input images are reduced by a factor of six in the ConvAE and by a factor of 18285 with the PCA: The higher dimension reduction takes

place using a linear transformation instead of exploiting the non-linear power of the ConvAE.

6 Conclusion

The proposed novelty detection approach combines three modules: a convolutional autoencoder for feature extraction, a principal component analysis for dimension reduction and visualization and a non-linear one-class support vector machine for novelty detection. The results of the experiments comply with the intuitive expectations, achieve the goal of reducing the amount of data that needs hand-labeling and are close to a similar supervised approach. More complicated novelties are harder to detect, which can be seen in the increased false positive rate. Future work includes extensive hyperparameter tuning for the ConvAE, reducing the features in its bottleneck layer to observe the reciprocity between non-linear feature extraction and linear dimension reduction, automatically determining the ideal γ and ν parameters of the 1CSVM as well as model ensembles combining supervised and unsupervised approaches.

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Chapter 4

Smart Healthcare and Safety Systems

The Acceptance and Consulting Quality of Automatic Emergency Call Systems for Cars

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Abstract. Since March 2018 cars in the EU need to be equipped with a car emergency call system called eCall. The continuous critique linked to eCall and data protection was the starting point for two studies: the first analysed acceptance factors of the eCall system, while the second study analysed the consulting quality in relation to data protection linked to emergency call systems in cars. The safety feeling generated by the existence of eCall, concerns regarding the data usage as well as trust in handling data have been identified as the main drivers for the acceptance of eCall systems. The second study showed that customers as well as seller/consultants are not yet properly informed about the new system.

Keywords: emergency calls, data protection, quality of consulting.

1 Introduction and Aims

The amount of produced cars in Europe is continuously increasing and has reached the number of over 17 Million cars for the year 2017 [1]. As a consequence the total amount of registered cars in the EU is currently bigger than 45 Million [2]. At this number, it is natural that the death toll in traffic accidents reached more than 26000 persons within the European Union [3]. Although this amount stagnates, it is still a considerable number. Only in Germany during the year 2015 3277 persons died as a result of a traffic accidents [3].

Often a seriously injured victim of an accident is not able to make an emergency call. This inability reduces the chance of survival of the victim considerably. To improve this situation, the European Union made the introduction of an automated emergency call for cars – called eCall - mandatory for the manufacturer of cars and trucks. This rule is in place since the 31st of March 2018 [4].

Since the introduction of eCall there was plenty of critique related to data protection. The aim of this paper is to evaluate acceptance factors for data protection as well as to evaluate the consulting quality related to the use of data in the context of emergency call systems.

The paper will give a brief overview of the differences between the two most important emergency system types. Then two studies will be addressed. While the first one is addressing customer acceptance of the eCall system, the second is addressing the topic eCall and data protection at the level of consultants of car dealers.

2 Comparing Emergency Call Systems

The eCall system integrates crash sensors that are able to identify a traffic accident. In case of a traffic accident, the emergency call system will initiate a free emergency call to the emergency number 112. During this call important data including position, time of occurrence of the accident, car identification number and direction of travel will be transmitted to an emergency call centre. Additionally, based on the position of the seat belts the system is able to identify the number of passengers traveling in the car involved in the accident [5]. The initiated phone call will enable the emergency team to talk to the injured persons and to collect additional information related to the accidents and to the types of injuries of the passengers [6]. After this, properly informed and equipped emergency units can be send to the accident as outlined in figure 1.

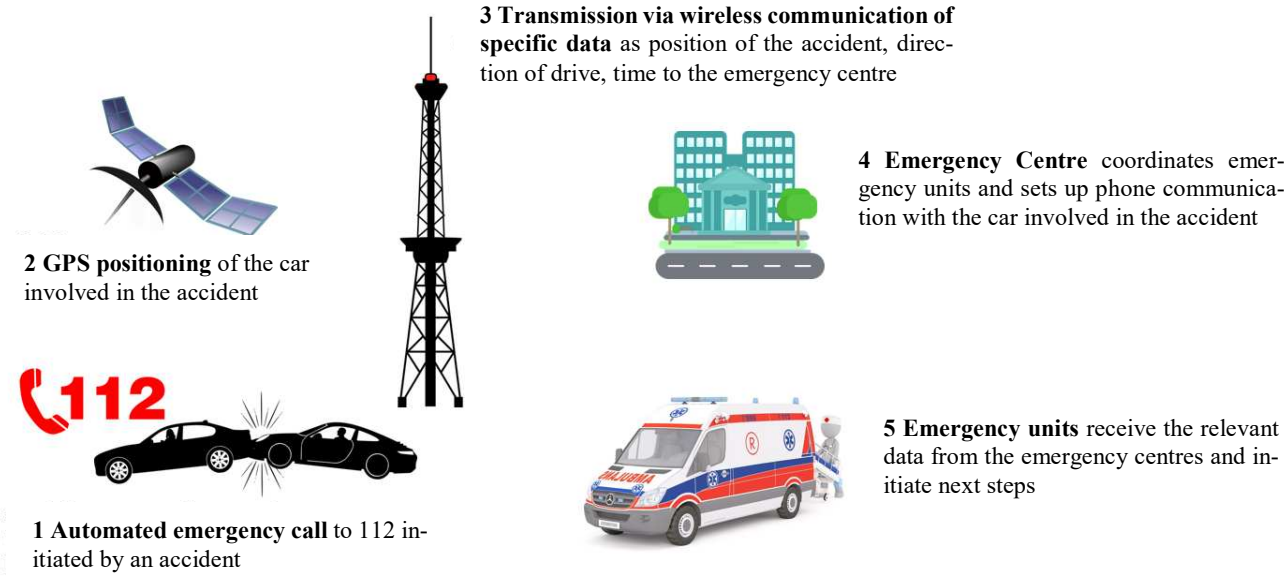

Fig. 1. Overview of the emergency processes initiated within the eCall system

The EU-eCall service requires the collection and transmission of data. However, personal data is protected by General Data Protection Regulation (GDPR) [7] and addition data protection regulations specified for the eCall service [4]. These regulations limit the use of data for rescue operations only. It is prohibited to use data for other objectives or to pass data to a third party [8].

In addition to the by law required eCall service, car manufacturer can offer their own emergency services, known as TPS-eCall-Services. These services do not have to comply with the strict regulations for eCall. As a consequence TPS-eCall services can collect more information than regular eCall services. Another difference relates to the online time of the service. While EU-eCall systems are activated only in an emergency case, TPS-eCall systems can be permanently online. Consumer protectors see this critical, being afraid that car manufacturer might be tempted to collect more data than necessary and make collected data available for additional commercial services. For a better understanding the differences between the two types of eCall services have been listed in the table below.

Table 1. Differences between the EU-eCall service and TPS-eCall services, based on [9]

Categories	EU-eCall Service	TPS-eCall Services
Services	Only emergency calls	Emergency call service combined with additional services, e.g. tracking, regular calls to service centres
Regulations	Legislation adopted by the European Parliament. It contains clearly specified regulations regarding the collection and processing of data	Privat-law agreement with the customer based on data protection regulations.
Emergency call forwarding	Forwarding to the next local emergency call centre (112)	Forwarding to a privat call centre of the supplier
Data content	Datatypes are contained in the minimal data set of EU-eCall	Contains more data than the data contained in the minimal data set.
Call priority	Has the same priority like a phone emergency call.	Normal call without priority
Can the service be deactivated?	Not possible	Possible

The incentives for the use of TPS-eCall services are many. Technically there is almost no limitation in storing data. As a consequence the technologies used within eCall allow access to data originating from different types of sensors, controllers as well as

microphones and speakers. This allows the generation of driving profiles that might be of interest for car manufacturers, insurance companies, suppliers and authorities. The amount of data collected by the different TPS-eCall services of car manufacturers is unclear to the public. Only car manufacturers know in detail what data is collected, processed and stored. Customers are required to rely on the transparency and honesty of car manufacturers, which is not easy on the background of the current mistrust.

GDPR issued by the EU in Mai 2016 defines clearly the condition under which the collection, processing and storing of private data is allowed. With regard to this any person can decide if she agrees to fill in a declaration of consent for the collection, processing and storing of its personal data. In reality there are a couple of hurdles. When this consent is not given, e.g. because car manufacturer did not outline the data to be processed in detail, this might exclude the customer from the use of additional services of the car manufacturer. This might limit also the amount of third party benefits, e.g. benefits of insurances linked to the availability of certain personal driving tracking data. Very often the customer is not aware of the existence of the EU-eCall service and is not aware of the difference to the TPS-eCall service provided by manufacturers. Therefor it is important that customers are informed properly during the vending consultation about the use of privat data by the different emergency call systems and its protection.

Up to now, there are no known theory studies on eCall services. As a consequence the aim of this study was to identify the acceptance factors of eCall services and to analyse how well car sellers are informed and are informing customers about eCall and data protection in vending consultations.

3 The Acceptance Study

3.1 Study Design

In the first study a theory based model has been developed with the aim to clarify the current level of acceptance of the eCall service. The used acceptance model is based on the “Unified Theory of Acceptance and Use of Technology” (UTAUT) [11]. However, it was necessary to modify the model: the constructs Behavioural Intention as well as User Behaviour have been eliminated since by law eCall will be used on a long term. In addition, it was necessary to extend the construct of Acceptance being the main construct. Since the construct Performance Expectancy has a direct influence on the intention of Acceptance it was kept in the model. As a result, the model provided empiric results based on data received from 174 persons that took part in the associated online survey during the summer 2017. About 55% of the participants where women while 45% were man.

The system of hypothesises used – represented in figure 2 – was causally analysed using Smart-PLS with the aim to verify the cause-effect relation.

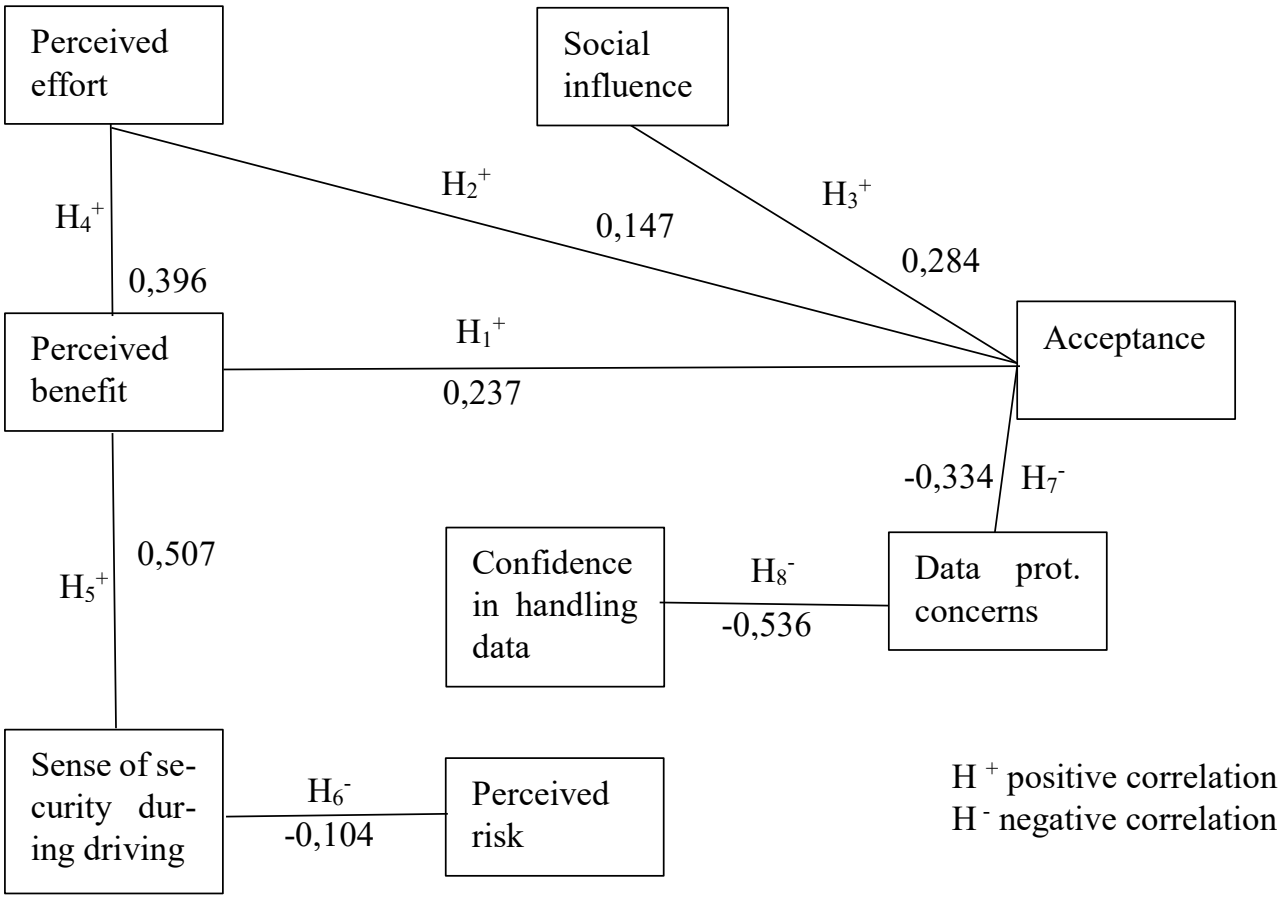

Fig. 2. Model used to analyse the acceptance of eCall including path coefficients

The PLS algorithm has three stages: In stage I for each latent variable - based on used data - values are estimated. These latent variables are used in stage II to estimate the size of effect of the structural model [12]. Each latent variable is the result of a linear combination of indicators. In the next step the iterative estimation of latent variables is done by optimising the estimated values using internal and external approximations. As a result the residual variance of the measurement and structural model is minimised. This procedure is repeated until a converging value is achieved [13]. In stage II the structural equation model with manifest variables is estimated [12]. As a result path coefficients are being identified. Using mean values and constants finally the linear regression function can be estimated.

The quality criteria used for analytical modelling using causalities are complying with the standard. They lead to a sound model.

3.2 Results of the Acceptance Study

Although car emergency services are supposed to be known by customers, only one third of the participant have heard of the eCall Service.

The perceived effort has an influence on the user perception of eCall and as a consequence has an impact on the acceptance of emergency call systems/services. The use of the system will be free of charge for the normal user. Two out of three users assume that there will be no costs associated with the use of eCall. This has a positive impact on the acceptance of eCall.

More than 60 % of those surveyed would feel much safer if eCall is available in their car. The feeling of safety has a strong positive influence on the perceived benefit of an eCall-System and thus has an indirect influence on the acceptance of the system. The feeling of safety is generated by trust into the reliability of the system. Tests showed customers that an emergency phone call to the emergency call centre could be setup during a couple of seconds making sure that the rescue operation is initiated immediately. First tests in Austria showed that the response time of the emergency units was reduced by 40-50% compared to the normal response time without eCall. The variation depends on the area of operation. The live-test proved that already 20 seconds after the accident the relevant data was received by the emergency call centre [10].

Trust in handling data has a direct influence on the concerns regarding data protection and as such has an influence on the acceptance of eCall systems. Almost 50 % of the surveyed participants do not trust that the system is protecting their data from third parties. They are afraid that their data is used as well for other aims. About 28% of the participants are afraid that by sharing all their data, they will result in a fully “transparent” driver. Nevertheless, the European Parliament rejected the deactivation possibility for the eCall system. As such, building up trust and transparency regarding the collection and use of data is necessary. Users need to be informed in a timely manner about the collected data and their use. There needs to be a differentiation between eCall system and private TPS emergency call systems. Private emergency call systems as well as additional services provided by car manufacturer are not falling under der regulation of eCall systems/services and as such are able to collect permanently data.

4 Mystery Shopping Study and Discussion

4.1 Study design

This second study had the aim to analyse the quality of consulting during the vending process with emphasis on eCall and data protection. Therefor non-representative Mystery Shopping Study was conducted in summer 2018. During this period 18 consultations with car dealers with the aim to buy a new car were carried out. The test buyer

logged the consultations. In the next step an analysis showed how good car sellers/consultants were informed about eCall und data protection and how good they informed potential customers about it.

One of the aims was to find out if car sellers/consultants could differentiate between EU-eCall und TPS-eCall systems. It was of interest if they knew which type of data sets were stored by each system. As the EU-eCall has a minimal data set specified by law, it was of also interest to see if they knew what data is collected and stored by the TPS-eCall systems. The car dealers involved where not informed about the mystery shopping as this might have influenced the results.

Central questions addressed were:

- For a specific car: is the implemented emergency call system the required eCall system or is it a TPS-eCall system of the car manufacturer?
- Does the car provide additional services that are connected with the eCall software? If available, how are these services working?
- What happens with the collected data? Is data forwarded to a third party? If yes, who is this third party?
- Has the user the option to deactivate TPS-services?

4.2 Results and Discussion of the Mystery Shopping Study

Overall we can confirm that the consulting quality related to eCall has potential for optimisation. Some seller/consultants declared that they did not have any training about eCall systems. The consulting quality provided by different persons has a high level of fluctuation as you can see in the summative evaluation in Fig. 3.

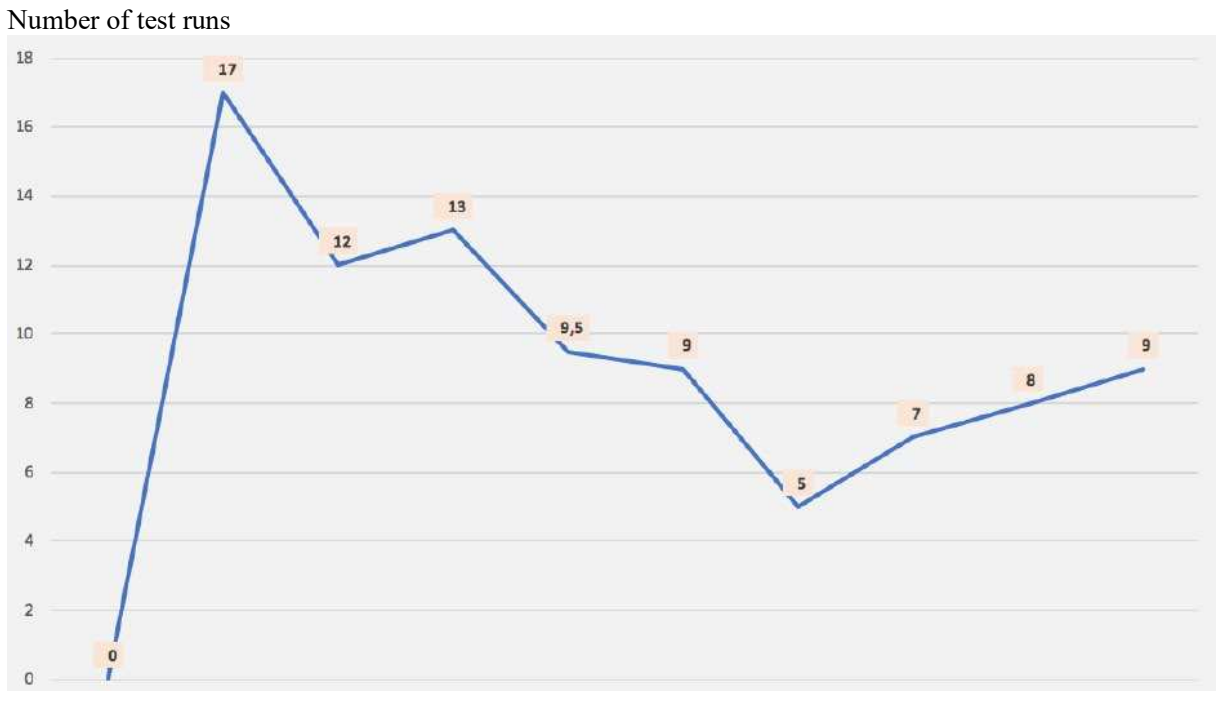

Fig. 3. Achieved positive responses to the 10 criteria during all mystery shopping's

The results of the relevant criteria are discussed below. Approximately half of the consultants were able to explain the eCall-System well (criteria 6). Approx. 66% were able to find the eCall emergency button (criteria 3). But none of the consultants addressed the topic eCall by themselves (criteria 1). Asked by the Mystery Shoppers about Connected-Services information about additional services was provided. However, none of them addressed the emergency call topic. Concluding this means that customers are expected to have a basic knowledge about emergency calls. In many discussions consultants mixed up the EU-eCall System with the TPS-eCall of the manufacturer. In one of the Mystery shopping's wrong information was given about the inability to switch off the eCall system.

The necessity for data protection trainings related to emergency call systems has been identified as well. Only four out of eighteen consultants knew what data is collected by the eCall system (criteria 7).
While some consultants did not reveal many information related to the aims and goals of data protection, others responded honestly to the questions (criteria 8). Asked about what happens with the collected data, some salespersons argued that data is used for guarantee handling and customer retention as well as forwarded to the manufacturers insurance for evaluation (criteria 9). Two salespersons think that car manufacturers generate user driving profiles and that drivers' profiles are already "transparent".
One of the salespersons argued that the customer has no right to disagree to the data protection agreement. Refusing customers the right of disagree with the data protection agreement would constitute a clear offence against GDPR. In none of the consultations a clear statement about which data is collected, processed or even forwarded to a third party was received. The same applies to the third parties by which data might be processed.

5 Conclusions and Outlook

The benefits of eCall (especially the safety aspect) outweigh the concerns regarding data protection and informational self-determination. When it comes to personal safety drivers are happy to share their personal data. From this perspective it makes sense to support the promotion of this system to all drivers.

But car dealers need to support this process as well, e.g. by training salesman and consultants on the topics eCall and data protection. This might be the right response to the increasing requirement for more specific information of customers. In addition it makes sense to increase the data protection awareness of consultants and sales persons. Data protection audits will help to make sure that processes are GDPR compliant. The availability of information about data collected, processed and stored in these services will help to achieve transparency and as such generate customer trust, since achieving trust is very important.

It will be interesting during future research to analyse the impact of the suggested changes on acceptance.

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Demonstrating Machine Learning for Cancer Diagnostics

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Abstract. This paper describes how machine learning systems can be explained and demystified for non-technical audiences through the use of an online simulation. This research is the result of a European Union funded project, SageCare, which focuses on developing machine learning systems to classify clinical and genomic data. In disseminating the use of machine learning to non-specialists we often encounter resistance or suspicion on the veracity of approach. Hence, we present artificial intelligence/machine learning for non-specialists and present a case study and an interactive simulation on how machine learning can be used in cancer diagnostics. The simulation system serves as a basis for both informing clinical practitioners how machine learning can be used to build diagnostic models and describes how feedback from users will be gathered and analyzed to assess how machine learning is viewed in such an application.

Keywords: First Keyword, Second Keyword, Third Keyword.

1 Introduction

The SageCare Project [1] tackles the important area of personalized medicine, by addressing health informatics in a holistic way by creating a platform that interlinks spatially distributed clinical care information sources, EHRs and associated genomic sequences, thereby allowing clinicians to make reasoned queries using machine learning over vast knowledge bases of health and research data. This requires a number of disciplines and skills to be brought together in order to achieve success, including clinicians active in the diagnosis and treatment of cancer. To gauge the effectiveness of machine learning in the domain of cancer diagnostics, a JavaScript simulation, based on a simulator developed by [2], is configured to build a machine learning model using a real cancer data set. The simulation serves as a basis of explaining the dynamics of machine learning to potential end users.

2 Cancer Diagnostics

Cancer is one of the diseases which has a huge impact on patients and their families, so understanding how artificial intelligence can be leveraged to aid diagnosis is important in order to help find ways to alleviate the prevalence of this disease. This paper outlines how machine learning driven artificial intelligence (AI) can be used to aid diagnosis of cancer by building a model that assesses visual input features of cell nuclei. It also serves as a useful example to non-specialists interested in AI to help them understand the dynamics of machine learning algorithms and to understand how to assess their performance.

Breast cancer is one of the most commonly occurring cancers, with over 2 million new cases diagnosed globally every year [3]. While around 5% to 10% of cases are due to inherited genes, such as variants of BRCA [4], there is a higher risk of developing this form of cancer linked to lifestyle factors such as alcohol consumption and obesity [5]. For example, overweight women have an increased invasive breast cancer risk versus women of normal weight [5]. However, the major risks associated with this disease are age, due to likelihood of mutations caused by cell division, and gender, as breast cancer mainly affects women. Breast cancer frequently occurs in the cells lining the milk ducts, where it is referred to as ductal carcinomas, and the tissue that produces the milk supplied to these ductal carcinomas, where it is referred to as lobular carcinomas [7]. Diagnosing such carcinomas involves taking a biopsy of cells from the site in question, which may be deep within the breast tissue. Early diagnosis is key to the effective treatment of such cancers, as studies have shown increases in cancer survival due to advances in early detection and treatment [8], so performing an effective assessment is critical. X-rays of the breast known as mammograms are frequently used as a screening method to identify potential cancerous growths, along with physical contact examination to determine if there is a need for further investigation. Suspect tissue is often biopsied using a fine needle aspiration, whereby a narrow hollow needle is inserted into the tissue to collect a sample of cells [9]. An example image of an invasive ductal carcinoma biopsy is given in Figure 1.

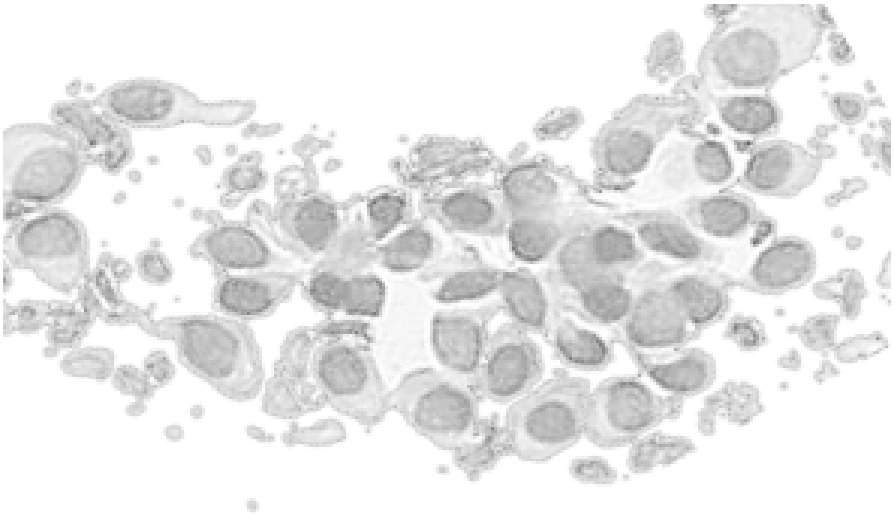

Fig. 1. Image capture of cell features of invasive ductal carcinoma.

These cells are then prepared for examination by a pathologist who examines the characteristics of individual cells, as many different cell features are thought be highly correlated with malignancy [10]. Malignant cells tend to be irregular compared to normal cells, so larger values for features related to shape, such as symmetry, fractal and concavity tend to indicate that the cells are cancerous. It is possible to use machine vision to detect such cell features from biopsies via a digital microscope. This is the basis of the widely studies Wisconsin breast cancer dataset, where 569 biopsies were collected and the following ten geometric features calculated for cells in each of the samples [11]:

1. The radius of the nucleus.
2. The perimeter of the cell nucleus.
3. The area of the cell nucleus.
4. The perimeter and area are combined to give a measure of the compactness of the cell nuclei using the formula:

$$\frac{perimiter^2}{area}$$

Cell nuclei that have an irregular shape will have a higher measure of compactness.

5. The smoothness as measured by the difference between the radii across the cell nucleus.
6. The number and severity of concave features around the cell nucleus.
7. The number of concave points around the cell nucleus.
8. A measure of symmetry, sampled at points around the cell nucleus.
9. A measure of the fractal dimension along the cell.
10. The texture of the cell nucleus by measuring the grayscale intensity variation across pixels within the cell nucleus.

The mean, max and standard error of each feature are computed for each image to give a total of 30 input features per sample, which are suitable for machine learning.

3 Machine Learning Approach

Machine learning is a computational approach to AI that uses algorithms that iterate over datasets to build statistical models [12]. Machine learning techniques can be broadly classified as supervised, which use labelled input data to train a model, or unsupervised algorithms that cluster data into related groups. The power of supervised machine learning is the ability to generalise to correctly classify unseen data, based on models built using training data. We use a Support Vector Machine (SVM) to build a machine learning model for the Wisconsin breast cancer dataset, using a portion of the data (80%) for training and the rest for testing the model (20%).

The SVM is a supervised learning algorithm that has been shown to have good performance as a classifier [13]. The SVM Algorithm trains by iterating over a set of labeled samples, which in this case are entries from the Wisconsin breast cancer dataset, which are labelled as either benign or malignant. A good way to explain the operation of machine learning is to use a two-dimensional input feature space as this allows us to more easily visualize the decision boundary that the algorithm produces. Figure 3

shows a number of examples from Wisconsin breast cancer dataset plotting the radius feature on the x-axis against the texture feature on the y-axis. An SVM algorithm finds an optimal decision boundary by finding data points, known as support vectors that maximise the separation between classes.

One approach to gauging the performance of the classifier is to compute the F1 score, which is a useful measure of the level of precision and recall in a machine learning system [14]. Precision is the portion of instances among the classified instances that are relevant, while recall or sensitivity is the fraction of correctly classified relevant instances that have been retrieved over the total amount of relevant instances. An algorithm with high precision over a data set will return more relevant results than irrelevant ones. For cancer diagnosis, this is critical as both false positives and false negative errors should be avoided. In particular, a false negative result should be avoided as the impact could result in missed life-saving treatment. Precision can be thought of as the ratio of correctly classified true positives t_p, over the sum of true positives t_p and falsely classified positive f_p:

$$Precision = \frac{t_p}{t_p + f_p}$$

An algorithm with high recall will classify most of the relevant data correctly and can be thought of as the ratio of correctly classified true positives t_p, over the sum of true positives t_p and false negatives f_n (the number of instances falsely classified as negative instances):

$$Recall = \frac{t_p}{t_p + f_n}$$

There is a trade-off between precision and recall as it is possible to have an algorithm with high precision but low recall and vice versa. For example, the algorithm may be precise by correctly classifying a subset of malignant breast cancer cases, however it could achieve this by being stringent in its classification and could exclude many other malignant cases, which would give it a low recall.

The balance between precision and recall can be captured using an F1 score which is the harmonic mean of the precision and recall scores, where a score of 1 indicates perfect precision and recall [15].

$$F_1 = \frac{2}{\frac{1}{recall} + \frac{1}{precision}}$$

The machine learning model should be trained in such a way that the algorithm does not overfit, which occurs when the algorithm fits a decision boundary tightly to all of the data, including any noise in the training data, so that it generalises poorly to any unseen input. To avoid over-estimation of model performance, a test data set is held back and is used as the final unbiased measure of the algorithm's performance on the training data. A model that produces a high score on the training set but a low score on the test set will overfit, while a model that produces a high score on the training set and a high score on the test set should provide good classifications. A model that underfits, by failing to find any useful decision boundary will perform poorly on both data sets.

The simulation in Figure 3 shows the F1 scores for the algorithm on the training set and the test set, thereby allowing users to gauge the performance of the algorithm. This

also challenges the user to investigate how tuning the hyper-parameters for a machine learning algorithm affects its performance and so will enhance their understanding of the dynamics of the problem.

In the example demonstrated to the non-specialist audience a two-dimensional feature space was presented. The simulator developed by Karpathy was enhanced to allow users to select which feature they would like to evaluate. Figure 3 shows use of a linear kernel when trying to find the ideal separation, and the F1 score for both the training set and test set is shown. The choice of using a kernel is an important machine learning hyperparameter; practitioners needs to consider if the data set is linearly separable or not. This simulation is presented as a game to the users, where the goal is to reach a perfect F1 score of 1 on the test data set.

The use of a nonlinear kernel is shown in Figure 3. Choosing a non-linear kernel for a linear data set will tend to cause the model to over fit the data, which will reduce its ability to generalize as indicated by a poor performance on the test data set F1 score. SVMs use a technique known as the kernel trick which maps data points to a higher dimensional space where a linear separation may be found [16].

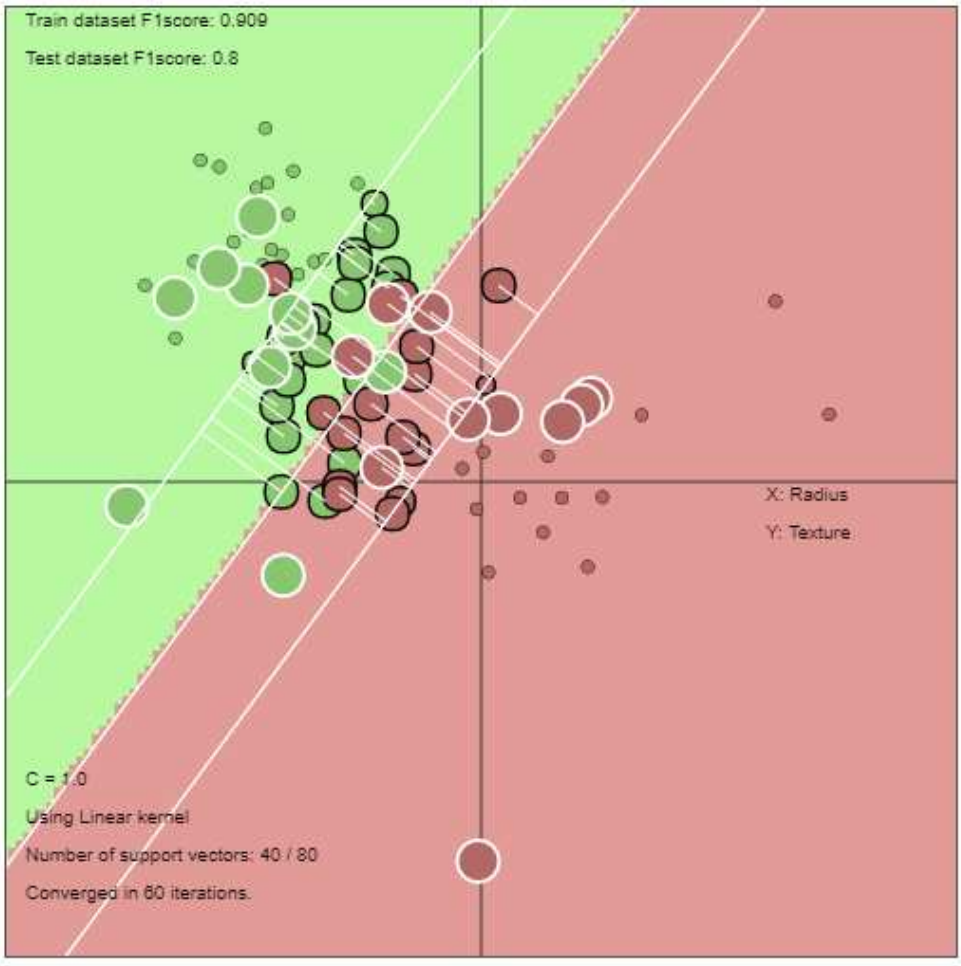

Fig. 2. An illustration of the performance of a SVM on the Radius and Texture features of the WBCD using a linear mode, based on a fork of an online SVM simulator [2].

A support vector machine can be tuned via a cost function, denoted C, which penalises the algorithm for points that fall within the margin. A small value of C, imposes a low penalty for misclassification, thereby allowing a "soft margin", which promotes better generalisation at the risk of lower precision. A large value of C imposes a high cost of misclassification, thereby producing a “hard margin", which promotes higher precision but poorer generalisation and recall. The JavaScript framework [2] allows users to modify the cost function C and are challenged to find a balance that maximises the F1 score.

For non-linear kernel the Karpathy SVM JavaScript framework uses a Gaussian radial basis function, which allows the SVM algorithm to fit the maximum margin separating hyperplane in a transformed input feature space. The radial basis function is controlled by the parameter sigma (σ), which determines the influence that feature vectors have on the kernel mapping. Intuitively, low values of sigma narrow the region of influence of the kernel for vectors in the feature space, which can cause the SVM to overfit the data. High values of sigma widen the region of influence, making the algorithm better at generalizing at the expense of losing precision. Users can experiment with features, kernels and hyper-parameters as shown in the adaption of Karpathy’s software, see Figure 3 (b). Communicating the effect of σ and other parameters, to non-technical audiences in a visual manner supports the objective of this study; to investigate how an interactive tool enhances their understanding and user of machine learning tools.

Fig. 3. Gaussian radial basis function non-linear kernel with (a) sigma = 0.16, C=1.0, causing overfitting and (b) with sigma = 0.5, C=13 improving generalization[1].

[1] Available at http://www.nac.unina.it/svm2/sage_care_svm_two_screen.html

4 Understanding AI

In the last decade, we have witnessed a growing interest on AI applications. Numbers of commercials on a variety of everyday objects (e.g. mobile phones, vacuum cleaners, thermostats etc.), present AI as an important added value. Indeed, it is. With AI powered cameras we can get better photographs, with an autonomous vacuum cleaner we can gain more spare time and with a smart thermostat we can save a lot of money on heating bills.

However, despite this growing interest, very often AI is perceived, by the general public, like a sort of magic, or, to put it in the words used by Arthur C. Clarke, an advanced technology indistinguishable from magic. But such perception has a problem in that it presents a technology's inner mechanisms as being incomprehensible.
Rather, AI is a powerful tool that can be harnessed for personal or professional purposes, even by lay people thanks to off-the-shelf software packages in which users are requested only to add their data. Adding data alone, however, could simplify the process too much, preventing users from grasping the inner mechanics of what they are using, leading to potential mistakes or misuse.

AI, undoubtedly, represents an effective tool to solve or to simplify many relevant problems in our daily lives. For this reason, we should disclose as much as possible about how certain algorithms work. Such an operation can be beneficial to improve a basic understanding of a particular algorithm, whether a user is just willing to better grasp a topic or where a user is interested in using that kind of technology with and increased awareness for his own purposes. This can provide the following benefits of explaining the technology to potential users as they can:

1) make better use of the tools,
2) better understand the problems it can and cannot solve and
3) make a more informed assessment and evaluation of the produced solution

5 Exploratory focus group

In order to understand which kind of information should be conveyed about an intelligent technology in general and in particular to a classifier system such as that presented in this paper, we organized a focus group, held in Rome in December 2018, with a small number of participants. Focus groups have a long tradition in behavioral sciences where have been used to understand how an issue or a product is perceived by a group of people [17].

Seven participants, 1 woman and 6 men, with an average age of 37.57 (SD= 6.23) with a background in AI research were identified within an Italian research center. For the aim of this exploratory work, participants were chosen for their unfamiliarity with support vector machines although well-versed in other AI techniques such as neural networks, genetic algorithms etc. The focus group was organized with the following structure:

1) Short introduction on the topic of the focus group
2) Brief presentation of the participants

3) Discussion of the topic:
   - Question 1: How do you think people perceive AI?
   - Question 2: Do you think it is necessary to explain how AI works?
   - Question 3: Which features of a classifier system should be stressed for educational purposes?
4) Presentation of SVMs through the software we developed
5) Request of feedback on the software as an educational tool

6 Qualitative results

The focus group lasted three hours and stimulated a very interesting discussion on the general importance of AI in our lives and the features that should be shared in order to increase people's awareness on specific algorithms.

The first question raised a dualistic view on AI. To the participants, people seem to see AI either as the ultimate evil or magic. Both polarized views, however, lack a realistic perspective and all the participants agreed with the fact that AI at the moment is an inflated word due to marketing purposes.

The second question divided the participants. Three of them underlined that in order to understand many AI algorithms a strong background in maths is needed, hence it is impossible to provide such kinds of concepts to a general public, who likely lack specific hard skills. The rest of the group in different ways highlighted the need to explain how algorithms work. In particular, two proposals emerged on how best to explain how AI works to members of the general public: a) using a very simple language without referring to mathematical jargon; and b) demonstrating algorithm with micro-educational software in which users can manipulate data and parameters.

The final question firstly collected a series of answers related to the fact that the outcome of classifiers system, regardless of the algorithm that is being used, is strictly connected to the data we put in. Secondly, although sometimes very complicated math is required to understand the specific aspects of an algorithm, an extremely simple formula can often be used to evaluate the outcome of a classifier (see for example precision and recall).

After the discussion raised by the first three questions, we presented our software (by explaining the objectives and the algorithm behind it) to the participants and asked them if it was, in their opinion, viable for educational purposes.

Participants appreciated two aspects of the software: 1) that is web-based and it is able to seamlessly run on mobile phones without issues, and 2) the two windows easily allow for seeing what happens to the outcome when different parameters are applied to the underlying algorithm. Less appreciated was the graphical aspect. Participants suggested to improve the graphics in order to make the training and the testing sets more visible.

An overall positive consideration emerged about the possible use of the software as an educational tool. Although not experts in SVMs, they understood how this type of classifier works in a relatively simplified way (here we remember that the participants shared an AI background)

7 Future research

AI and its applied arm, machine learning, are becoming an important part of our daily life. Our mobile phone recognizes our vocal commands and the AI powered cameras can take pictures with a professional quality. Applications, however, are not limited to our spare time. AI can also be added to the toolkit of our professions: a biologist or a psychologist, for example, could exploit a machine learning solution for their own purposes. In particular, a biologist could use a classifier such as the one described in this paper to classify his/her own data points or re-run the algorithm with new collected data. In order to do that it is not required to be a data scientist but just to be able to use an off-the-shelf solution with a proper awareness.

Qualitative data collected in an exploratory focus group seems to suggest that our approach goes in this direction, however, in order to evaluate its effectiveness we need quantitative data. Gathering this quantitative data will be the objective of the next step of this research.

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Support Vector Machine Learning for ECG Classification

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Abstract. Connected health has huge potential to enhance the diagnosis, monitoring and treatment of a range of conditions. With advances in wearable technology it is now becoming more feasible to monitor and control a range of conditions. This includes heart conditions, which can now be monitored via wearable devices such as the Apple Watch, which is a propriety device that uses machine learning to predict likelihood of arrhythmia and other heart conditions. This paper investigates a Support Vector Machine Learning approach for ECG monitoring and outlines advantages of such an approach. This paper shows that support vector machines can provide useful classification on ECG signals using the Kaggle ECG Heartbeat Categorization Dataset and is potentially a viable machine learning approach to ECG classification.

Keywords: Machine Learning, ECG, Arrhythmia, Connected Health.

1 Introduction

Connected health is a model for the management and delivery of healthcare that uses technology to provide remote services [1]. It aims to optimize the use of re-sources, provide additional opportunities for patients to engage with clinicians and to allow them to participate more in their own care [2]. It leverages relatively low-cost consumer technologies to deliver patient care outside of the clinical setting to provide support in remote care, chronic care, disease and lifestyle management. It is often deployed over existing technical infrastructure such as 4G mobile networks and plans are already evolving to provide connected health services over 5G networks [3].

Consumer devices such as wearables are accelerating the acceptance of connected health solutions [4]. For example, insurance companies are prompting the use of wearable health and fitness trackers and regulatory bodies such as the U.S. Food and Drug Administration are streamlining the approval process for digital health products from smartwatch companies Fitbit, Apple and Samsung [4].

In terms of recent advances in connected health, Apple has hit the headlines in Q4 2018 by launching a new Apple Watch with built in ECG functionality [5]. This is a big step in wearable eHealth devices as it uses a machine learning algorithm to classify data gathered from the watch's sensors. This algorithm can be used to detect Atrial

fibrillation (A-fib), which is an irregular heartbeat that is linked with an increased risk of heart failure, dementia, and stroke. A-fib is often symptomless and contributes to approximately 130,000 deaths annually in the United States.

An electrocardiography (ECG) is a record of the electrical activity of the heart usually gathered using electrodes placed on the skin [6]. To capture ECG signals the user must create a closed circuit across their chest. Apple get users to do this by simply placing their finger on the front of the watch, so that an electrode touching the wearers wrist on the back of the watch can read the signal. Where the real innovation comes in is the use of machine learning to classify these signals.

Apple developed this machine learning AI using deep learning technology known as convolutional neural networks (CNNs), which are inspired by models of how the brain works. CNNs are the basis of many AI applications especially in the field of computer vision. Such neural network technology is now widely available to developers on AI platforms from Microsoft Google, Facebook and many more. However, a major disadvantage of ANNs is convergence to local minima rather than finding a global minimum. Support Vector Machines were chosen for this study as they provide a way to circumvent such issues, as SVMs tend towards an optimal margin separation, as the search space constraints define a convex set. Furthermore, ANNs are prone to overfitting, whereas SVMs provide intrinsic margin control meta-parameters, which can be configured to reduce overfitting.

SVMs deliver a unique solution, since the optimality problem is convex. This is an advantage compared to Neural Networks, which have multiple solutions associated with local minima and for this reason may not be robust over different samples.

Moreover, a highly cited paper from Manuel Fernandez-Delgado et al evaluated 179 classifiers from 17 machine learning classes on 121 data sets from the UCI data base [7]. They found that the classifiers most likely to perform the best are the random forest (RF) and SVM with a non-linear kernel. In this paper, we will explore the performance of SVM's on the ECG data from "ECG Heartbeat Categorization Dataset" hosted on Kaggle [8].

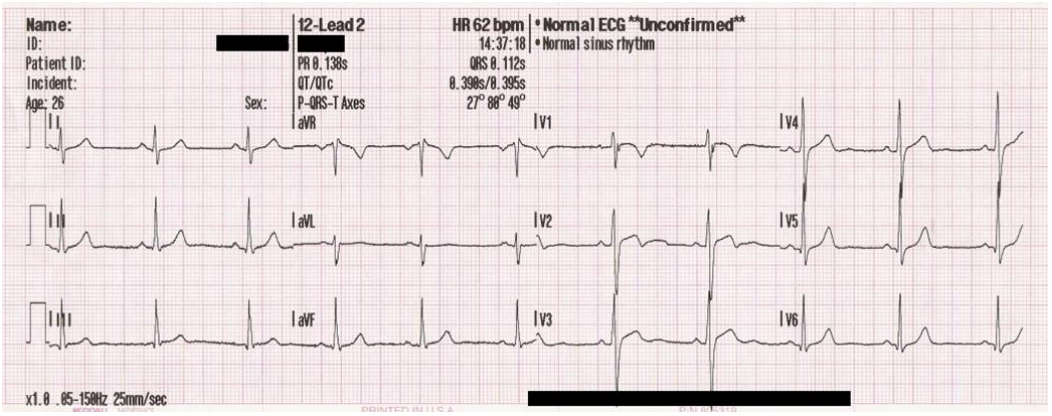

Fig. 1. Example of an ECG electrocardiogram, source: https://bit.ly/2GvS4Ej.

2 Methods

The data used in this study is from the MIT-BIH Arrhythmia Dataset [8] and the signals used in this data set contain a mix of normal heartbeats and heartbeats affected by different forms of arrhythmia. Signals are normally collected and charted in an electro cardiogram, see Figure 1, but in this data set the signals are separated into individual heartbeats.

2.1 ECG Data Sets

The data used in this study is available at https://bit.ly/2XadCLV. This data was used in exploring heartbeat classification using deep neural network architectures [9]. The signals correspond to electrocardiogram (ECG) shapes of heartbeats for the normal case and the cases affected by different arrhythmias and myocardial infarction. These signals are preprocessed and segmented, with each segment corresponding to a heartbeat. The type of heart beat for each sample is stored in the last column of each row, where the beat type is represented by the following integers.

- Normal (N) = 0
- Supraventricular (S) = 1
- Ventricular (V) = 2
- Fusion (F) = 3
- Unclassified (Q) = 4

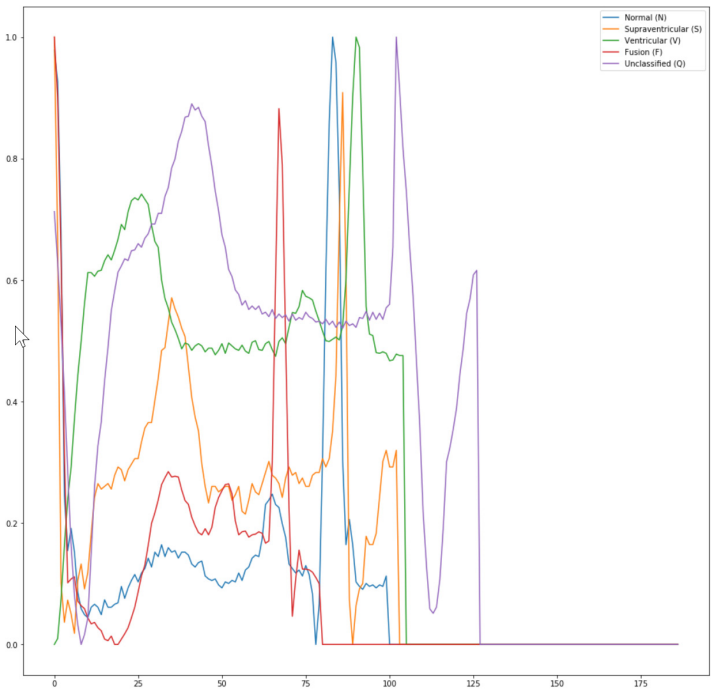

Fig. 2. Samples of the ECG data set.

Abnormal heart beats include supraventricular tachycardia, which is an abnormally fast heart rhythm arising from improper electrical activity in the upper part of the heart. A sample of the various heartbeat types from the data set is shown in Figure 2.

A stacked bar chart is presented in Figure 3, showing that the data set is massively imbalanced towards normal heartbeats. Dataset imbalance is a significant issue in machine learning as over represented exemplars can skew the machine learning model towards classifying input data into these overrepresented classes. This issue is explored in the results section of this research and rectifying approaches are proposed as future work. Figure 3 also shows the split between training data and test data. The test data was held back until the final evaluation phase of the machine learning model built using the training data.

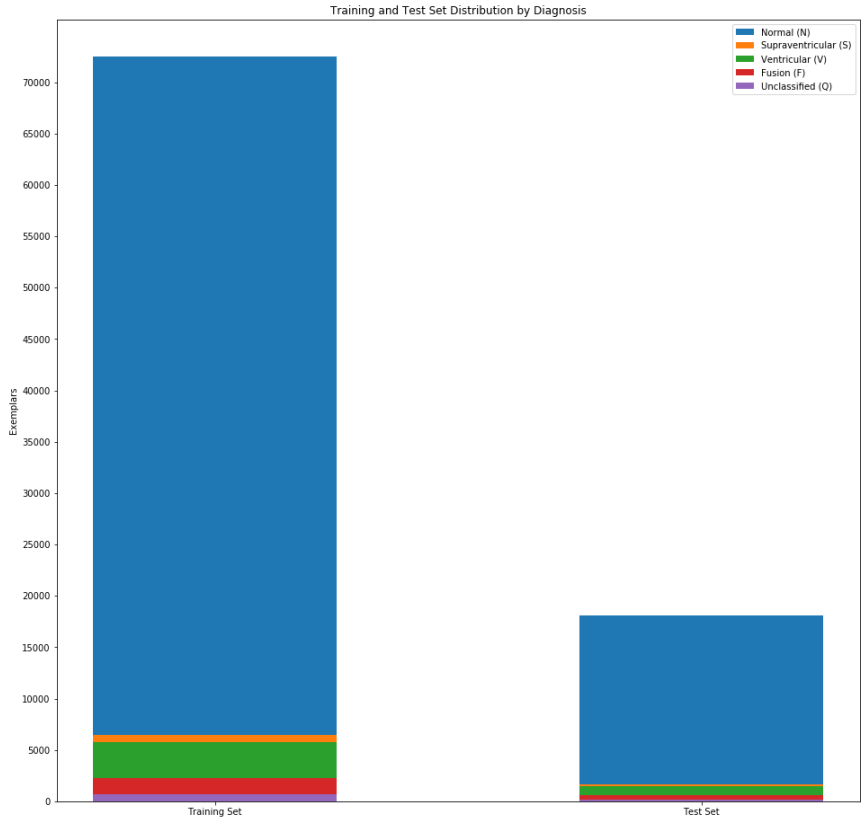

Fig. 3. Stacked bar charts shown data set composition and the split between training data and test data.

2.2 Support Vector Machine

The power of machine learning is in its ability to generalize by correctly classifying unseen data based on models build using training data. Here we use a Support vector machines to build a machine learning model for the ECG dataset, using a portion of the data (80%) for training and the rest for testing the model (20%), reproducing the data split used in the CNN study by Kachuee et al [9].

A Support Vector Machine (SVM) is a supervised learning algorithm that has been shown to have good performance as a classifier [10]. The SVM Algorithm iterates over a set of labeled training samples to find a hyperplane that produces an optimal decision boundary by finding data points, known as support vectors that maximizes the separation between classes.

In order to gauge the performance of the classifier an F1 score is computed, which is a useful measure of the level of precision and recall in a machine learning system

[11]. This can easily be extended to multiclass problems by calculating averages of scores for the classes in question [12]. Precision is the portion of instances among the classified instances that are relevant, while recall or sensitivity is the fraction of correctly classified relevant instances that have been retrieved over the total amount of relevant instances. An algorithm with high precision over a data set will return more relevant results than irrelevant ones. For cardiac diagnosis this is critical as false positive and in particular false negative errors should be avoided. Precision is the ratio of correctly classified true positives t_p, over the sum of true positives t_p and falsely classified positives f_p:

$$Precision = \frac{t_p}{t_p + f_p}$$

An algorithm with high recall will classify most of the relevant data correctly and can be thought of as the ratio of correctly classified true positives t_p, over the sum of true positives t_p and false negatives f_n (the number of instances falsely classified as negative instances):

$$Recall = \frac{t_p}{t_p + f_n}$$

There is usually a trade-off between precision and recall as it is possible to have an algorithm with high precision but low recall and vice versa. For example, the algorithm may be precise by correctly classifying a subset of arrythmia cases, however if it could achieve this by being stringent in its classification and could exclude many other cases, which would give it a low recall.

The balance between precision and recall can be captured using an F1 score which is the harmonic mean of the precision and recall scores, where a score of 1 indicates perfect precision and recall [13].

$$F_1 = \frac{2}{\frac{1}{recall} + \frac{1}{precision}}$$

The ECG dataset is partitioned into training and test sets as shown in Figure 3. The SVM machine learning model is trained using the data set and this should be done in such a way that the model does not overfit the data, which occurs when the algorithm fits a decision boundary tightly to the data, including any errors in the data, so that it performs poorly on any unseen input. To avoid overfitting a test data set is held back and is used as the final unbiased measure of the algorithm's performance. A model that produces a high score on the training set but a low score on the test set will have overfit the data, while a model that produces a high score on the training set and a high score on the test set should provide good classifications. A model that underfits, by failing to find any useful decision boundary will perform poorly on both data sets.

SVMs also use a technique known as the kernel trick, which maps data points to a higher dimensional space where a linear separation may be found [14]. The choice of using a kernel is an important machine learning hyperparameter and practitioners needs to consider if the data set is linearly separable or not. Choosing a non-linear kernel for a linear data set will tend to cause the model to over fit the data, which will reduce its

ability to generalize as indicated by a poor performance on the test data set F1 score. In this study we establish the best algorithm hyper-parameters by performing a grid search. The hyper-parameters for the support vector machine implemented in this study include a cost function denoted C, which penalizes the algorithm for points that fall within the separating margin. A small value of C, imposes a low penalty for misclassification, thereby allowing a "soft margin", which promotes better generalization at the risk of lower precision. A large value of C imposes a high cost of misclassification, thereby producing a “hard margin", which promotes higher precision but poorer generalization and recall. The challenge here is to find a balance that maximizes the F1 score.

The SVMs can use a linear kernel or non-linear kernels such as Gaussian radial basis function, which allows the SVM algorithm to fit the maximum margin separating hyperplane in a transformed input feature space. The gamma hyper-parameter controls how far the impact a single training has on the model, with low values having a ‘far’ influence and high values having a ‘close’ influence. High values of gamma narrow the region of influence of the kernel for vectors in the feature space, which can cause the SVM to overfit the data. Low values of gamma widen the region of influence, making the algorithm better at generalizing at the expense of losing precision. To find optimal setting for C and gamma a grid search was performed, see Figure 4.

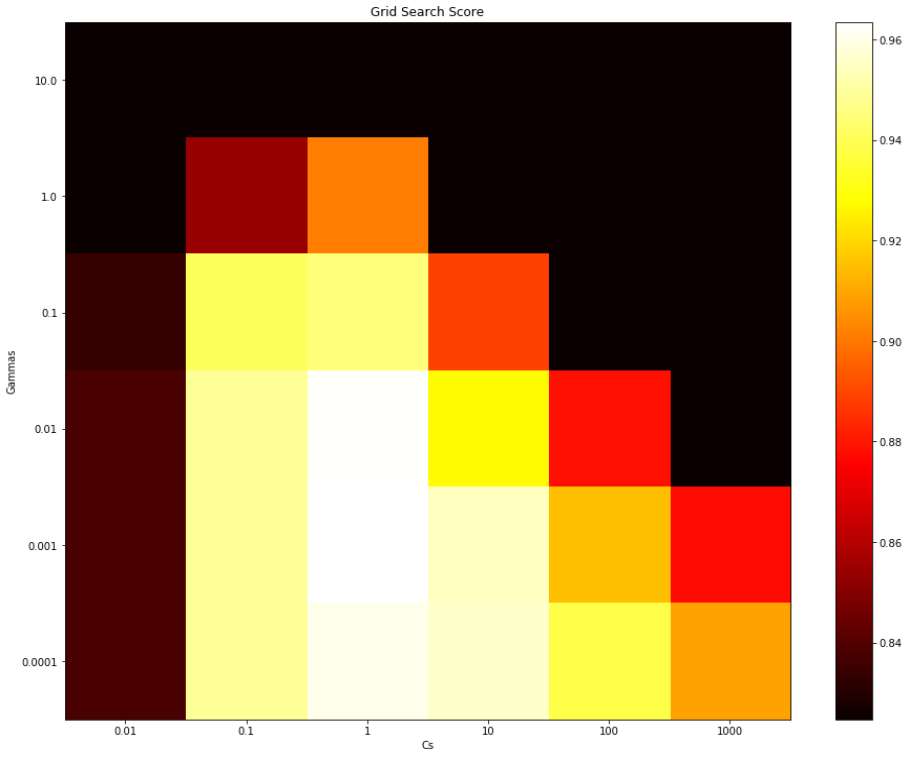

Fig. 4. Grid search scores for the hyper-parameters C and gamma, plotted as a heatmap. Optimal results are in the region C=1, gamma=[0.001:0.01].

3 Results

The `GridSearchCV` method of the `scikit-learn` python machine learning package was used to perform an exhaustive search over the C and gamma support vector machine parameters and both linear and non-linear radial basis function kernels (rbf) were evaluated:

```
tuned_parameters = [{'kernel': ['rbf'], 'gamma': [1, 1e-
1, 1e-2, 1e-3, 1e-4, 1e-5], 'C': [0.1, 1, 10, 100,
1000]}, {'kernel': ['linear'], 'gamma': [1, 1e-1, 1e-2,
1e-3, 1e-4, 1e-5],'C': [0.1, 1, 10, 100, 1000]}]
```

The scores are plotted as a heatmap, showing that optimal results are in the region C=1, gamma=[0.001:0.01], see Figure 4.Using these grid search results it is possible to find good support vector machine configuration settings to produce the results shown in Figure 5.

	precision	recall	f1-score
0	0.97	1.00	0.98
1	0.96	0.58	0.72
2	0.97	0.88	0.92
3	0.77	0.43	0.55
4	1.00	0.89	0.94
micro avg	0.97	0.97	0.97
macro avg	0.93	0.76	0.82
weighted avg	0.97	0.97	0.97

Fig. 5. Precision Recall and average F1 scores on a SVM model built using the full data set, and tested on the unseen test data.

The F1 score is 0.97 for the micro average, which computes global metrics by counting the total true positives, false negatives and false positives. However, this can be misleading for imbalanced data sets, which is the case here. A more pragmatic measure is the macro average, which computes metrics for each label, and finds their unweighted mean, which in this case is 0.82. This metric does not take label imbalance into account and indicates that the model would not perform accurately in its current configuration and it is likely to make classification errors for under-represented instances. Nevertheless, the results are encouraging with a *weighted* average of 0.97. This is calculated by finding the average score weighted by support, which is the number of true instances for each label [12]. This is meaningful as it accounts for label imbalance, as shown in Figure 3.

A confusion matrix for the system evaluated on the full test set is shown in Figure 6, where each row of the matrix represents the instances in the predicted classes, while each column represents the instances in actual classes. While the results are not sufficient accurate classification across all classes, the results are encouraging. These results

are effected by the massive bias towards normal heartbeats in the current data set. Kachuee *et al* [9] have dealt with this issue using data augmentation; by deriving new samples from the existing classes and altering the heartbeat signals amplitude and wavelength and their approach has improved their CNN classification accuracy. Such techniques also work for support vector machines [15] and will be applied to this work in future research.

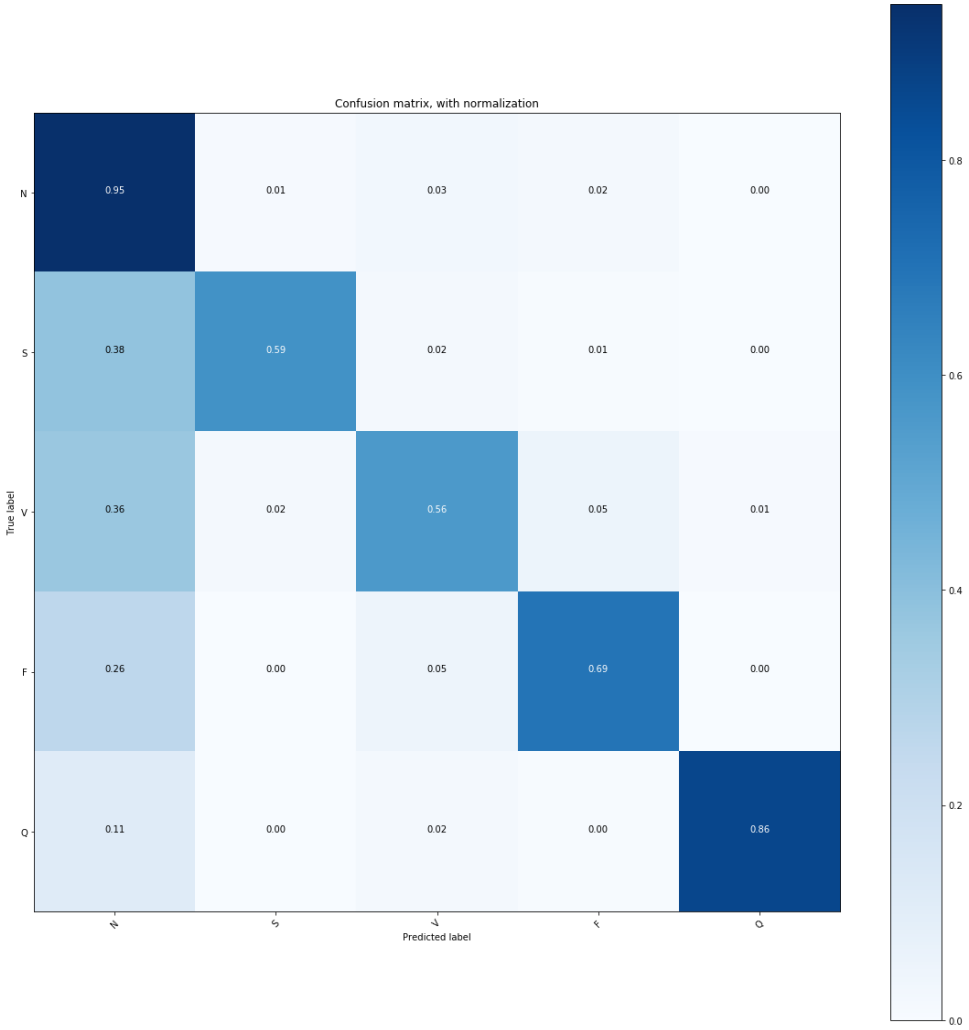

Fig. 6. Confusion matrix of SVM on full ECG data set.

4 Summary

A support vector machine was built to perform analysis on electrocardiogram signals and a grid search was performed to find SVM hyperparameters that balance precision and recall. The resulting SVM produced a weighted average F1 score of 0.97, although the macro-average F1 score was 0.82, due to imbalance in the data set. This compares well with the deep learning approaches such as those used by Kachuee et al [9], where data augmentation resulted in a F1 score of 0.95. These results indicate that support vector machines can provide useful classification on ECG signals with the added benefit of providing a basis for converging to a global minimum and can be configured to

avoid over fitting. This SVM approach aligns with results reported by Manuel Fernandez-Delgado et al [7], who evaluated 179 classifiers on 121 data sets from the UCI database. They found that one of the classifiers most likely to perform the best is the SVM with a non-linear kernel and the results presented here provide a basis for similar findings.

Future work will expand on these findings by evaluating data augmentation techniques informed by a time series analysis of the various heartbeat types. A comparison with other machine learning techniques will also be performed including evaluation of random forest, convolutional neural networks and other approaches.

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Machine Learning for Melanoma Management in a Clinical Setting

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Abstract. This paper describes work in progress on a melanoma management platform known as Simplicity MDT, which is in use in major hospitals for the collection, management and analysis of clinical data. It includes a facility for uploading and managing high resolution digital colour photographs of melanoma lesions. As the data managed by this platform is structured and annotated, it is proposed that this could serve as a basis for supervised training datasets for machine learning. Machine learning models trained using this data can serve the wider community for screening, diagnostic and prognostic purposes. The proposed machine learning architecture includes integration with a model zoo, which provides networks that are pre-trained on publicly available datasets. An overview of the current system is presented and a roadmap for future developments is outlined.

Keywords: Machine Learning, Melanoma, Connected Health.

1 Introduction

The motivation for the development of a machine learning driven melanoma management platform stems from engagement with clinical end users, doctors, oncologists and other clinical specialists who are searching for innovative solutions to impact the treatment of melanoma. Melanoma is a malignant tumour of melanocytes with about 160,000 new cases diagnosed annually, with high prevalence among Europeans. This is a serious health issue and the aim of this research is to impact the diagnosis of this disease by the proposed integration of machine vision-based classification, through deep learning technology, with the myriad of information sources in electronic health records captured through multi-disciplinary team discussions.

Multidisciplinary care is currently accepted as best practice in the delivery of high-quality cancer management in Ireland and internationally. Multidisciplinary Team Meetings (MDTMs) take place at regular intervals, where a team comprised of medical experts across different relevant disciplines come together to discuss patient cases, review treatment, and plan treatments [1]. Care delivered to patients through a multidisciplinary approach results in positive outcomes especially in terms of diagnosis and treatment planning, patient satisfaction and improved survival rates. Participating in

MDTM's also has positive outcomes for clinicians – centred around the opportunity for education, improved communication and working relationships. While MDTMs enhance healthcare, they are mostly reliant on antiquated paper-based systems and integrated software management tools that are sorely lacking. Moreover, there is a lost opportunity for allowing patients to participate in the care pathway. The melanoma management platform Simplicity MDT provides significant opportunity for gathering clinically labelled digital images of melanoma lesions (see screenshot of system in Figure 1). The system has already managed over 8,000 cancer cases, including over 1,000 melanoma cases with digital imaging. This rich data set provides a basis for machine-based assessment by allowing health professionals to gather valuable supervised training data that can be used to augment existing deep learning models to enhance clinical assessment.

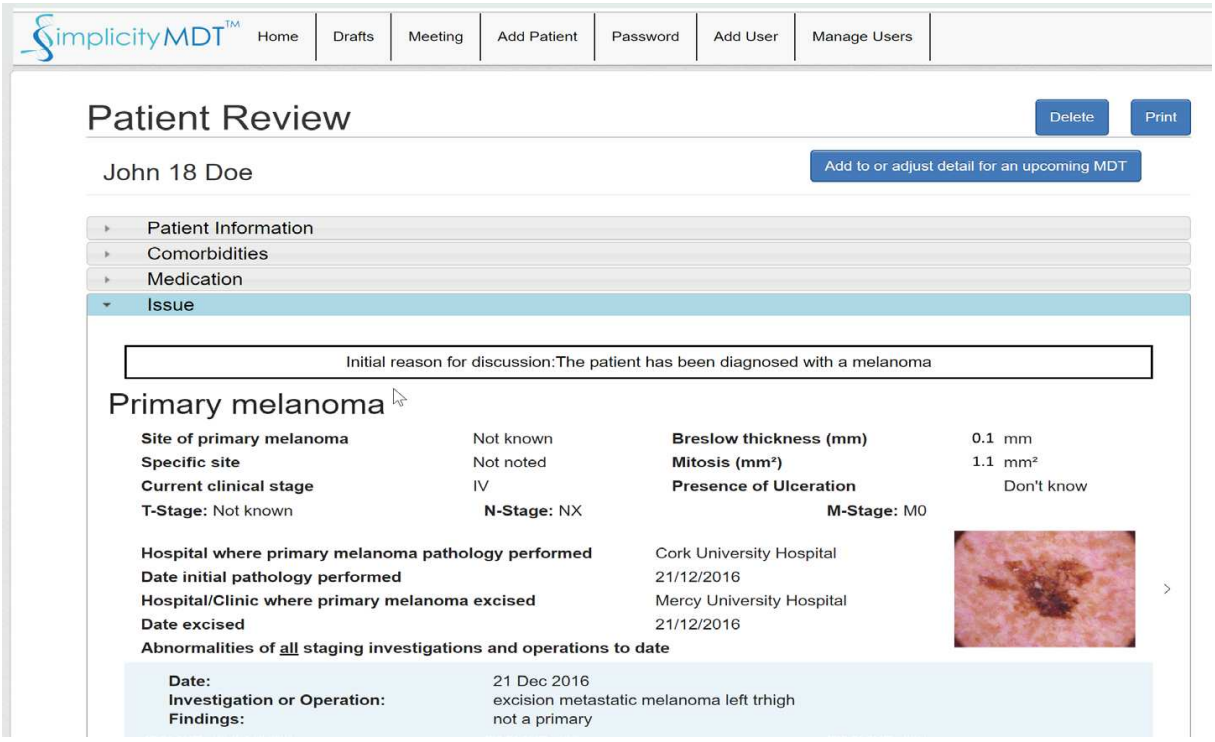

Fig. 1. Screenshot of Simplicity MDT with clinically labeled images.

2 Machine Learning for Melanoma Applications

The term machine learning is used to refer to the field of computer science concerned with developing algorithms that can mine datasets to build statistical models [2]. Machine learning systems rely on training data that can either be labelled or unlabelled [3]. Labelled data allows researchers to apply "supervised" learning algorithms, which can progressively train models to find associations between input patterns and their expected labels [4]. Labelling data can be extremely expensive and time consuming, so any framework that facilitates the collection and labelling of data can serve as a useful basis for building supervised machine learning models [5]. Unsupervised machine learning models on the other hand do not require labelled data, but in turn can't be used

to generalize label mappings for new data, instead finding use in more niche applications, such as anomaly detection.

Deep neural networks are a class of ML model that come in a variety of architectures, but all are characterized as having a large number of layers, which are used to detect low-level features and map these two increasingly complex models in the higher layers of the network architecture [6]. Deep neural networks have had significant impact on the classification of skin cancer as outlined in the Nature publication from Estava *et al*. [7], where they note that automated classification of skin lesions using images is a challenging task owing to the fine-grained variability in the appearance of skin lesions. A class of deep learning networks, known as convolutional neural networks (CNNs), have demonstrated impact in challenging visual classification tasks in a variety of domains [8] [9] [10] [11] [12] [13]. Estava *et al*. developed a CNN for the classification of skin lesions using digital images, using only raw pixels and disease labels as inputs and tested its performance against 21 qualified dermatologists on clinically assessed images with the following binary classification use cases:

- Keratinocyte carcinomas (the most common skin cancer) versus benign seborrheic keratoses.
- Malignant melanomas (the most fatal skin cancer) versus benign nevi.

Their system performed as well as the experts across both tasks, indicating that machine learning can achieve a level of accuracy comparable to a dermatologist for skin cancer classification. Estava *et al*. proposed that deep neural networks deployed to devices such as smart phones, could bring important dermatology assessment to a wider audience and can possibly deliver universal access to diagnostic care.

We plan to take up this challenge, by designing an integrated cloud based mobile solution that can enhance automated skin cancer classification by leveraging mobile edge computing (MEC), which provides cloud computing capabilities at the edge of the network [14] and optimises performance by bringing computing resources to the data. Furthermore, recent advances in edge computing will have profound impacts on healthcare systems [15] [16].

Connected healthcare has already been enhanced with the proliferation of technologies [17] and mobile hardware is having a positive impact on healthcare, e.g. the monitoring of hypertensive patients with connected blood pressure monitors. Similarly, there have been a number of smart-phone apps developed for the detection of melanoma [18] and while they provide an array of features including information, education, classification, risk assessment and change monitoring, they can only provide limited processing power due to the current processing limitations of mobile devices.

Smart mobile networks offer increased processing through mobile edge computing, which offers low latency, high bandwidth and localized cloud computing capabilities [19]. A major benefit of 5G technology is the provision of *ad hoc* local cloud instances via a mobile network [20], which allows participating institutions to "*securely share patient genomic, imaging and clinical data for potentially lifesaving discoveries. It will enable large amounts of data from sites all around the world to be analyzed in a distributed way, while preserving the privacy and security of patient data at each site*" [21].

3 Future Work

We aim to develop Simplicity MDT as a system for gathering high quality clinically labelled digital images and integrate this system with the advances in both mobile edge computing and deep learning to provide universal platform for assessing suspect skin cancer lesions. The system will have the following features:

- Use of state-of-the-art pre-trained melanoma machine learning models, based on evaluations of results using ImageNet, VGG19, ResNet-50 [22], Inception [11] and newer architectures, including PolyNet [23], ResNeXt [24], Densenet [25], SENets [26] and DualPathNet [27] [22].
- Machine learning implemented via mobile edge technology in a secure and federated environment [28]. The use of mobile edge local cloud computing will allow clinicians in distributed locations, to securely review, edit and discuss cancer cases in real time within multi-disciplinary teams.
- Ongoing experts "human-in-the-loop" to constantly label, validate and update models [29] [30]. Our Simplicity MDT software platform serves as a basis for collecting numerous multivariate labels which can be used to help build prediction and classification models for melanoma images and other datasets.

In addition, a vast range of techniques can be used to enhance classification and object detection. Having a network of partners, collaborators and consumers can provide a wealth of access to resources for creating quality labeled data sets.

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Current Cybersecurity Maturity Models: How Effective in Healthcare Cloud?

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Abstract. This research investigates the effective assessment of healthcare cyber security maturity models for healthcare organizations actively using cloud computing. Healthcare cyber security maturity models designate a collection of capabilities expected in a healthcare organization and facilitate its ability to identify where their practices are weak or absent and where they are truly embedded. However, these assessment practices are sometimes considered not effective because sole compliance to standards does not produce objective assessment outputs, and the performance measurements of individual IS components does not depict the overall security posture of a healthcare organization. They also do not consider the effect of the characteristics of cloud computing in healthcare. This paper presents a literature review of maturity models for cloud security assessment in healthcare and argues the need for a cloud security maturity model for healthcare organizations. This review is seeking to articulate the present lack of research in this area and present relevant healthcare cloud-specific security concerns.

Keywords: Healthcare, Cyber security, Maturity Model, Cloud Computing

1. Introduction

A maturity model is used as a tool to assess an organization's effectiveness at achieving a particular goal. It can also facilitate an organization's ability to identify where their practices are weak or absent and where their practices are truly embedded. Cyber security maturity model is a tool that can track improvements made over time from embedding security within an organization's daily and strategic workflows, and between similar organizations in an industry.

Security and privacy of patient information are of utmost priority to all healthcare stakeholders. These reasons mostly limit the adoption of cloud computing and the requirement to link isolated electronic healthcare systems [1]. In order to ensure a secure environment for the interconnected systems, it is important to assess the overall security posture of the healthcare organization. The processes and activities are stated at different levels of maturity and compared with the healthcare organization's practices to assess its overall cyber security maturity. The outputs provide better

awareness, visibility and accountability [2], and can reveal the overall security posture of an organization. Healthcare cyber security maturity models provide a collection of capabilities expected in a healthcare organization with an effective approach to cyber security. Therefore, security decisions are supported by capabilities' assessment outputs obtained at different stages, compared against description of processes and activities mapped to cyber security best practices, guidance, and standards [3].

Most recent cyber security maturity models are built on assessing compliance to cyber security standards and guidance or on assessing specific information systems (IS) components like networks, vulnerability risks and intrusion detection [4, 5]. However, these assessment practices are considered not effective because sole compliance to standards does not produce objective assessment outputs, and the performance measurements of individual IS components does not depict the overall security posture of a healthcare organization. These discrepancies affect their adoption as models to derive reliable assessable outputs. In order for interconnected healthcare systems to communicate effectively without worsening the overall security of the system, each healthcare organization's security posture should be well known using reliable and important cyber security indicators that bring visibility and build trust among participating organizations [6].

This paper presents a literature review of cyber security maturity models utilized for cloud security assessment in healthcare and proposes the need for a cloud security maturity model for healthcare. The review includes cyber security maturity models tailored to healthcare assessment in cloud computing, and it is not confined to only academic literature but also includes industry literature. This review is seeking to articulate the present lack of research in this area and present relevant healthcare cloud-specific security concerns. The rest of the paper is organized into the following manner. Section 2 presents methodology, section 3 highlights cloud-specific security standards, best practices and guidance applicable to healthcare, whereas section 4 highlights current cyber security maturity models employed in healthcare cyber security assessment in cloud computing. Section 5 provides the conclusion and further work.

2. Methodology

The research methodology ensued logical and combined reviews based on concept-centric frameworks [7]. The research parameters, and search terms were formulated according to a predefined set of rules, which informed the combination of search terms. Since this research is in the information systems (IS) field, logical literature review guide was also employed since it allows detailed explanation of the process, being comprehensive in scope, and providing an opportunity for repeatability [8, 9].

The methodology consists of four stages: identification, screening, eligibility and the analysis of included publications. Important is that the process should have a clear and repeatable protocol that is followed. Specifically, 93 information sources were identified in the first stage by systematic literature search using a structured approach.

Secondly, the screening of the titles, abstracts and meta-data such as the quality of the source or the type of source, the relevance of the title and abstract led to the exclusion of 56 publications. In the third stage, the literature were fully read. Based on their content, 16 publications were further excluded as out of scope. In the final stage, the remaining 21 publications were critically reviewed as part of this paper. The literature review methodology was based on Liberati [8].

Despite adopting a rigorous approach to reviewing the publications, there still exist the risk of having overlooked important contributions by excluding cyber security maturity frameworks from the search because these could not produce measurable outputs to determine cyber security posture. Since the research topic is still emergent in nature, it makes sense that results are currently being on-going research. However, assessing the quality of the frameworks and models-in-progress is an arduous and error-prone task. By limiting the review there was focus on mature research adhering to the high-quality standards and workflow dynamics of healthcare, which in turn, ensures quality in the reported findings.

3. Cloud security standards, best practices and guidance in healthcare

Standards, guidance, and best practices have been in use for a very long time, and their similarity is that they are reactive in nature. There will always be a gap between deciding whether something is needed and achieving implementation, which may span years. This becomes more of an issue for international standards due to the differing agendas being pursued by different countries, which can further increase the gap to implementation. The problem is yet further worsened in a technological environment, such as security in computing, and especially in a fast-moving technology like cloud computing. However, not only is technology rapidly changing, but the threat environment is also developing at a considerable pace [10].

International Organization for Standardization

ISO 2700-series standards produced by the International Organization for Standardization (ISO) and International Electro technical Commission (IEC) provide best practices recommendation that covers the fundamental requirements of information security management systems, guidelines and principles for the implementation of such systems. The ISO 27001 [11] is valid to all organizations regardless of their size and industries. It specifies the method that organizations should use for information security and the essential components. It also ensures the identification and management of risks are properly verified. Compliance saves organizations the financial penalties and losses associated with data breaches, comply with business, legal, contractual and regulatory requirements, protect and enhance their credibility and reputations.

ISO 17522 [12] and ISO 27799 [13] standards are targeted for health informatics. They provide guidelines for designing health specific information management systems based on ISO 27002, and control patient safety within such systems respectively.

ISO 27001 can be integrated with ISO 27799 standard to address healthcare specific risks. ISO 27017 [14] provide detailed guidance and recommendations for cloud adoption. The ISO 22857 addresses the protection requirements to facilitate cross-border transfer of personal healthcare data [15].

However, these standards do not completely address some of the healthcare-specific concerns, healthcare organizations have not been able to adapt the standards, guidelines and best practices from the frameworks to their specific context and develop practices that meet their own needs. Other concerns include extensive time and expense of complying with different standards, and the need for clarity and simplicity with implementation.

Health Information Trust Alliance

Healthcare industry leaders provide a harmonized, certifiable framework for all organizations that create, access, store, or exchange sensitive and/or regulated health data using HITRUST (Health Information Trust Alliance). The HITRUST Common Security Framework (CSF) version 9 [16], is a comprehensive, risk-oriented framework that normalizes the cyber security requirements of healthcare organizations. It is based on federal legislation such as HIPAA (Health Insurance Portability and Accountability Act) 164.502(ii), and globally recognized standards and guidance including ISO 27799 using ISO 27002, NIST SP 800-53 r4 AC-19 [17]. It provides scalable security requirements tailored to the needs of the healthcare organization, allowing healthcare organizations monitor and maintain compliance with HITRUST data security controls across their cloud infrastructure including multi-cloud deployments.

The HITRUST framework's mapping with the NIST CSF reveals, the HITRUST framework provides healthcare industry-specific model implementation while the NIST framework provides broad guidance to critical infrastructure industries on organizational-level risk programs that are holistic, based on principles and used across industries. A major constraint for HITRUST framework is that it is yet to receive worldwide acceptance.

National Institute of Standards and Technology

In addressing cyber security, many entities both within and outside of the healthcare sector have voluntarily relied on detailed cyber security guidance and specific standards issued by NIST. The National Institute of Standards and Technology (NIST) developed a set of guidelines on security and privacy in public computing, SP 800-144 [18]. It provides an overview of the security and privacy challenges for public cloud computing and presents recommendations that organizations should consider when outsourcing data, applications and infrastructure to a public cloud environment. NIST also developed a special publication, SP 800145 [19] for definition of cloud computing which has been globally accepted. SP 500-299 framework [20] was developed to identify core set of security components that can be implemented in cloud to secure the environment, the operations, and the data migrated to the cloud. It also released SP 500-291 Cloud Computing Standards Roadmap [21], SP 800-146 Cloud

Computing Synopsis and Recommendations [22], and SP 500-292 Cloud Computing Reference Architecture [23]. SP 800-66 [24] was developed regarding the guidance for IT security planning, implementation, management, and operation. It includes publications that address many security areas that are impacted by the HIPAA Cyber security Rule. NIST 800-66 provides guidance as to how to map HIPAA controls with NIST 800-53. This is the only guideline that is specifically focused on healthcare although it did not make mention of cloud computing.

In addition, to address the ever-increasing attacks on critical infrastructure, NIST also developed the Cyber Security Framework (CSF) that provides an incident management model that various industries can leverage for improving the management of cyber security risk, and built on ISO 27001, COBIT [25], and NIST 800-53. The framework is clearly structured in terms of the areas of cyber security that need to be implemented. This supports the relevant stakeholders to assess cyber security and identify gaps. Howbeit, the shortfall of the framework's security controls was that they were specifically designed for US Federal agencies, and not accepted worldwide. Initially, it was not sufficiently specific about cloud environments, but now, major cloud service providers, Amazon Web Services [26], Microsoft Azure [27] have taken steps to align their offerings to the framework addressing the ambiguities about the use of the CSF in the cloud.

Health Insurance Portability and Accountability Act

The HIPAA was developed in order to ensure security and privacy of individually identifiable health information. HIPAA deals with security and privacy through its privacy rule [28] and security rule [29]. The privacy rule ensures the flow of health information needed for quality care by addressing proper use and disclosure of health information. The security rule aims at protecting the privacy of individuals' health information by adopting new technologies with a goal of achieving improved quality and efficiency of patient care. It operationalizes the protection mechanisms contained in the privacy rule. HIPAA privacy and security rules are applied to healthcare providers and non-healthcare providers supporting the healthcare providers holding or transmitting health information in electronic form. HIPAA compliance cannot be overlooked when it comes to cloud computing, however, it is no longer enough for a vendor to simply claim "HIPAA readiness." Its controls are indicated as required which makes implementation unclear. HIPAA is not "certifiable" resulting to the need for healthcare organizations to influence internal or external assessors to perform self-assessment for compliance.

The scope of security and privacy protections available in HIPAA are extended through the Health Information Technology for Economic and Clinical Health Act (HITECH). In the healthcare industry, so far HITECH [30] provides legal liability for non-compliance to HIPAA, and ensures the disclosure of breach and unauthorized use of electronic health records to necessary stakeholders.

Cloud Security Alliance Standards

Cloud Security Alliance (CSA) developed security guidance for critical areas of focus in cloud computing including various versions. Version 1.0 [31], Version 2.1 [32], Version 3.0 [33], and Version 4.0 [34]. The latest version focused on meeting the demand of security changes. It also introduced better standards for organizations to manage cyber security for cloud by implementing security domains. The guidance can be applied to cloud service model (IPSaaS) and four deployment models (Public, Private, Community, and Hybrid Cloud) with derivative variations that address specific requirements. The guidance included thirteen (13) different domains, which are divided into two general categories: governance and operations. The governance domains focus on broad and strategic issues as well as policies within a cloud computing environment, while the operations domains focus on more tactical security concerns and implementation within the cloud architecture.

This guidance is relevant to cloud computing, its service models and its deployment models. As regards cloud security management, the guidance focuses on cloud-specific concerns: interoperability and portability, data security, and virtualization. Dividing the implementation domains into two groups with strategic and tactical categories is another salient point of the guidance. This approach allows cloud consumers, providers to bring financial, and human resources into security consideration. Furthermore, the guidance can be mapped to existing security models including the Cloud Control Matrix [35]. Despite these benefits, the guidance lacks assessment guide for each domain. In addition, it does not consider security metrics for security practices. Therefore, organizations find it difficult to determine the security level of a domain.

There are several standards, guidelines and directives that are strongly complied with in all industries but, as commonly observed, they are not specifically focused on the healthcare industry nor do they meet the entire requirement for healthcare cloud. To address the healthcare cloud-specific needs, various selection of standards is expected to be based on parameters, such as scope, level of integration, industry applicability, prescriptiveness, scaling, tailoring, compliance, certification, shared assurance, assessment guidance, and tool support.

4. Review of current cloud security maturity models in healthcare

Many healthcare security leaders are recognizing that compliance activities are important, but not enough to adequately mitigate the risks of data breaches and attacks.

Information Security Focus Area Maturity Model

The Information Security Focus Area Maturity (ISFAM) model is a focus area-oriented maturity model, originally proposed as a method for incremental progression [36]. It consists of a fixed number of maturity levels, each process identified by a focus area/domain, is assigned its own number of progressively more mature capabilities. The model is able to determine the current information security maturity level.

ISFAM model has 12 maturity levels and 13 focus areas. In these focus areas, 64 capabilities are assigned at the various maturity levels. The assessment of the maturity level is executed through a survey or a directed interview with an expert. The ISFAM covers the complete domain of information security, combining the application of ISO 2700-series, chapters from CISSP (Certified Information Systems Security Professional), Standard of Good Practice of the Information Security Forum (ISF), and the IBM Security Framework [37]. Its subsequent practices in information security divides the capabilities within the maturity model into four (4) groups such as, design, implementation, operational effectiveness, and monitoring.

As with all focus area maturity matrices, the lowest implemented capability defines the maturity level reached. ISFAM has successfully been evaluated using a medium-sized telecommunications organization. Despite its extensive and relatively fine-grained, and its practical approach are based on IBM's experiences, the ISFAM model remains designed as a sector-specific maturity model - small and medium-based organizations as its focus. In addition, it was developed for application with software development, and was specifically made for information security problems obtained from IBM's experience. Lastly, it made no mention of been applicable to future technologies such as cloud computing.

Cloud Security Capability Maturity Model

The Cloud Security Capability Maturity Model (CSCMM) includes domains and maturity levels. There are twelve cloud security domains and four maturity levels. Each domain consists of a set of cyber security practices, and the practices are achievement objectives specific for each cloud security domain. The maturity levels apply to each domain and specify progression of maturity. The model can be tailored for suitable objectives of different cloud service model (IPSaaS) and deployments (Public, Private, and Hybrid Cloud). Lastly, it provides the guidance to support the organizations implement and enhance their cyber security capabilities on cloud system [38].

There is not a complete cloud security standard because cloud technology is evolving much faster than standards [39]. Therefore, creating a set of cyber security domains just based on the current security standards does not fully consider emerging issues and attack surfaces. CSCMM was built from a systematic review approach on existing cloud security models and standards, traditional security maturity models, as well as trends in emerging technologies. As a result, these twelve security domains, eight security domains are from traditional maturity models, and four cloud specific security domains were chosen as they cover comprehensive aspects of cyber security and accommodate emerging security issues.

To assess the maturity level of the model in general and a security domain in particular, a security metrics framework was proposed. This framework includes relevant quantitative metrics for measurable assessment. It presents a balance assessment of the overall security of an organization qualitatively and quantitatively. For senior managers, it offers assessment of the security status for making decision concerning

business plan and direction. For security practitioners, it offers proactive measures and responsive actions. In addition, CCSMM model has 3 dimensions such as domain, levels and community (such as organization, community, state), this makes the model more suitable for organizations of different sizes, however, this model is considered technically complex to implement in healthcare [40–42].

Further twelve (12) cyber security maturity models were reviewed to investigate their strengths and weaknesses. These similarities identified amongst these maturity models are; all the models are hybrid-type maturity models with their multi dimensions including security domains and maturity levels, most security domains vary from infrastructures, data, networks, human, application, communications, compliance, to legal and contractual. To implement best security practices, security standards such as NIST, ISO 27000 series, COBIT are the baseline to implement and measure security levels in all models. Most of the models have implementation process through four steps from evaluation, gap identification, priority and planning, and plan implementation. Lastly, most of the models implement a 5-level framework to assess security state of each domain. These 5 levels involve a 3-stage process, the first stage is with no security management implementation, following stage focuses on the implementation of security standards to control security concerns. The third stage is an automatically security management with full security implementation. This stage is considered the innovative stage with highest security.
The differences also identified includes, each model has domains with different security requirements based on the goals of the model, making each model to have different advantages. None of these models mentioned extend their application to cloud computing environments and were industry-generic not streamlined to healthcare environment.

NHS National Infrastructure Maturity Model

The National Infrastructure Maturity Model (NIMM) Programme designed by Connecting for Health (CfH), has provided useful guidance, national standards, best practices and capability maturity tool for National Health Services (NHS) IT organizations to benchmark their local IT infrastructure services/capability in order to create a road map for improvements. It supports healthcare organizations to assess the maturity of different components of their business and IT capabilities. The assessment will provide an indication of how mature the organization is in a particular area and what steps should be taken to improve maturity. Healthcare organizations are to exercise the 12 NIMM core capability assessments in the first instance. Afterwards, a roadmap should be formulated to improve maturity, then assessments that are more specific to the healthcare organization should be selected and completed, and the outputs from these are then incorporated into the formulated roadmap [43].
Most healthcare trusts are required to work towards Level 3, Standardized – Consistent and predictable services, increasing the maturity of their infrastructure and service provision, moving from manual configurations to managed systems with automation and proactive monitoring of services. The Healthcare organizations recognize the fundamental part played by infrastructure in underpinning all information management and technology (IM&T) strategy and so has adopted the NIMM [44].

This model is still presently relevant in the cyber security maturity assessment of healthcare organization and stated to be platform-independent, however, it does not take into consideration the rapidly changing landscape of technology, such as characteristics of cloud and its resulting threats.

Health Information Network Capability Maturity Model

Health Information Network (HIN) Capability Maturity Model is a tool that will support the objective assessment and formulate plans for improve operational capabilities, level of service and value delivered by HIN organizations. This fully vetted and accepted pan Canadian model can serve as a strategic and operational planning tool. It was established based on other maturity models in healthcare and other industries, Canada Health Infoway's strategic opportunities for action and key enablers [45], HIN Planning and Operations Leading Practices Discovery Framework [46], and observations and input from the leading practice organization interviews. It is intended to be a tool for guiding stepwise assessment which can be used to determine a jurisdiction's current capability maturity level, categorize an objective maturity level appropriate to the jurisdiction's needs, and develop a roadmap for progression toward that desired maturity level.
HIN Capability Maturity Model comprises of 10 capability domains and 5 maturity levels for each. It also includes an aggregate maturity across all domains, which can be used to broadly compare and communicate the overall maturity of the HIN. In order to apply this model, it is required to be refined with input from current jurisdictional HIE organization operators, system planners, and policy makers, and tools for self-assessment, action planning, and progress monitoring will also be required to make it consistently and uniformly applicable [47]. Its shortcomings are in tune with the NHS NIMM.

In summary, it can be inferred that mostly cyber security models require revision because of its fragmented and local approach. This review has established that cyber security maturity models support effective and efficient management of the security of their organizations. More importantly, stakeholders operate along secure mature path as mapped out by the maturity model to ensure overall security of the organization, rather than applying all the security controls available. Despite all these benefits, maturity models only provide a baseline-compliance model rather than the desired cyber security model that can deal with emerging cyber environment, its demanding cyber security usage, as well as its sophisticated attacks.

5. Conclusion and Future work

This paper reviewed cyber security standards, best practices, and guidance, and models including cloud security models, cyber security capability maturity models, mostly applicable within the healthcare environment. The main insight to be considered about the review is the present inadequacy of cyber security maturity models to effectively assess security in healthcare organizations actively using cloud computing.

Three specific issues were identified: First, the influencing factors of cyber security of a security maturity model should be more than standards-compliance. Second, integrate identified relevant factors into the maturity levels, and determine appropriate metrics for security assessment. Third, the model should be malleable for ensuring current cyber security and extensible for dealing with security for emerging cyber threats. These are the research problems this research intends to mitigate or resolve by the proposal of a maturity model - Maturity Model for Healthcare Cloud Security (M^2HCS). By identifying interactions between the several domains of healthcare information security and signifying them cogently in the M^2HCS, the model aims to be able to mitigate reactive assessment of security in healthcare cloud environment, and support incrementally operations to improve information security maturity within the healthcare organization.

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Anonymizing clinical and genetic data of patients with minimum information loss

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Abstract. While collaboration in research requires the publication of data as well as exchange of them between institutions, these data often contain personal information that according to ethical requirements and existing legislature, are not allowed to be disclosed. Anonymization of these data is therefore mandatory. In previous work we have presented a framework for anonymizing patient data using Data Cubes. Though efficient for anonymization, the Data Cubes approach often lacks in flexibility. In the current work, we present an alternative approach which is based on disclosing a row based anonymized version of the original data set. The methodology is more versatile, while it also preserves the statistical characteristics of the original data set. We demonstrate this by considering an SVM predictor that tries to estimate the value of Breslow's depth, based on the values of another clinical variable, namely Clark's level, and the expression count of a skin cancer related gene (CDKN2A). The predictions are shown to have the same characteristics for both the original and the anonymized data sets.

Keywords: Data Anonymization, Privacy Models, ARX framework

1 Introduction

While publication and exchange of clinical and genetic data is crucial for research, it is often the case that data contain sensitive information; information that, if disclosed, may cause harm to the patients. It is therefore mandatory, both in ethical and in legal terms, to respect and protect the individual's right to anonymity for the patients whose data are used for research. With the advent of GDPR[1] in particular, which is binding for all member states of the EU, the set of rules that govern patient personal data is clearly defined both for Data Controllers and for Data Processors. GDPR requires that, except for some specific cases, sensitive and personal data to be anonymized when they are disclosed to the public. Anonymized, in this sense, means that an attacker cannot reverse engineer the anonymized data set in order to retrieve the original data containing the sensitive information.

In previous work[2], we have demonstrated a methodology that allowed the anonymization of data, by using the aggregate structure known as a Data Cube. This methodology produced completely anonymized data sets, which maintained the statistical properties of the original data set, thus being effective for the purposes of analysis. It

relied upon identifying attribute combinations of interest, and then aggregating over the patients that shared the same values for these combinations. If, for example, the attributes of *diabetes* and *smoking* were to be measured, a two-dimensional data cube would have been created. If the data cube is denoted as *DC*, then *DC[0][0]* would contain the number of patients that had no diabetes and were not smoking, *DC[1][0]* the number of non-smokers who had diabetes, and so on. The above methodology, while producing sound results, suffers from two main drawbacks

The first one was that of inflexibility. In order to produce a Data Cube, a set of attributes and a categorization schema for each one of these attributes was chosen. If, however, other attributes were to be added or removed, the Data Cube needed to be reconstructed from start.

The second one was the one of performance. When combining clinical and genetic data, which are typically stored in different files, the amount of join operations led to a growth of the required amount of time needed to prepare data for processing. This growth, while polynomial, still poses a limiting factor when producing large Data Cubes. Although it has been demonstrated that by using High Performance Computing techniques, this overhead can be reduced by a cubic factor[3], the order of the polynomial overhead depends on the amount of attributes needed to be included. Thus, after a point the data pre-processing will become slow even by using HPC techniques.

In this work we introduce a new methodology that performs anonymization directly in the patient data. The transformation may be applied to the whole data set, which is then distributed in row format. Since the transformation is applied at the row level, it is linear in time and attributes of interest can be removed/added in a time efficient manner. The methodology will be applied in a use case that involves data of patients treated for melanoma.

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2 Theory

In the most direct sense, a set is to be considered anonymized if no personal information of the data subjects is exposed to potential attacker. In the case of row-based format of data, this means that an individual cannot be linked to her corresponding entry in the data set. In a typical case however, especially those involving patient data, anonymization must be forced in the stricter sense, so that not only personal but also sensitive information is protected[6]. To make this clearer, we consider two more disclosure cases, against which an anonymization algorithm must protect the data subject.

Membership disclosure, involves the knowledge of whether data regarding an individual are contained in the dataset or not. *Attribute* disclosure, involves the knowledge of whether a specific attribute, has a specific value for an individual. Membership and attribute disclosure allow an attacker to discern sensitive information regarding individual(s), even without re-identifying the data set. For example, if an attacker knows that a subject is part of a double-blind placebo control clinical trial for a new drug

developed for melanoma, then she knows that the subject has melanoma with a probability ~50%.

The different disclosure cases force the categorization of subject attributes into four types:

- Identifying attributes, that contain subject's personal identifiable information (PII) and which are, in any case, removed from the set.
- Quasi-identifying (QIA) attributes which though they cannot be used on their own to identify a subject, they can be used, in combination with other variables to identify subjects.
- Sensitive attributes (SA), which contain information about subjects with which the subject should not be associated with. The presence of melanoma referred to earlier is a typical example of a sensitive attribute. Genetic information, which can now be linked to existing or potential health issues, such as predisposition to cancer, is also considered sensitive information.
- Non-sensitive attributes, which are irrelevant for the purposes of re-identification

QIA are transformed, while sensitive attributes are transmitted as is, provided that certain constraints are held. These constraints are enforced to prevent re-identification and are defined by the so-called privacy models

2.1 Privacy Models

Privacy models concerning anonymization can be very diverse; for the purposes of the present work we consider only the ones that are relevant to the use case of melanoma patients to be presented.

- *k-anonymity*[7]: This the most basic model; all other models are typically an extension of k-anonymity. Let a group of entries that shares the same values of QIA be called an equivalence class. k-anonymity enforces each equivalence class to have a size of at least k.
- *l-diversity*[8]: This model demands that each SI has at least l distinct values in each equivalence class.
- *t-closeness*[9]: this model demands that the distribution of the SI in each equivalence class is similar to the one of the whole dataset.

Figure 1 depicts a simple example demonstrating the meaning of *k* and *l* values. Anonymization with the desired characteristics is achieved with performing transformation on the QIA; the most typical ones are generalization, where values are grouped under categories, and suppression, where part of the information is masked.

Race	Birth	Gender	Postal Code	Diabetes
White	1980	male	20*	Yes
White	1980	male	20*	No
White	1980	male	20*	Yes
White	1982	female	18*	Yes
White	1982	female	18*	Yes
Black	1982	male	18*	Yes
Black	1982	male	18*	No

Figure 1: Data set with a k-value equal to 2. Postal codes and birth dates are suppressed to achieve the required k-value. Since the 2nd equivalence class has only one distinct value for the sensitive information of diabetes, the l-value is equal to one.

3 Application

In the case of patient data, anonymization needs to be such that no sensitive information may be attributed to a single patient. The transformed data set however, needs to exhibit the same statistical characteristics as the original one; otherwise the dataset will lose its validity and will be of no scientific value to the entities that share the information. For the purposes of the current work, we considered datasets that contain data of patients that were treated for melanoma. These data were retrieved in the context of the SAGE-CARE project and correspond to real patient data that are stripped from any PII. They contained both phenotypical information, concerning the clinical picture of the patient as well as genetic information corresponding to expression counts of the patient's genes. Satellite data, contained subject's information such as height, ethnicity etc. are also included in the dataset. These satellite data will be considered QIA in our model.

For anonymizing the dataset, we transform the set by requiring a k-value of 5, l-value of 2 and t-closeness of 0.2. The transformation is carried out by using the ARX framework[6]; for each of the QIA a hierarchy was defined that was used for implementing the generalization strategy. Figure 2 depicts a sample listing of the code used to anonymize the data set.

```
ARXConfiguration config = ARXConfiguration.create();
config.addPrivacyModel(new KAnonymity(5));
config.setSuppressionLimit(0.02d);

data.getDefinition().setAttributeType("breslow-depth", AttributeType.SENSITIVE_ATTRIBUTE);

config.addPrivacyModel(new EqualDistanceTCloseness("breslow-depth", 0.2d));

// l-diversity
config.addPrivacyModel(new DistinctLDiversity("breslow-depth ", 2));
```

Figure 2: Sample code listing depicting the data set anonymization. A k-value of 5 is defined with a suppression limit equal to 0.02. The sensitive attributes are then set (breslow depth is depicted in the example). The required t closeness and l values is then applied to each sensitive attribute (again, this is depicted for the Breslow depth attribute in the sample code).

3.1 Demonstration

To demonstrate that the transformation allows the data set to keep its main predictive features, we will show how a typical *Support Vector Machine* [11] (SVM) classification performs under the two data sets. We consider the original data set and take as an example the case of three sensitive information, namely the Breslow's depth, the Clark's level and the expression count of the *Cyclin-dependent kinase Inhibitor 2A* (CDKN2A) gene. The Clark's level is a measure of the depth that the melanoma has grown into the skin and of the levels of the skin that are affected. It is used as a prognosis factor in melanoma. Breslow's depth is another prognostic factor that measures the depth of the tumor using ocular micrometer. Breslow's depth is a more accurate prognostic factor that Clark's level; for bigger values of Breslow's depth specifically, the Breslow depth has a significantly better value as a predictor. The CDKN2A gene and its mutations on the other hand, has been shown to be linked with the appearance of skin cancers [12]. When the weaker predictor (Clark's level) is combined with the gene count, we expect the results to have a better predictive value. Figure 3 depicts the results of an SVM classification for the Breslow's depth of a patient's melanoma based on the values of the Clark's level and the CDKN2A expression count. The results suggest that for low expression counts of CDKN2A, the Clark's value is suggestive of the Breslow value. When the expression increases however, the Clark's level is no longer a good predictor for the Breslow's depth; indeed, a high expression of CDKN2A seems to be correlated with low Breslow's depth.

Figure 4 depicts the same classification when applied in the anonymized data set. Taking into account the difference in the scaling produced between the two cases, the classification has the same characteristics. It is to be noted, that the aim of the above experiment is not to extract any significant medical conclusions; indeed there are far more elaborate statistical models to demonstrate correlations between various phenotypical and genetic attributes. The main goal of the experiment is to demonstrate that

the anonymized data set has the same statistical characteristics and that any conclusions drawn from the original data set, persist to the anonymized one.

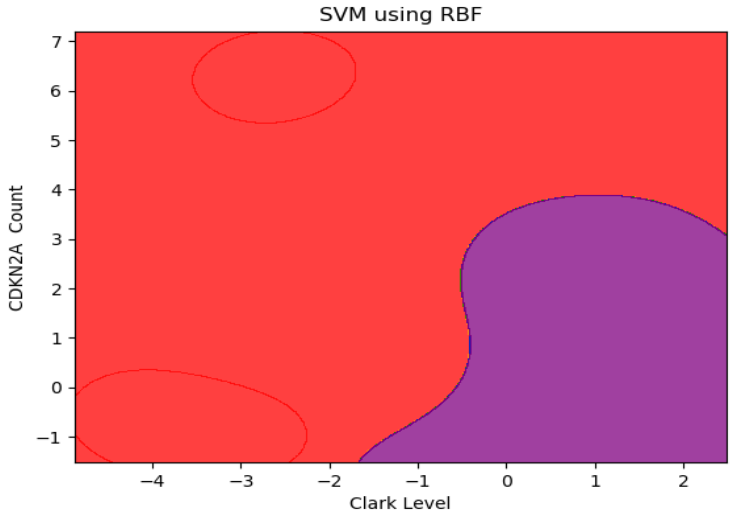

Figure 3: SVM classification for the Breslow-level for the original data set. Red(purple) areas depict low(high) values. The values are depicted scaled. For low Clark level (left part of the diagram), the Breslow's depth is also low. When the Clark's level is high, the Breslow's depth is also high only for low expressions counts of the CDKN2A gene (lower right part of the picture).

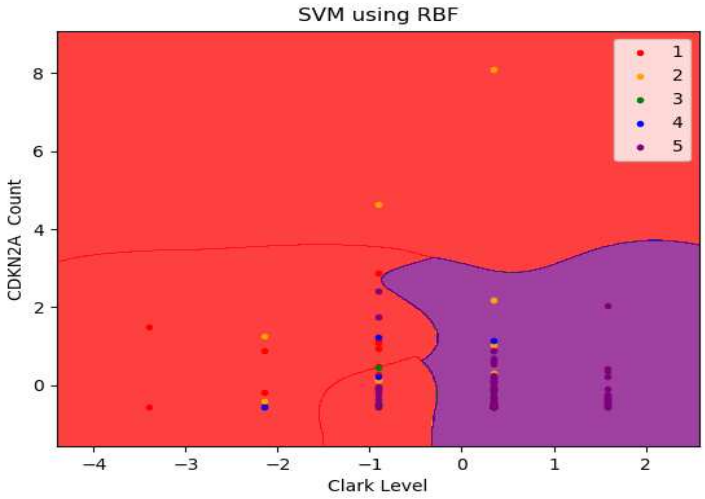

Figure 4: SVM classification for the Breslow-level for the anonymized data set. Red(purple) areas depict low(high) values. The values are depicted scaled. The test data are also depicted, with 5 ranges for Breslow's depth values as shown in the legend. When the Clark's level is high, the Breslow's depth is also high only for low expressions counts of the CDKN2A gene (lower right part of the picture).

4 Conclusions and further work

In the present paper we demonstrated that datasets containing phenotypical and genetic data can be effectively anonymized, with any information loss not leading to a substantial change to the data's statistical characteristics. The methodology can be applied to patient data and these can be shared between parties in a manner that does not compromise patients' personal and sensitive information and that is also compliant with the requirements of GDPR. The transformed data moreover, exhibit the same statistical

characteristics as the original data; their scientific value is therefore not compromised by the anonymization transformations.

Further work involves demonstrating the same result by using a model that will be proven to be applicable to a generic case, involving arbitrary number of attributes; the model will also provide metrics that will indicate the amount of information loss imposed by the transformation, thereby quantizing the efficiency of the anonymization.

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MindManager: The Psychologically Informed App to Manage Weight Loss

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Abstract. Obesity is an increasing societal problem in the western world. The consequences of obesity can be physical, social, mental, and economical. The attempt to counteract these consequences has led to the vast production of knowledge, advice, weight-loss diets, and exercise regimes, all in the aim of helping people lose weight. The desire for people who are obese to lose weight is also high. Yet despite this, people often struggle to successfully lose weight. One prominent cause of this is the difficulties people generally have in managing their goals, setting realistic expectations, developing healthy habits to help achieve their goals, and keeping track of their progress. This has led to the development of psychologically based programs to help people reach their goals, with varying levels of success. The data from these programs have helped researchers narrow down key steps in successful goal management, such as: asking users to define and articulate a reason for their goal, breaking goals into achievable and concrete sub-goals, and enabling users to share their progress. This paper describes how these techniques have formed the foundation of a weight-loss app, *MindManager*, to help people lose weight and manage their progress effectively.

Keywords: Obesity, weight-loss, goal management, psychology, e-health.

1 Introduction

Obesity is an increasingly prevalent societal phenomenon. In 2016, 13% of the world population was obese [1]. The amount of people obese in the world has almost tripled since 1975. This is particularly the case in WEIRD (Western Education Industrial Richly Developed) societies, where socioeconomic developments in the last century have led to the production of cheap and widely available calorie dense foods and beverages. For example, in 2014, 51.6% of the population of Europe was overweight [2]. The unintended consequences of this is that people are far more likely to die by a heart attack or other obesity related issues, such as diabetes, than at any previous time in history. Convenience has come at a cost for many people in Western society.

Those who are obese do not only suffer physical consequences, but also suffer socially and mentally. People who are obese are seen on average as less attractive potential romantic partners than those who are not [3]. People who are obese are more likely to be targeted for bullying and harassment than those who are not [4]. People who are obese are more likely to be judged as having poor will or character from assumptions that they lack control over their mind or body. People who are obese are more likely to suffer from difficult mental health issues, such as depression and anxiety, which can cause the person to continue eating, exacerbating their weight difficulties [5]. People who are obese are on average less healthy, happier, sexually active, and mentally well than those who are leaner.

All these physical, mental, and social consequences have led to a different type of cost, economical. Over $60 billion is spent each year in the USA alone, via Weight-watchers, mobile apps, technology, weight-loss apparatus, diets, weight programs, gym memberships, all in the aid of losing weight [6]. However, despite all of this, most people each year do not end up losing the weight they have gained. A significant portion of those who do lose weight tend to regain it within a few years [7].

2 Psychology of Weight Loss.

People are desperate to lose weight but seemed unequipped to actually achieve it. This is despite the range of potential methods at their disposal that have been shown to be reliable predictors of weight loss. Such methods can range from the dietary: simple calorie counting, low carbohydrate diets (e.g. Keto or Atkins), vegetarian or vegan diets. To eating restrictions: intermittent fasting. To increased physical exercise: taking up a sport, joining a couch to 25k program. To therapy and/or emotional support [8]. Other methods that are psychological/behavioural in nature have also proven effective, such as: reducing plate size in order to feel more satiated with servings or shopping on a full stomach in order to reduce the tendency to impulse buy high fat and high caloric sugar foods [9]. With the introduction of the internet and its contents (e.g. YouTube video, Podcasts, Forums for weight loss), there has never been a time where any individual person can learn more about their body and nutrition than ever before. And yet, despite this, our obesity problem remains.

From a psychological perspective, this indicates that it is not the information or methods that are the problem for people, but the way people are using this information to inform their goals and/or maintain those weight loss goals. Whilst it is clear that people routinely set weight loss as a primary objective to be reached, they may not be setting appropriate enough sub-goals in a way that meshes well with their underlying goal-monitoring systems. For example, people are more likely to achieve their goal (e.g. to lose 52lbs next year) if they break their goal into smaller-sized short-term sub-goals (e.g. to lose 1lb a week). This allows the person to have a concrete achievable goal within a short period of time, which if they achieve will more provide a sense of achievement and desire to keep on their goal path, and if they fail to achieve allows them to change their goal approach. However, people do not use this method for their goals. This is a failure in understanding their own psychological constitution.

3 MindManager

How can the psychological mechanisms and goal-monitoring interventions that predict better chance of successful weight loss be implemented into an app that will be able to help manage people's weight loss? This paper introduces the *MindManager* app as a way to incorporate these mechanisms. The app is a chat based system that attempts to aid the user into articulating the reasons as to why they want to achieve their weight loss goal, identify particular methods and techniques to achieve that goal, set concrete but semi-flexible sub-goals in their tasks, develop habits in order to change their mindsets and behaviours, and monitors their progress and provides feedback in order to allow the person to optimize their weight loss progress.

The design of the system is based off on several theoretical/empirical theories. *MindManager* makes use of the empirical literature found on the importance of goal articulation. This is why the system asks users to provide a semi-detailed reason as to why they want to achieve the goal. The system also asks users to imagine their best possible future if they were to achieve their goal (i.e. if they could have what they want, what would that look like?). It also asks them to imagine a worst possible future if they were not to achieve their goal (e.g. I gain more weight, I become unattractive to my partner, I get diagnosed with diabetes, I suffer from a heart attack, etc.). This is to encourage the users to think of reasons to positively approach their goal and negative reasons to avoid their undesired future.

Another reason as to why the system includes an interactive writing exercise is that it encourages intrinsic motivation and promotes better well-being. Multiple writing programs have been developed, such as those developed by the research teams under Psychologists James Pennebaker and Jordan Peterson [10] [11]. Both have been found to improve performance on their respective output tasks. Pennebaker's research has found that those who disclosed negative emotional experiences in a way that encouraged them to make a coherent narrative of their memory, enjoyed numerous physical and mental health benefits in the future compared to those who did not. Peterson's *Self Authoring Program*, which in its initial phase focused more on academic performance and young-adult self-improvement, found that participants were able to significantly boost their grades and reduce drop-out rates. This applied for students in multiple universities cross culturally. Peterson's research also found that the more people disclosed in their writing program, the better the effect was. In order to perform difficult tasks over long-period of times in order to achieve an abstract goal, people need a strong articulated reason as to why that goal is beneficial and why it is meaningful to each person.

However, where the *MindManager* differs in comparison with these other writing programs is its use of repeated feedback, developing of habits, and goal-updating input. Self-Authoring, for example, is a one-time writing program (albeit it can be carried out at the user's own pace over several days and even weeks). It is a low frequency, high intensity program. *MindManager* however is a high frequency, low intensity program. Users are asked to give relative quick and short answers at each particular period. The *MindManager* system uses language analysis, Likert-scales, personality information, to make informed decisions about the well-being of the user. It will seek further information from the user periodically (which can vary depending on the particular user and

their goals). The benefit of this is that the system can dynamically adapt to the ongoing situation of the person.

4 Production and Testing

The *MindManager* system is still in its early stage of production but based on the substantial evidence found in previous research, there is optimism for its success. From their meta-analysis of the literature, researchers found several key factors that promoted successful goal attainment [12]. These were: the ability to broadcast and share results socially, incorporating both outcome goals (e.g. I want to 50 lbs. slimmer) with behavior goals/habits (e.g. I want to eat more fruit and vegetables), it incorporates sub-goals, it provides feedback to the user, and it encourages users to provide routine feedback on their goal-status. The system also incorporates methods of Cognitive-Behavioral Therapy to encourage the user to identify why they are not successfully pursuing the goal and what potential inhibiting behaviors and/thoughts are getting in their way (e.g. the tendency to catastrophize over failures). The system then attempts to help the user navigate those behaviors and thoughts in a goal-oriented manner.

The *MindManager* system will be tested with research participants. Whilst the full details of the research study have not been yet worked out, there is a basic structure that will be followed. Once a full prototype mobile app has been developed participants will be recruited who express an interest in weight loss. Participants will be assigned to one of two groups. One group will be assigned to a pen and paper app weight loss program/or an app-based program that is high intensity and low frequency. The other group will be assigned to use the *MindManager* app. Participants in each group will be asked to track their weight over 12 weeks. Both programs will use similar features, writing tasks, identifying goals and sub-goals, but their goal-monitoring and goal-updating approaches will be different.

5 Conclusion

The *MindManager* App will implement multiple effective goal-monitoring methods in the aid of helping people manage their weight loss. The chat-based system encourages users to articulate their goals and reasons for such goals, develop plans of actions to move towards those goals, developing healthy and functional habits, and the system provides updates and feedback based on their progress. Testing of the *MindManager* will begin at some point in 2019.

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Chapter 5

Smart Factory and Robotics

Determination of real-time operating data by means of pattern recognition from energy profile in production

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Abstract. Manufacturing companies operate in increasingly turbulent and discontinuous environments. The rapid speed of change, coupled with a high complexity of cause-effect relationships of industries, globally-dispersed markets, technologies and economic areas create great challenges to the manufacturing systems. This particularly concerns SME's, whose competitiveness is increasingly dependent on their ability to dynamically respond to these in an adequate fashion. Adding to this, is the growing awareness of natural resources, requiring consistent energy conservation measures.
The following article addresses this problem and introduces the concept, developments and first application experience of the research project iKnowControl, which enables to identify real-time operational data using pattern recognition from energy profiles based on existing energy data collection systems. Using suitable pattern recognition methods, energy consumption data, among other things, could be read, and thus the part currently being manufactured on a particular machine, or the number of parts already being manufactured plus the average production time is recognizable. The described method offers a sufficient transparency and significantly improved options for increasing the level of automation and integrating suitable Industry 4.0 solutions, especially for small and medium production companies.

Keywords: Resource Efficiency, Manufacturing System, Pattern Recognition

Motivation

Constantly increasing competitive and cost pressures, as well as increased demands on technology and flexibility pose major challenges for manufacturing companies. Adding to this, is the growing awareness of natural resources, requiring consistent energy conservation measures. According to a study by the FELTEN Group, energy efficiency in terms of production has reached a leading position in the ranking of strategic priorities. It is now on the same level as the goal of increasing cost-effectiveness in production.

According to this study 59 percent, 57 percent respectively of the 250 companies surveyed, attach great importance to these two goals, followed by the improvement of production management (53 percent) and process optimization [1]. There are large numbers of providers of energy data collection systems, so that producing companies recognize energy waste and increase their energy efficiency through targeted, mostly organizational measures. Examples include employee awareness, on-demand switching on and off of less heavily used machines, and systems/modules to avoid high base-load consumption. In addition, this can be used to meet certification requirements that have a monetary impact [2][3]. However, in all these solutions it must be criticized that they are very much subject to manual evaluations and interpretations for the implementation of measures. This means, that the exploitation of the potential of energy efficiency in production is far too much dependent on the knowledge, the motivation and the implementation capacity of the persons responsible for energy management. Additional relevance lies in answering the question as to what extent the insights gained are implemented in the company, in particular by the production staff, which often have a hard time identifying the topic of energy efficiency in its corporate relevance in practice.

Considering the international state of the art, there are various solutions that incorporate energy efficiency in the production calculus, such as the control of peak load in production. The disadvantage of such solutions lies in the fact, that they relate exclusively to the energy consumption of controllable systems and units. Nowadays, it is possible to regulate ovens, compressors or ventilation, to name some examples, when a fixed peak load is exceeded or threatens to be exceeded in a certain power range. However, the inclusion of planned and released production orders with their routings and quantities does not take place. Despite recorded energy requirements for individual work operations, potentials are wasted since they are not considered in operational planning. Short-term adjustments within production control do not take place due to energetic aspects [1] [2] [3].

The possibility of feedback - based on the existing energy consumption of machines/ facilities and their work operations - on current production progress and status messages on machine conditions is not being used. Using suitable pattern recognition methods, energy consumption data, among other things, could be read, and thus the part currently being manufactured on a particular machine, or the number of parts already being manufactured plus the average production time is recognizable. In the event of large individual deviations or machine downtimes, that are due to prolonged base load operation, this information should immediately be reported to the responsible parties. The continuous collection of this classic real-time operational data is only possible through the integrated networking of machines and systems based on modern MES systems (Manufacturing Execution System). However, such solutions - even in smaller versions - are very cost-intensive and thus hardly ever used in smaller companies and only to a limited extent in medium-sized companies. As a result, there are no efficiency advantages that could result from greater process transparency and significantly improved options for increasing the level of automation and integrating suitable Industry 4.0 solutions.

State of the art

In literature there are different approaches which try to consider the planning of the energy consumption into the production control. Newer interesting approaches shall be presented in the following:

- The research project EnHiPro (Energie- und Hilfsstoffoptimierte Produktion) is funded by the BMBF and based on a continuous energy data collection. It addresses the question of how the efficiency of energy and auxiliary materials can be improved. Therefore technical and organisational methods are developed to evaluate the energy efficiency as well as their effects [4].
- AssiEff (Assistenzsysteme für die auftragsbezogene, effiziente Produktion) is a research project which try to improve the operational excellence in production facilities during operation. A special start-stop control allows an automatic shutdown of not needed machine components to save energy. In addition, an energy efficient sequence of order should lead to further reductions [5] [6].
- Similar to the AssiEff in the reaserch project EWOTeK (“Effizienzsteigerung von Werkzeugmaschinen durch Optimierung der Technologien zum Komponentenbetrieb”) intelligent strategies to shift order sequences were developed. Because of a continuous energy data collection pending production orders are evaluated and adjusted as needed [7].
- In the project E-SimPro is the focus at the reduction of production costs of production facilities. With the help of a developed software the cost-effectiveness of the whole production infrastructure can be evaluated by simulating the energy need. So a machine based quantification of energy needs for defined production orders is expected [8].

Moreover, existing software solutions shall be introduced which integrate energetic aspects into functionalities of production planning and control systems (PPC):

- The company FertigungsLeitSysteme GmbH has developed the software tool which use PPC data and point up improvements in the production process and needed adjustments to save energy [9].
- The factory-planning software IMValidation produced by iFAKT GmbH simulate and compare different planning scenarios. For each planning alternative different production figures (e.g. capacity, buffer, cycle time) will be shown. This data among can be analysed to find the most energy efficient production strategy other things [10].
- ProModel is a software toll from the company ProAspect GmbH. It helps to achieve sustainable improvements in the production by planning, evaluation and optimisation of production processes. Due to an integrated simulation different aspects of a production infrastructure can be modified to analyse to effects and find the most efficient production strategy by considering the energy consumption [11].

Considering the analyzed state of the art, there are various solutions and techniques to improve the energy efficiency in production by using new information and communication technologies. So different solutions allow a direct integration of energy data into production planning and control systems. The disadvantage of all of them is the need of cost intensive machine networking. Because of the high investments especially small and medium enterprises (SME) have reservations to implement such an infrastructure. A more suitable and cheaper approach is the use of electrical wiring in production infrastructures to draw conclusions to the current production process.

The project iKnowControl

Based on the described problem situation, the research project "iKnowControl" was initiated, which is funded within the framework of the Hessian LOEWE 3 program by the Hessen Agentur GmbH in the period from 01.01.2017 to 31.12.2018. The project consortium led by Prof. Sven Rogalski consists of a system development company and two application companies as well as the University of applied sciences Darmstadt.

Project goal

The aim is to identify real-time operational data using pattern recognition from energy profiles based on existing energy data collection systems that many German companies are already using as a result of legal guidelines and tax reductions. By using the existing communication structure of an energy acquisition system, this data should be made available to production management without the construction of additional structures / system solutions (such as MES). At the same time, it is intended to detect energy load peaks in the planning phase of production and disposal processes by providing the energy requirements corresponding to the planning systems (usually Enterprise Resource Planning (ERP) is used). The hardware and software components to be explored and prototypically developed should on one hand be tested in the area of product manufacturing, using the example of cutting CNC production. On the other hand, a trial of these solution components should be tested in the field of waste recovery processes.
As a result, it should be demonstrated that for smaller and medium sized companies or company location sites it is also possible to record and evaluate energy-relevant process relationships cost-effectively on a continuous basis and to make the resulting information available to operational management in form of operating data.

System concept

The figure below shows the system concept of iKnowControl, which is explained in more detail below:

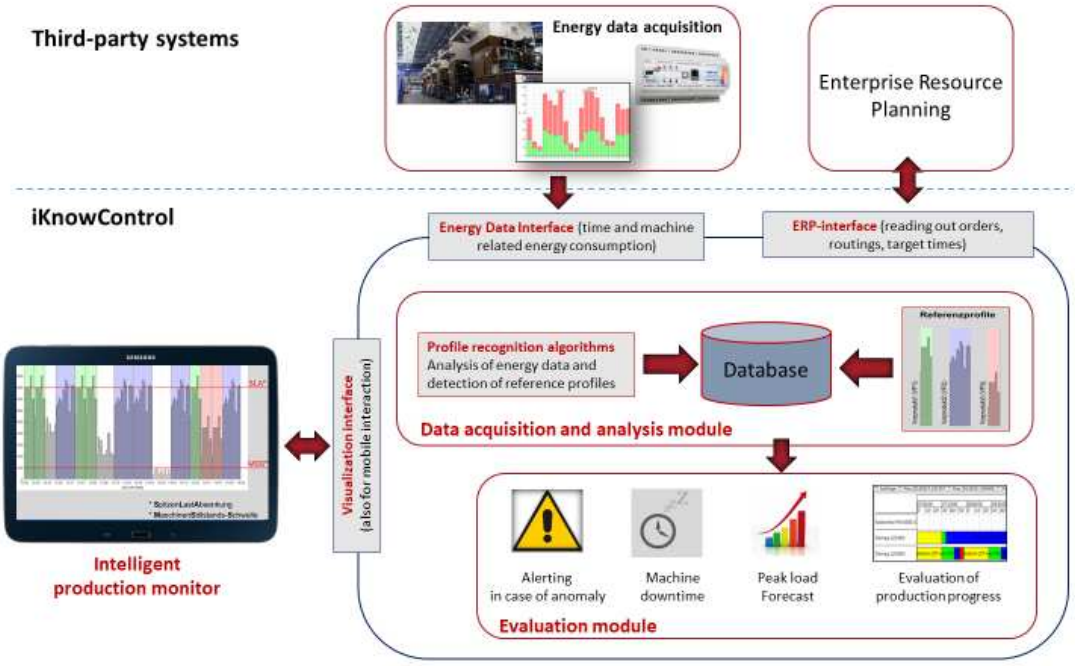

Fig. 1. System architecture of the iKnowControl solution

To carry out the required evaluations with the iKnowControl system, it is necessary to continuously record the energy consumption of machines/facilities in relation to time and machine. For this purpose, a hardware interface for energy data acquisition via external systems is required (see Figure 1). It is used to detect analog and digital signals in industrial environments and is a hardware that provides various interfaces (Ethernet, RS485, USB, etc.). A second software-technical interface enables the information coupling with the system world of the ERP in order to record time and product-relevant order and work plan data.

All data collected by iKnowControl are stored in a uniform database (see Figure 1). By creating semantic relations between machine operation, product, process duration and energy demand, the prerequisite for context-based queries is created. Using so-called reference profiles, which are collected once for a product by reading its energy profile under technical-personal evaluation. The occurrence of a stored reference profile in the database is detected in real time and assigned to the referenced product by using a profile detection algorithm.

As a result of available relations in the data base, the automatically recognized reference profiles and intelligent queries can be generated dynamically via a so-called evaluation module (see Figure 1). On one hand, it is possible to call up classic operating data, such as the number and type of products already processed on one or more machines, as well as their average energy requirement and process time. On the other hand, machine utilization and standstill times can be determined by the definition of limit values for the base load operation of machines /facilities. The same applies to forecasts and anomalies, since the necessary energy requirements of individual work operations are known, and these only have to be calculated cumulatively, which leads to a corresponding alarm when a limit value is exceeded.

On the one hand, the information determined with the evaluation module can be made available directly in the ERP via the existing ERP interface in order to initiate measures (for example, rescheduling). On the other hand, using the visualization interface provided in the iKnowControl system, you can use your own web-based visualization called "intelligent process monitor" (see Figure 1). All information obtained based on the evaluation module is individually retrievable to indicate to the persons responsible (e.g., PPS planner, master, machine operator).

Service experience

In this chapter the first project results, which were made based on prototype solution modules at the CNC cutting production as well as the waste recovery company, will be presented.

Energy data evaluation in the field of waste disposal

At waste recovery company, the field of waste crushing was chosen as the subject of investigation. First, energy-intensive station within the waste processing facility, the various wastes are delivered, transported to a conveyor belt with an excavator and fed to the crushing plants, which has different levels of energy demand and load peaks depending on the type of waste. Using an app specially developed for this project, the excavator driver uses a tablet to determine the type of waste he is currently unloading. The waste-related weight of an excavator bucket is reviewed here at regular intervals to ensure the most accurate possible evaluations. By combining this information (type of waste and weight) with the energy needs of the waste crusher, a dynamic determination of the energy input for an explicit type of waste per bucket is possible (see Figure 2). This opens up new evaluation and planning options for the company. Among others ensuring the early determination of the energy demand for shredding processes, which already plays an important role in the planning of the waste supply to avoid cumulative peak loads in relation to the entire site. The same applies to the controlling at the site, since the newly gained transparency has led to a significantly improved cost calculation for the waste to be disposed.

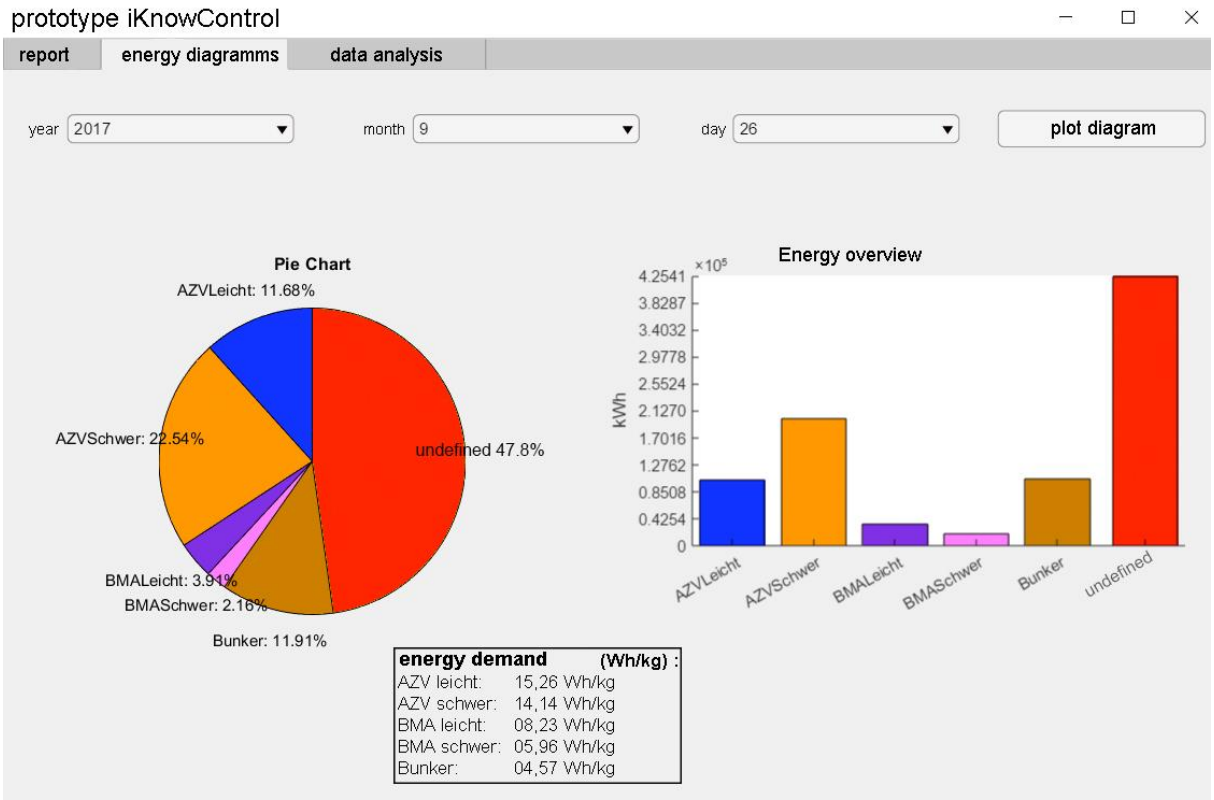

Fig. 2. Presentation of different types of waste with the corresponding energy requirement at the iKnowControl process monitor at waste recovery

Energy data evaluation in the field of CNC machining

With approximately 30 employees the CNC cutting company produces various precision parts on CNC lathes and milling machines, from small to large series production. Due to the lack of continuous, digital operational data acquisition, an energy measuring system was installed, which records the power consumption for two selected machines. During the investigation period a total of four different types of repeating parts were produced on these machines which made it possible to achieve a high degree of reproducibility and thus a good recognition of the reference profiles in the live energy data. After the so-called learning of the collected reference profiles into the system, it was shown that the profile recognition algorithm explored in the project already shows a very good level of realization. As a result, the products manufactured on the two machines could be automatically identified based on their specific energy profiles and further processed for the purposes of operational data analysis. The detection rate of the currently pre-prototypic algorithm is over 99%. The following figure shows a screenshot of the iKnowControl process monitor with the results of the reference profile recognition.

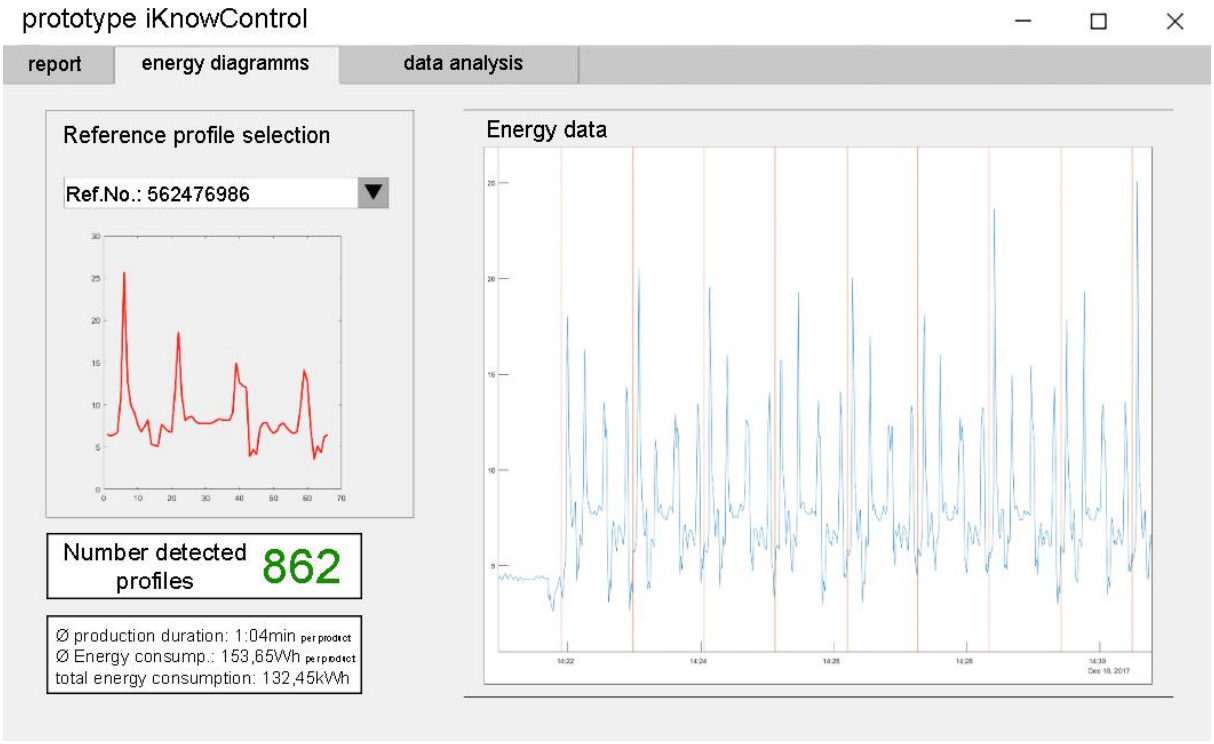

Fig. 3. Presentation of the results of the profile recognition algorithm on the iKnowControl process monitor at CNC production

Summary and outlook

So far, the results of the project provide a promising picture of the use of pure energy measuring systems for the prediction, planning and control of production and disposal processes. Thus, even smaller companies can benefit from a modern information provision in real time, which opens further possibilities for this target group in the context of Industry 4.0. It has been demonstrated, if only in selected case studies with limited complexity, that intelligent data evaluations based on the developed energy profile recognition algorithm are possible. A much more comprehensive use of the iKnowControl solution is to be expected. The results described here have already been achieved after a relatively short realization time and form an excellent platform for the outstanding R & D activities in the remaining nine-month project period.

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Towards Digital Knowledge Transfer in Small and Medium-Sized Manufacturing Enterprises

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Abstract. This paper gives an insight into the project "Education 4.0 for SMEs". Small and Medium-sized Enterprises (SME) in the high-technology sector of lightweight-construction are implementing more and more digitization processes for their industrial settings. These processes strongly depend on internal knowledge transfer. We consult these SMEs to find out which kinds of digital learning technologies and pedagogical concepts are useful for their in-company education and training. Besides featuring well-known learning technologies such as wikis, videos and webinars, novel learning methods based on mixed-reality will be developed and tested.

Keywords: Knowledge Transfer · Learning Technologies · Education Tools and Methods · SME.

1 Introduction

More and more branches of industry have started using lightweight construction materials consisting of carbon fibre reinforced plastic (CFRP) over the last years. Often referred to as "black gold", carbon composites are known for their special physical features, including being extremely light, and as such have gained influence in industry as well as research. The specific composition of the material makes an application in well-established areas of use (such as the sports sector, construction of airplanes etc.) [3, p. 9] possible, as well as providing innovative potential for a variety of products that are only at the start of market penetration [7, p. 30]. Apart from the ongoing development of composites, digitization

is the second large challenge that composite companies are facing today, especially Small and Medium-sized Enterprises (SME), that abound in the composite sector. On the one hand, they need to implement digitization processes in their industrial setting, the result of which is referred to as "Industry 4.0" [2] in Germany. On the other hand, the challenge of digitization is closely connected with meeting the customers' needs for digitizing complete value-adding networks typical of the composites branch. As production cycles become shorter and shorter and technical innovations abound, plant construction and the development of new machines have to comply with ambitious requirements aiming at both high efficiency and flexibility.

Employees have to keep abreast of these developments, but often lack the necessary IT skills. According to a study by the Centre for European Economic Research (ZEW) about "Digitization in medium-sized companies, its status quo, recent developments and challenges" [6], only one in five companies has a comprehensive digitization strategy. The largest obstacles are the lack of IT skills (67%), reservations about data protection and data security (62%) as well as high costs (59%).

Thus, as Industry 4.0 projects are implemented, the staff need to aquire different and new qualifications and skills (e.g., in specific software, IT technologies, or machines), but also concerning skills in interdisciplinary cooperation. A study by the German Economic Institute [8] shows that 85% of enterprises in Germany invest in their employees' further education and training. To this end, enterprises offer classical ways of training like seminars, but increasingly also use informal formats that allow their employees individual on-the-job training, be it supported by digital media or in the form of information meetings. However, a majority of employees does not feel well prepared for digitization, as 72% claim to lack the time for further trainings on digitization issues and 59% say that their employer does not offer any further training on said topic according to the German Association for IT, Telecommunications and New Media [5].

This situation is the starting point of the project on "Education 4.0 for SMEs". It aims at finding out more about possible support of SMEs in their digitization challenges in terms of knowledge transfer. In a high-technology sector such as the composite sector, it is essential to collect a company's knowledge of specific software, IT technologies, or machines and to share this knowledge among its employees. Hence, the main objective of the project is to research and develop organizational and technical solutions to support SMEs in the composite sector by introducing or improving digital knowledge transfer in order to prepare them for the challenges of "Digitization" and "Industry 4.0". To achieve this, we are working with selected SMEs from the composite sector association Carbon Composites e.V. (CCeV) which is also a project partner.

This paper, after sketching the research question in section 2, outlines the approach of the project, dividing it into an organizational and a technological dimension (cf. Sect. 3). Due to the close connection of digital learning and knowledge transfer, not only to the skills but also attitudes of the learners themselves, it is paramount to include reflections on the motivational design relevant to the

project's proceeding (cf. Sect. 4) before giving an outlook of the conclusion in section 5.

2 Research Question

SMEs within the lightweight construction sector mostly focus on developing their production processes, but this development highly depends on their employees' know-how. Demographic change, the lack of skilled workers and a growing importance of knowledge-intensive ways of production as a consequence of the current digitization process [1] even add to this dependency, besides knowledge management, the project addresses (digital) training and education processes in SMEs, which are often neither well defined nor efficient. Discussing these difficulties with a group of SMEs, our project focuses on the following research question:

"How can SMEs be supported in digitization challenges through digital knowledge transfer and learning offers so that they can integrate these digital learning processes into their day-to-day work as easily as possible?"

Based on this research question, we have defined three research interests, which are sketched in the next three sections.

2.1 Type of Training: General vs. Specific Knowledge

A first focus of our research interest lies on the type of training. Therefore, the project aims at assessing which digital tools or strategies perform best within certain contexts and for which types of knowledge. One context includes trainees during their vocational training, which is based on a dual system in Germany. This means that trainees attend vocational schools, where they are provided with general knowledge about their future jobs. At the same time, they work in a company, where they acquire more specific knowledge, e.g., containing company specific information. This differentiation in general and specific knowledge can be mirrored for other further education opportunities within the company.

Thus, in a context of on-the-job training, for example, education media for generic topics could be developed and shared with other companies, making use of the network of composites companies we address during the term of our project. Possible topics might be safety requirements, machine operation descriptions, or – on a meta level – digital tools themselves as a support for digital learning (see Sect. 3.2).

2.2 Type of Trainee: From Consumers to Producers

A second part of our research question can be seen as addressing the role of the learner, which goes hand in hand with certain learning strategies or methods. While in the area of knowledge management it is common to self-document know-how, it is unusual for employees to develop learning media. This might be the case due to the lack of tools that can be used without special educational skills. However, young people in vocational training today are used to producing

presentations, blogging, writing and commenting within social media and even creating graphics and charts. Also a lot of people working in the training sector of SMEs are used to develop simple kinds of learning materials like operational sequence descriptions as text or graphics. All these people are able to describe detailed facts in a face-to-face situation.

So, why not use a camera to produce a video? It will not look like a perfectly produced video with a professional speaker, special cuts, or be perfectly illuminated. But it will fit perfectly in internal training scenarios; and meanwhile smartphones provide adequate video quality. Moreover, using mixed reality (MR) technology it is possible to record motion sequences and annotate them with context-sensitive information in 3D. In this way, for example, an operational sequence can be shown in 3D, e.g., how to set up a machine. Starting from this sample of digital methods, the project will explore in which ways and how effectively employees develop, use and react to which measures.

2.3 Type of Devices: Office vs. Shop Floor Environments

A sustainable implementation of digital strategies of learning and knowledge transfer in SMEs of the composite sector entails specific challenges. A fundamental distinction between such companies and typical office workplaces is that access to IT equipment is not granted in factory buildings. Especially in the composite sector, dusts of composite material would destroy standard computer equipment within a short period. Therefore we are discussing with SMEs within our project-network how to support learners and media producers – on average there are two PCs available for a whole manufacturing department (on the basis of interviews with our project partner SMEs).

Since media affinity of learners is important for deciding which kinds of media should be offered, for example in an e-learning course, we want to develop a study on the media affinity of employees in the composite sector. This study should recommend which kind of media is efficient in which use case based on demographic as well as social or cognitive factors, for example age, affiliation to a specific department, or one's level of experience.

3 Approach

Based on the main objective of the "Education 4.0 for SME" project, i.e., to support SMEs in their digital knowledge transfer, the project implements four measures in close collaboration with the selected SMEs of the German composite networks CCeV. This is shown in Fig. 1. These measures are evaluated and best-practices are condensed. Within the network, every SME shall have access to a broad base of tools, best practices and support about digital knowledge transfer. On a supraregional level synergies and cooperation structures between SMEs are initiated.

Starting with the determination of requirements within SMEs, individual concepts and solutions for digital learning are developed. In order to provide

innovative solutions, the project also includes demonstrations of digital learning technologies such as mixed reality scenarios, webinars or videos. Lastly, in order to improve the implementation of specific tools and strategies, the project supports the collaborating SMEs in this phase in line with demand. Exemplary content will include safety instructions and the set up of machinery. Aiming at sustainable solutions, the project focuses on helping enterprises develop and implement digital knowledge transfer themselves. In concrete terms, SMEs should be supported to integrate digital media into their own training and personnel development strategies.

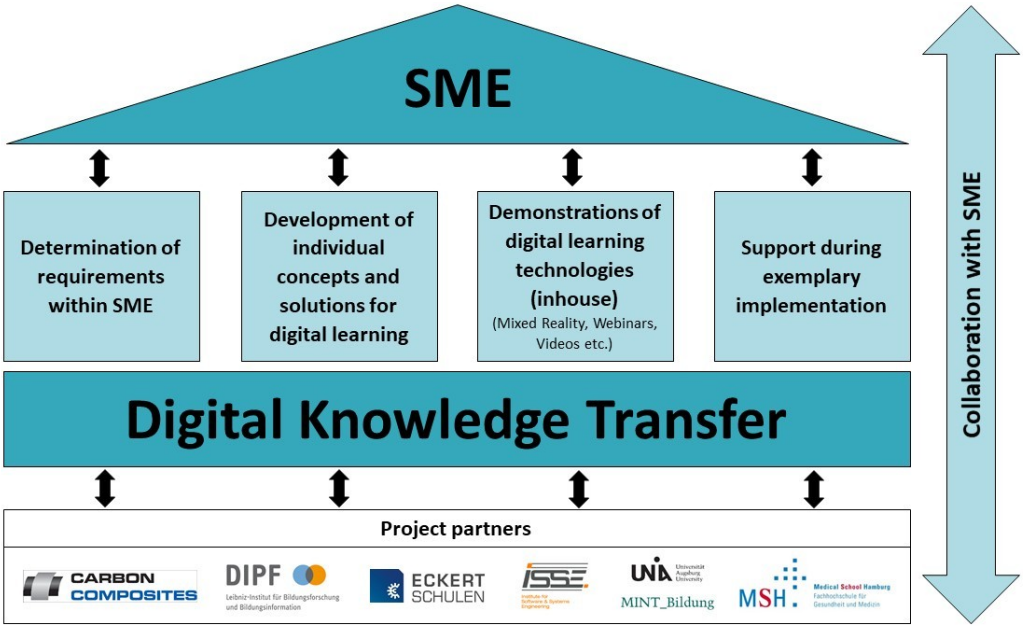

Fig. 1. Approach of the "Education 4.0 for SMEs" project.

By the close cooperation with individual SMEs, we aim at achieving some general insight into possibilities and challenges of digital knowledge transfer in a high-technology sector such as the composite sector. We expect that these insights will have an organizational (cf. Sect. 3.1) as well as a technological dimension (cf. Sect. 3.2).

3.1 Organizational Dimension

On the organizational dimension, the topics of concrete learning modules include specific solutions for requirements identified in a respective analysis, such as digitization of existing strategies of knowledge transfer. Here, organizational factors such as the structure of the company with respect to its different departments and existing strategies of knowledge transfer are at the center of interest in order to explore the effectiveness and sustainability of the chosen strategies. This includes personal factors, such as gender, age, cultural background, or level of experience. Through a mobile learning studio provided by our project, SMEs

can use required technical infrastructure within the company to develop and evaluate different knowledge transfer and learning strategies. Moreover, employees will be qualified to create their own learning modules based on their specific knowledge and their point of view.

3.2 Technological Dimension

The project will feature a broad range of different digital learning and knowledge management technologies. The SMEs are thus able to test and evaluate different approaches. Moreover, it allows us to compare different technologies for the same content. Thus, best practices can be developed for different categories of content. In addition to well-known digital teaching-learning solutions (such as wikis, podcasts, webinars or video conferencing), novel digital learning infrastructures are used. A mixed-reality (MR) learning environment is being developed for this purpose. This allows users to perform a learning module while interacting with machines. In such a setting, context-sensitive information can be shown directly where it is relevant (e.g., at a button or a lever). With this MR learning environment, employees should be enabled to "record" their typical setup or operation procedures for a machine. As a consequence, they digitize their machine-specific knowledge and make it available to other, less experienced colleagues.

4 Motivational Design

To ensure the objective of achieving progress in embedding digital learning methods into the manufacturing sector, a motivational design is conceptualized. This design will serve the purpose of supporting the processes of self-regulation while performing a learning action. The basis for creating the motivational design is a hierarchic developmental model which consists of three extension levels (see Fig. 2). This gradation does not only help to ensure the productivity of the hereby developed learning system but also enables evaluation at an early stage.

The *Integrated Model of Learning and Action* (German: Integriertes Lern- und Handlungsmodell; ILHM) [4] is used as the theoretical foundation of the model as well as findings from the research of SensoMot (German: Sensorische Erfassung von Motivationsindikatoren zur Steuerung adaptiver Lerninhalte). The levels, more specifically the learning content and the single features, are being developed considering the context of lightweight construction.

The ILHM consists of a motivational phase, an intentional phase and an action phase. All three phases contain several segments, for which oneself needs to be in different affective states. Specific feedback processes, assuming they were successful, will then help to keep a self-regulated learning motivation [4].

The objective – to increase the motivational fit between the needs of the learner and the digital educational offer – can be realized through the user's feedback processes which will allow an adaptation of the presented materials and/or methods. For that purpose, the motivational needs will be integrated into the motivational design, e. g. the need for deciding on a learning content

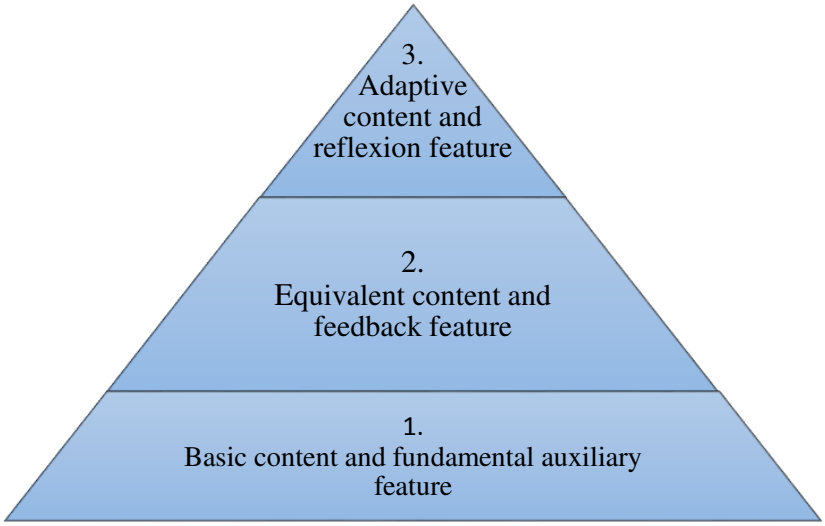

Fig. 2. Hierarchic Developmental Model.

and a strategy autonomously. It is important to consider the segmentation of learning content, multiple learning strategies the user will have access to, as well as accompanying feedback and auxiliary features. Based on the motivational design, motivational indicators will be drawn to then be integrated into the SensoMot project where physiological parameters will be identified and collected. By creating those parameters, it will be possible to automatically match a certain digital learning environment to the motivational needs of the learner. Hence, through the individualization of the learning experience, the motivational design should offer a more profound motivational approach, specifically a higher learning efficiency, a linkage of learning contents and a transferability of those contents, which will result in higher memory capacity for the learned content.

The motivational design should also be applicable to the context of mixed reality (MR), minimizing immersion and therefore decreasing the blocking of a learning experience. Particularly in the manufacturing sector, introducing such a design is of great importance in order to ensure the maximization of successful learning in the context of machine- and target-oriented apprenticeship and training.

5 Conclusion

In this paper, we presented the research question of the "Education 4.0 for SMEs" project and introduced its approach. The SMEs we are targeting are from high-technology sectors – in our special case from the lightweight-construction sector. In a high-technology sector, the employees' knowledge of specific software, technologies or machines are crucial for the success of a company. Hence, the main objective of the project is to research and develop organizational and technical solutions to support SMEs in the composite sector by introducing or improving digital knowledge transfer. For this kind of knowledge, relevant employees must be enabled to create digital learning modules in a few steps. Hence, employees

must be enabled to become producers as opposed to consumers of digital learning solutions. To achieve this, we closely collaborate with selected SMEs from the composite sector association CCeV on an organizational as well as on a technological dimension. From the latter, we consider well-known digital teaching-learning solutions and novel digital mixed-reality learning infrastructures.

Acknowledgements

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E-Waste & the Circular Economy: An Irish SME Context

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Abstract. E-waste is a term given to waste generated by electrical and electronic equipment (WEEE). It is one the fastest growing waste streams in the EU, and it is expected to grow to more than 12 million tonnes by 2020. WEEE raises a dual problem for the environment; on the one hand, the composition of WEEE is highly toxic and represents a serious threat to the environment, and on the other, there are precious materials that can be recovered from WEEE; materials that can be used in the production of other goods. Reverse logistics is mainly the backward flow of used products from consumers to producers. Remanufacturing brings the benefits of availability, economics and security, energy savings, and reduction in the need for dirty processes. The estimated value for all manufactured products in the remanufacturing intensive sectors is €1.5 trillion.
The growing problem of E-waste is defined in this research, and the benefits of the services that 'Wisetek', (the company at the core of this research) offer for managing this E-waste issue are outlined. E-waste is a solution for data centres and Wisetek are leaders in the circular economy. Their services include remanufacturing IT equipment and then remarketing to approved buyers. This research study recommends that Wisetek adopt an innovative approach through their strategic decision making to transfer their competencies into the EU. The strong presence that Wisetek have in other key global regions must be enhanced into the European market.
Keywords: E-waste, Circular Economy, Reverse Logistics, Remanufacturing, Data Centres, GDPR.
Keywords: First Keyword, Second Keyword, Third Keyword.

1 Introduction

Wisetek are IT asset disposal (ITAD), reuse and data destruction services providers. Leaders in the circular economy, their services to clients include global site audits of IT equipment and providing their clients tailored reports. Wisetek's TotalRMA™ web portal provides data centres with secure and easy to use online system, that allows data centre personnel to register redundant product details. Wisetek provide remanufacturing services of IT equipment. This involves dismantling IT equipment and any recovered components are tested. Components that are reusable are then re-marketed to approved buyers, defective or non-usable components are responsibly recycled to the R2 standard (Wisetek.net). This research study is an empirical investigation into the importance of reverse logistics, remanufacturing and electronic recycling in data centres, in particular a focus on the data centre hubs in Germany and The Netherlands. Western

Europe has established a number of technology hubs in major cities including Dublin, London, Amsterdam and Frankfurt, that are growing rapidly. The study examines a range of topical issues in cloud computing and data centres. The issues of remanufacturing and reverse logistics, along with recycling of electronic waste (E-waste) with regard to current legislation, cyber security, corporate social responsibility (CSR) and efficiencies in data centre infrastructure management are investigated. The next section presents the research context and research question.

1.1 1.1 Research Context

The circular economy is perhaps the biggest revolution for the global economy in the last 250 years and is gaining momentum (Timmermans, 2016); in 15 years from now, it could be worth $4.5 trillion. Geissdoerfer et al., (2017) define the Circular Economy as a regenerative system in which resource input, waste emission and energy leakage are minimised by slowing, closing and narrowing material and energy loops. A circular economy requires a transformation of both production and consumption systems; the standard approach for creation, fabrication and commerce of products is challenged (De los Rios and Charnley, 2016). The concept of the circular economy is, to an increasing extent, treated as a solution to a series of challenges, (Lieder and Rashid, 2016) such as waste generation, resource scarcity and sustaining economic benefits. Switching from the current linear model of economy to a circular one, has recently attracted increased attention from major global companies e.g., Google, Unilever, Renault, noted by Lewandowski, (2016) and policymakers attending the World Economic Forum. The reasons for this are very significant financial, social and environmental benefits (Lewandowski, 2016). Reverse logistics, indicating the process of this return flow highlighted by Olariu (2014) encompasses such activities as the movement of returned products, facilities to accommodate returned items and overall remedy process for returned items. The area of reverse logistics has recently received considerable attention, due to a combination of environmental, economic and social factors (Olariu, 2014). Reverse logistics refers to the series of operations as articulated by Alshamsi and Diabat (2015) that initiate at the consumer level with the collection of products and terminate with the re-processing of these products at remanufacturing facilities. Reverse logistics, which is mainly the backward flows of used products from consumers to producers, is an important stage while constructing a recovery system (Alshamsi and Diabat, 2015). A remanufactured component is, by definition, (Robinson, 2014) going to provide the same service as the original, so that the original component or system considerably extends its life, therefore, end-of-life scrapping is postponed. Remanufacturing and refurbishing activities also may be included in the definition of reverse logistics (Robinson, 2014). The development of remanufacturing highlighted by Xiong et al., (2016) in many industries where high-profile manufacturers like Boeing, Caterpillar, General Electric, IBM, Kodak, Volkswagen and Xerox initiate a business model in which remanufacturing is an integral part (Xiong et al., 2016). Remanufacturing makes up a small share of European manufacturing output, accounting for an estimated 1.9 % of total production value in these sectors. The four key regions estimated to account for some 70 % of remanufacturing value in Europe are, Germany, the UK,

Ireland, France and Italy. Germany undertakes most remanufacturing by a significant margin, making up almost a third of the European market (Remanufacturing.eu). E-waste is a term given to waste generated by electrical and electronic equipment (WEEE) (Heacock et al., 2016). This comprises of equipment such as televisions, mobile phones, computers, IT equipment and household appliances. E-waste is produced in staggering quantities, estimated globally to be 41.8 million tonnes in 2014 (Heacock et al., 2016). It is one the fastest growing waste streams in the EU, with some 9 million tonnes generated in 2005 and expected to grow to more than 12 million tonnes by 2020 (Ec.europa.eu). Baldé et al., (2014) note that in Europe, the total E-waste generation was 11.6 million metric tonnes in 2014. The European countries with the highest E-waste generation in absolute quantities are, Germany (1.8 million metric tonnes), The United Kingdom (1.5 million metric tonnes) and France (1.4 million metric tonnes) (Baldé et al., 2014). Recycling for E-waste will be a necessity, not only to address the shortage of mineral resources for the electronics industry, but also to decline the environmental pollution and human health risk (Zeng et al., 2017). The rapid consumption of new electronic devices has expanded the volume of E-waste, Gonul Kochan et al., (2016) and this has created a potential threat to the environment. Recycling of E-waste can help stem the proliferation of E-waste and its environmental threat (Gonul Kochan et al., 2016). In Europe, manual dismantling as a first treatment step has been gradually replaced by mechanical break up of appliances, (Salhofer et al., 2016) followed by sorting out of hazardous and valuable components (Salhofer et al., 2016). Recycling of electronics is good for the environment when done in an appropriate manner as it recovers materials for reuse and reduces waste in landfills (Ceballos and Dong, 2016). Cloud computing has become the next logical step for the IT industry. It's the new strategic weapon in enterprise computing and the new norm in every sector of society. Businesses, educational institutions, governments, community organizations and individuals are looking at cloud offerings to manage information, instead of infrastructure (Bojanova et al., 2013). The cloud computing paradigm has sustained its growth, which has led to increase an in size and the number of data centres. Data centres with thousands of computing devices are deployed as back end to provide cloud services (Shuja et al., 2016). Data centres are physical infrastructures that are used for housing and operating servers, routers, switches and networking systems, along with, storing and processing a large amount of data belong to an organisation (Sapdatacentre.com). These new data centres are the physical manifestation Katz (2009) of what Internet companies are calling cloud computing. The physical environment of data centres are strictly regulated and air conditioning is used to control both the temperature and humidity, Jones et al., (2013) and data centres also have water and smoke detection systems and sprinkler systems. Powerful cooling systems are required to offset the heat produced by the servers and more energy is needed for cooling, than for data storage and processing (Jones et al., 2013). Data centres must provide not only performance guarantees, but reliability ones as well (Wood, 2011). Disaster recovery services attempt to protect applications by continuously replicating to a secondary data centre, that can be switched to, in the event of catastrophic data centre failure (Wood, 2011). The aims of this research study are to provide an analysis of reverse logistics, remanufacturing and electronic recycling in the data centre hubs of Frankfurt and Amsterdam and how likely is

it that the service offerings of Wisetek will fit into these markets in the future. The next section presents the literature review for this research study.

2 Literature Review

2.1 Data Centres

A data centre (or datacentre) is a facility composed of networked computers and storage that businesses or other organizations use (Rouse, 2010). Data centres are described by Flucker and Tozer (2013) as mission critical facilities; they are essential for the business to carry out its mission and hence any interruption in service, downtime or unavailability usually has a significant cost impact (Flucker and Tozer, 2013). The concept of data centres has been around since the late 1950s, when American Airlines and IBM partnered to create a passenger reservations system, automating one of its key business areas (Woods, 2014). Server virtualization technologies first appeared in the 1960s to enable timesharing of expensive hardware between multiple users (Dasgupta et al., 2011). Carcary et al., (2013) note that by 2011, it had become the top technology priority for organizations worldwide to reach $241 billion by 2020. Hao et al., (2010) state that today's large data centres are the computational hubs of the next generation of IT services (Hao et al., 2010). This is disputed by Fulton III (2016) stating that the Internet of Things (IoT) would be a cleverer architecture than a colossal hub-and-spoke topology that testifies to its power to change the landscape of data centres. IoT could, if it continues to develop the way it has, draw more compute, storage and bandwidth power towards the edge away from centralized facilities and closer to where these various streams of data are being gathered (Fulton III, 2016). A data centre typically houses a large number of computing and storage nodes, interconnected by a specially designed network, namely, data centre network (DCN) (Xia et al., 2016). Data centres that house the cloud systems, revealed by Preimesberger (2015) that serve up the apps used on connected devices, are popping up all over the globe and often in cities away from the traditional core markets (Preimesberger, 2015). Yesilyurt and Yalman (2016) suggest that this model has become more desirable for all institutions, organizations and for personal use thanks to the storage of 'valuable information' at low costs, access to such information from anywhere in the world, as well as its ease of use and low cost (Yesilyurt and Yalman, 2016). The proprietary rating system begins with Tier 1 data centres, which are basically warehouses with power and ends with Tier 4 data centres, which offer 2N redundant power and cooling in addition to a 99.99% uptime guarantee (Colocationamerica.com). Arno et al., (2012) state that the Tier classifications provide guidelines and a gradient scale of data centre designs, that can be used in conjunction with reliability engineering to design or evaluate an existing critical facility (Arno et al., 2012).

2.2 Types of Data Centres

Data Centre Hosting is provided by a facility that stores and maintains servers and applications for clients and it can help companies reduce capital expenditures and accelerate the implementation of technology with on-demand services (Cyrusone.com). Guo et al., (2017) outline that colocation data centres who rent out spaces to multiple tenants to house their servers, are another important but under-explored type of data centre (Guo et al., 2017). Masoud et al., (2017) state that internet exchange points (IXPs) emerged to remedy the deficiency of peering connections among autonomous systems (ASes) and play an important role in reducing the cost of transit connections over the Internet (Masoud et al., 2017). It is outlined by Benson et al., (2010) that as data centres become increasingly central in Internet communications, both research and operations communities have begun to explore how to better design and manage them (Benson et al., 2010). Security and privacy of data are some of the most important issues of cloud data services (Tang et al., 2016). It is noted by Silverman (2016) that in November 2015, Target settled with the consumer class for $10 million plus $6.75 million in attorney's fees. In May 2016, it settled with the last third of the issuing banks for nearly $60 million, with just under $20 million in fees and expenses for plaintiffs' counsel following their data breach. Silverman (2016) further notes that Home Depot settled its consumer claims at $19.5 million for damages and prevention plus around $8.5 million in fees and costs (Silverman, 2016).

2.3 E-Waste

As of 2010, the Environmental Protection Agency, according to Dewey (2013) reported that of the 2,440,000 tons of disposed of technology waste which included computers, monitors, hard copy devices, keyboards and mice, televisions, mobile devices and TV peripherals, 1,790,000 tons were sent to landfill and only 649,000 tons, or 27%, was recycled (Dewey, 2013). Rosenfeld and Feng (2011) convey that electronic waste is responsible for 70% of the heavy metals (including mercury and chromium) found in landfills (Rosenfeld and Feng, 2011). In January 2003, the EU issued a directive on E-waste to deal with increasing quantities and the included hazardous components (Favot and Marini, 2013). It is claimed by Peagam et al., (2013) that very little business to business WEEE is reported as collected in the EU in compliance with the WEEE Directive, which uses the policy principle of extended producer responsibility (EPR) to ensure that WEEE is managed correctly (Peagam et al., 2013). A series of reports revealed that such major E-waste flows reach China, India, Pakistan, Ghana and Nigeria, outlined by Kuper and Hojsik (2008) that in these countries, refurbishment and recycling activities are mostly carried out by the informal E-waste sector, which is characterized by poor working conditions with insufficient management of hazardous substances leading to adverse impacts on human health and the environment (Kuper and Hojsik, 2008). As the world’s largest dumping ground for E-waste, much of the population in Guiyu, China is exposed to heavy metals due to informal E-waste recycling processes (Song and Li, 2015). Vick (2016) notes that data centre decommissioning has recently become an evolving function that is more than just IT Asset. Remanufacturing,

by taking back used products, can help firms meet environmental regulations and improve economic benefits (Han et al., 2016). Ruth (2009) concludes that significant new regulations for IT equipment disposal to stringent energy-efficiency specifications for PCs and monitors to national standards for data centre power savings, Green IT is an "in" topic (Ruth, 2009).

2.4 E-Waste Legislation

Abu Bakar and Rahimifard (2008) explain that in Europe, 7.3 million tonnes of WEEE were created in 2002 and the growth rate of WEEE is 3 to 5% per annum, with a significant amount of this waste used to be dumped into landfills without any pre-treatment, has resulted in the introduction of a European WEEE directive (Abu Bakar and Rahimifard, 2008). Manhart (2011) records that in the last decade, electrical and electronic equipment (EEE) such as computers, mobile phones and DVD players, increasingly became mass products in emerging economies and even developing countries (Manhart, 2011).

2.5 IT Asset Disposition (ITAD)

Disposal or Excess Inventory Management (including Remarketing and Consignment), is about closing or merging a data centre without a huge loss to your company's revenue (Vick, 2016). IT asset disposal is getting rid of personal computers, servers and other obsolete or unneeded devices in a secure and environmentally sound manner (Carr, 2007). Haas et al., (2015) outline that the circular economy is a simple, but convincing, strategy, which aims at reducing both input of virgin materials and output of wastes by closing economic and ecological loops of resource flows (Haas et al., 2015). There is a window of opportunity to escape the "dump regime", dumps are being challenged by the circular economy, which has established instability in the "dump regime", (Johansson et al., 2012). Diabat et al., (2013) outline that remanufacturing is the basis of profit-oriented reverse logistics in which recovered products are restored to a marketable condition in order to be resold to the primary or secondary market (Diabat et al., 2013). Paterson et al., (2017) state that remanufacturing is a product recovery strategy resulting in end of life products being returned to as new condition or better and receiving a warranty at least equivalent to the original (Paterson et al., 2017). It is stated by McKeen and Smith (2010) that Total Cost of Ownership (TCO) advocates for a holistic view of IT costs across the enterprise over time, grouped into a series of direct and indirect cost. Knowing the full costs allows organizations to make optimal decisions regarding the enhancement, retirement, renewal and/or replacement of critical IT assets (McKeen and Smith, 2010). Shin et al., (2013) state that conventional data centres, based on wired networks, entail high wiring costs, suffer from performance bottlenecks and have low resilience to network failures (Shin et al., 2013). Saran (2013) outlines that tackling energy efficiency in a datacentre's operations is the main way to limit its carbon footprint and the cooling system is the biggest culprit in terms of inefficiency (Saran, 2013). Hou et al., (2013) conclude that many IT service providers are

in dire need of new servers that can support their applications/services efficiently while keeping the cost of their data centres under control (Hou et al., 2013).

2.6 Frankfurt and Amsterdam Data Centres

The combined material weight of the servers, networks and storage systems in the German data centres is 37,500 tonnes, whereas the total product weight of all terminals comes to 134,300 tonnes (Fichter and Hintemann, 2014). Frankfurt data centres are among the world's most carrier-dense with DE-CIX Frankfurt, the largest Internet exchange point in the world (Equinix.com). DE-CIX Frankfurt, the flagship in a family that includes facilities in New York, Istanbul and Dubai is the No.1 Internet traffic hub on the continent, during peak traffic times, the exchange can move data at a rate equivalent to processing 4 billion emails per second (Hackett, 2015). Telecomworldwire.com claim that Amsterdam is a digital gateway, allowing businesses to reach 80% of Europe within 50 milliseconds (Telecomworldwire.com). Hackett (2015) concludes that geographically situated, between several important digital destinations, Frankfurt, London and Paris, the Amsterdam Internet Exchange serves as one of the biggest traffic routers in the world, channelling roughly 700,000 terabytes a month (Hackett, 2015).

2.7 General Data Protection Regulations (GDPR)

Directive 95/46/EC on the protection of individuals with regard to the processing of personal data and on the free movement of such data (the "Data Protection Directive" or the "Directive") was adopted as a legislative measure in October 1995 (Carey, 2010). The Federal Data Protection Commissioners (2017) notes that the current European Data Protection Directive will be replaced in May 2018 (Ec.europa.eu). Zhang and Dong (2016) remark that to ensure the security of the outsourced data, data users need to periodically check data integrity (Zhang and Dong, 2016). It is explained by Rasheed (2014) that for many companies the remaining barriers to adopting cloud computing services are related to security and one of these security issues is the lack of auditability for various aspects of security in the cloud computing environment (Rasheed, 2014). That concludes the Literature Review and the next section presents the Methodology for this research study.

3 Methodology

3.1 Case Study Research

Yin (2009: 18) defines a case study as "an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident", (Yin, 2009: 18). There is a need to clarify and unify the understanding of what is meant by a case study pointed out by Runeson et al., (2012) and how a good case study is conducted and reported (Runeson et al., 2012).

3.2 The Methodology and Strategy for this Research Study

This study was exploratory in nature and after an extensive review of the existing work in the area, in was believed that a post-positivistic approach was the best method that would afford the most integral range of new data to develop new findings for this research study. A qualitative research approach was considered as the best way to accomplish the research objectives outlined earlier in this paper. Given the research objectives and the research question that needed to be addressed, the researchers believed however, that a quantitative approach would not generate the rich quality of data required for this research study, hence, the qualitative path. A thorough review of secondary research through peer review academic journals, books, newspaper articles, industry specific magazines, official government statistics, doctorate dissertations, conference publications and internet websites were undertaken. From this, to create a process of gathering information from the primary sources, semi structure interviews were undertaken. First, five semi structured face to face interviews were undertaken with the board of management of the company at the core of this study – Wisetek, and then, twelve semi-structured face to face interviews with senior executives in data centres who had significant experience in the filed were completed. A pilot interview was conducted first to check for any research issues and to illuminate biased and ensure reliability and validity.

3.3 The Data Collection Process

A list of interviewees was developed that would best provide the primary data results needed to achieve the objectives of this research study. The sample of the interviewees was purposely selected and directed at senior management in relation to their academic qualifications and business experience within data centres specifically. The interviewees were geographically located in the data centre hubs of Frankfurt and Amsterdam and in Boston, Massachauttes in the USA. An interview guide consisting of four questions was prepared for the management of Wisetek to obtain a macroenvironmental overview of the services of Wisetek for data centres and microenvironmental overview of Wisetek. The questions were discussed in detail and then pilot tested with a business advisor in the field. From the results of the pilot test, there was obvious ambiguity in one of the questions that was asked. The questions were then adjusted to allow the participants a clear understanding of how to answer. These researchers then proceeded to carry out the interviews with the management of Wisetek. The same process was followed for the twelve other participants from the data centres. A test was undertaken with an expert in the field to gains insights and to improve the guide. A concluding interview guide of 10 questions was finalised after the pilot process. The researchers believed that these questions were clear and easy to understand and would provide valuable primary data for this research study.

3.4 Data Analysis

There are seven key methods of analysis, four of which are the pattern-based methods of thematic analysis, interpretative phenomenological analysis, grounded theory and pattern-based discourse analysis (Braun, 2013). Coding and categorising are ways of analysing that can be applied to all sorts of data and are not focused on a specific method of data collection as pointed out by (Flick, 2007a). This is not the only way of analysing data, but it is the most prominent one, if the data result comes from interviews, focus groups or observations. The main activities are to search for relevant parts of the data and to analyse them by comparing them with other data and by naming and classifying them (Flick, 2007a). Thematic analysis focuses on the data at hand (Rosenblatt, 2015) rather than demanding a process of repeated analysis, repeated grounds of data gathering and multiple stages of theory development. Flick (2007b) notes that for the design of case study triangulation, similar questions arise as for designs in qualitative research in general. Triangulation can be used in the context of one of the basic designs in qualitative research. You can plan a case study using a variety of data sorts or different methods or theoretical approaches.

4 Main Findings and Discussion

4.1 Competitive Edge

Supporting (Han et al., 2016; Paterson et al., 2017), this current research has found that Wiseteks' services provide a competitive edge for data centres from their quality, efficiency, innovation and customer responsiveness in services of data sanitisation and remanufacturing. This current research has found that 83% of respondents determine that the circular economy and remanufacturing provide a competitive edge to data centres through providing end of life value to the IT assets, converting end of life assets into revenue and decreasing the cost of replacement assets. Similar to Jayaram and Xu (2016) who found that firms that have a closer alignment between external and internal knowledge appear to excel in both quality and efficiency (Jayaram and Xu, 2016).

4.2 Influencers of Change

In support of (Favot and Marini, 2013; Peagam et al., 2013) this current research study has found that the key core influencers of change for data centres are from the changes in technology and legislation. There exists an environment of responsible recycling and of green IT and green computing in companies. This current research has found that 66% of respondents determine that legislation is the key core influencer of change while 33% of respondents believe that with the growth of data centres, scaling, cost reduction and getting value is the key core influencer of change. Seeberger et al., (2016) previously found that the USA is a major producer of E-waste, although its management practice and policy regulation are not sufficient to meet the challenge.

4.3 Exporting of Competency

In line with (Clegg, 2011; Eicher, 2016; Joardar et al., 2014), this current research study has found that the exporting of competency as assessed in Wisetek is through auditing the standards set by Wisetek and the consistency in the facilities in geographic regions. This current research has found that 66% of respondents believe that auditing of facilities is how the exporting of competency is viewed. Hillier (2016) previously outlined that the acquisition of one firm by another is, of course, an investment made under uncertainty and the basic principles of valuation apply. One firm should acquire another only if doing so generates a positive net present value for the acquiring firm (Hillier, 2016).

4.4 Competency Assessment

In line with (Cadle et al., 2014; Gander, 2017; Gębczyńska, 2016), this current research study has found that competency is assessed in Wisetek internally and externally through their critical success factors (CSF's), key performance indicators (KPI's), Lean manufacturing and certification programmes. This research found that 60% of participants believe that Wisetek's competency is assessed through their certification and manufacturing. It has been previously highlighted by Zhang et al., (2016) that Lean Manufacturing has a higher implementation rate than Six Sigma in the logistics industry. This is because process variations, what Six Sigma tackles, are often not a main concern in logistics processes due to the absence of physical transformation (Zhang et al., 2016).

4.5 Understanding of IT Asset Disposition

Supporting (Carr, 2007; Haas et al., 2015; Johansson et al., 2012) this current research has found that IT Asset Disposition is understood as the disposal of switches and servers other unwanted IT equipment from data centres. This current research has found that 100% of respondents in Germany and The Netherlands determine that the IT Assets need to have their data shredded before disposal to eliminate the risk of data breaches. It has been outlined by Lowe (2011) that a critically important part of data lifecycle management is destroying data at the end of a medium's useful life. If this step is overlooked, it can lead to disastrous results. Recommended methods for destroying data on magnetic media are shredding, degaussing, department of defence level data overwrite, smelting and encryption from the beginning (Lowe, 2011).

4.6 The Services Expected from an IT Asset Disposition Services Company

In support of (Tang et al., 2016; Silverman, 2016;) this current research found that services expected from an IT Asset Disposition Services Company are a full service of in house certified data destruction of sensitive equipment containing private and protected data. This current research found that 100% of respondents from Germany and 50% of respondents from The Netherlands believe that destruction of data and handling

of private and protected data is the top priority. It is stated by Salisch and Mayfield (2017) that the financial, operational and reputational damage from a data breach can be enormous and can imperil the very existence of a breached organisation (Salisch and Mayfield, 2017).

4.7 Capital expenditure v running cost expenditure

In support of (Hou et al., 2013; McKeen and Smith, 2010; Saran, 2010), another finding of this current research is the importance of capital expenditure v running cost expenditure in decision making, when evaluating IT Asset purchase provides variable information. This current research has found that 40% of respondents in Germany and 100% of respondents in The Netherlands believe that OPEX and total cost of ownership (TCO) is becoming more important in evaluating IT Assets. According to Gendron (2014) when IT infrastructure are acquired, they are traditionally treated as CAPEX. They are recorded as an asset on the balance sheet and depreciated over time. Buying infrastructure for in-house installation is CAPEX and buying services from a cloud vendor is OPEX. There is a trade-off between CAPEX and OPEX that occurs when moving applications to an external cloud (Gendron, 2014).

4.8 Corporate Social Responsibility

In support of (Dewey, 2013; Favot and Marini, 2013; Rosenfeld and Feng, 2011), this current research found that Green IT is what companies want to be part of. It is outlined by Dalvi-Esfahani et al., (2017) that some suggestions are made to foster and enhance psychological drivers in order to motivate managers to adopt Green IT in organisations, though there is a need to formulate proper strategies and educational methods to reinforce individual factors of decision-makers more towards environmental sustainability (Dalvi-Esfahani et al., 2017).

4.9 Benefits for the Data Centre Market

In support of (Carr, 2007; Johansson et al., 2012), this current research found that the benefits to the data centre market, from and ITAD services company are, that it generates value and provides a competitive advantage to data centres. Contrary to Shin et al., (2013) noting that data centres have performance bottlenecks and have low resilience to network failures. This current research has found that 40% of participants from Germany and 50% of participants from The Netherlands believe that income from the disposal of E-waste is a benefit for the data centre market. It was previously stated by Shuva et al., (2016) that E-waste can be viewed as a resource for metals, as it does not only contain the common metals like iron (Fe), aluminium (Al), lead (Pb) and copper (Cu) but also traces of precious and rare elements such as gold (Au), silver (Ag), tin (Sn), selenium (Se), tellurium (Te), platinum (Pt), palladium (Pd), tantalum (Ta), cobalt (Co) and indium (In). The recovery of these trace elements is vital, not just because it has high commercial values, but also for resource efficiency (Shuva et al., 2016).

4.10 Certification Programme

In line with Peagam et al., (2013) and Ruth (2009) another important finding of the current research is the value of a certification programme. It provides assurance that compliance with regulations is met. This current research has found that 100% of participants from Germany and The Netherlands believe that a certificate programme will motivate and help the industry as long as the certification has meaning and will add value. Renckens (2015) that non-state certification programmes can emerge as a result of both failed or absent governmental regulation and international cooperation, the case of E-waste recycling certification shows that even when an international agreement with widespread membership exists, non-state regulation covering problems dealt with under the agreement can still emerge. Established to be used globally, these programmes do add important elements to existing public E-waste legislation in countries that have ratified the Basel Convention or which have promulgated legislation dealing with collection and take-back of E-waste, hazardous content of electronic devices, or recycling practices (Renckens, 2015).

4.11 Services to build on WEEE

In support of Abu Bakar and Rahimifard (2008) and Manhart (2011), this current research found that 100% of participants from Germany and 50% of participants from The Netherlands believe that services who build on the existing WEEE requirements are to provide transparency and a clearer framework of the regulations along with integrating the certificates with ISO standards. “It has been previously highlighted by Khan et al., (2014) that key players particularly the developing countries, should have a voice in the decision of WEEE management. It is important to have a neutral arena where the solution for WEEE management can be achieved by mutual consultation (Khan et al., 2014).

4.12 Changes and trends in collection targets

Contrary to (Favot and Marini, 2013; Peagam et al., 2013; Ruth, 2009), this current research has found that 60% of participants from Germany and 25% of participants from The Netherlands are aware of focus groups that are working on E-waste legislation and they are unaware of any lobby groups that are dedicated to collection targets. It has been previously stated by Atasu et al., (2016) that the issue of the disposal of waste electrical and electronic equipment (WEEE), firms are frequently unaware of the threats posed by such legislation, poor at anticipating its provisions and effects, and generally not very skilful at representing their interests in the political process (Atasu et al., 2016).

4.13 Data protection for end of life equipment

In support of (Carey, 2010; Ec.europa.eu; Rasheed, 2014; Zhang and Dong, 2016), another important finding of this current research is the stringent controls and rigorous audits of returned material to protect against data breaches. This current research found

that 60% of participants from Germany and 75% of participants from The Netherlands have procedures in place to prevent data breaches of end of life equipment. It is stated by Martin et al., (2017) that transparency and control in a firms' data management practices can suppress the negative effects of customer data vulnerability. Mere access to personal data inflates feelings of violation and reduces trust. The negative effects, as well as spillover vulnerabilities from rival firms' breaches, on firm performance. The severity of the breach hurts the local firm but helps the rival firm (Martin et al., 2017).

4.14 Remanufacturing as a Key Business Driver

In support of (Han et al., 2016; Paterson et al., 2017; Robinson, 2014; Xiong et al., 2016), another important finding of this current research is that remanufacturing is a key business driver. This current research found that 60% of participants from Germany and 25% of participants from The Netherlands believe that remanufacturing is a cost driver that facilitates pricing models. It is stated by Kwak and Kim (2017) that the potential of generating green profits through remanufacturing needs to be supported by optimal pricing and production planning. Potential concerns and barriers to OEM remanufacturing, which include unproven economic profitability and the environmental sustainability of remanufacturing, imbalance between the supply of end-of-life products and demand for remanufactured products and the risk of cannibalizing new product sales (Kwak and Kim, 2017). This concludes the discussion of the main findings. The next section presents the recommendations and final comments.

5 Conclusion

This research study has evaluated Wisetek as an international organisation operating in different key geographic regions. The operational excellence has been the most distinct value associated with the success of the company to date, however, as an international organisation, there are many challenges for Wisetek operating in a global market, with significant competition from other large players. This research study has determined that it is imperative for the future success of Wisetek to expand and enhance its shareholder value. There is an immense opportunity to develop innovative strategies that will enhance the ability for Wisetek to grow in Europe and Wisetek should commence a plan to transfer their competencies into Germany and The Netherlands. The marketing of Wisetek needs to focus on becoming more visual in these geographic regions and not, however, just during times when organisations require their services. The marketing expertise and budgets that larger competitors of Wisetek possess suggests that these competitors will continue to be a visual presence in the target markets and on a global stage. Wisetek cannot underestimate the influence that high profile organisations can have on the market of the country that they are operating in.

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Framework for requirement analysis in the design of collaborative robots on construction sides

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Abstract. The workplaces on construction sites are comparatively little automated, as they have a high degree of flexibility in tasks and a diverse physical environment, that makes a high level of automation difficult. However, the physical workload is often very high for construction workers, leading to a high risk for musculoskeletal disorders. It would therefore be conceivable to use physical assistance systems to reduce the workload of the construction worker. This might be achieved by collaborative robots: they can combine the advantages of a robot with those of humans to adapt to different situations.
The following article develops a framework for the requirements that are necessary in order to design a collaborative robot for the work on construction sites. For this engineering and ergonomic approaches are combined. Based on a work system approach and requirements examined for fixed work cells in the industry, the characteristics of the work on a construction site are clustered to. That can be used to derive requirements for the assistive robot.

Keywords: Construction work, human robot collaboration, work system analysis, requirements

1 Introduction

Most construction workers work on their jobs and tasks decentral on their sides under all weather conditions. Therefore, the workplace of the construction worker is regularly changing, when a new project starts. Also building itself contains the remodeling of the environment. This requires a high flexibility and adaption to the physical environment in which the tasks are carried out. Furthermore, one worker often performs a variety of tasks with different demands within their jobs [1]. Compared to automated systems, humans excel in mobility and adaption to new spaces and tasks [2–4] This is the reason why, in most cases, the work on construction sides has a low level of automatisation. However, the risk for musculo-skeletal disorders due to physical workload is high for construction workers. For example, musculo-skeletal disorders caused 20,1 % of the work incapability days in 2016 [2]. Following the TOP principle, usually applied in ergonomics [5], technical solutions should be used first of all to reduce the physiological strain on these workstations.

One possible technical solution is the use of collaborative robots for tasks with high physical demands. A collaborative robot can be defined as a robot that works in close proximity with the work person in the same workspace and is closely interacting with the work person in order to achieve their common work goal [6]. As collaborative robots might be able to work closely together with the human, they combine high repetition accuracy and high physical action force with the benefits of the human worker. Therefore, collaborative robots have been widely advertised as assistive systems adaptable to the work persons needs in industries [4].

This contribution aims to develop a framework for the analysis of user requirements for collaborative robots on construction sides. The framework should help to analyze the special circumstances, on construction sides and due to the near collaboration of human and robot.

2 Method

A multidisciplinary approach is used, combining engineering and ergonomic knowledge, to set the framework. First common methods and procedures in product development process from an engineering and an ergonomic point of view are reviewed. Afterwards general frameworks for requirement analysis are introduced. Then application of these methods in the field of human robot collaboration regarding task allocation and requirement analysis is reviewed.
Based on these insights, a framework for the development of the requirement analyze is derived. To identify the context of use, the work system approach has been used.
Key groups that are derived from the reviewed literature, that consider topics that need to be addressed when designing a robot for a job on a construction side.

3 State of the Art

There is a wide range of methods and approaches that are proposed for product development process they differ in the specific problems that need to be considered the design. Different standard approaches are used for the design of human robot collaboration. While Ore et al. [7] and Duffy et al. [8] adapt the generally known product design process from Pahl and Beitz [9], Nelles et al [10] choose the framework of the human centered design process. Both Ogorodnikova et al. [11] and Weber et al. [4] presents a framework for the development of the work station with high focus on safe physical interaction.

The requirement analysis is a crucial part of all product design processes [9]. In the user centered design process, the requirements are derived from the context of use [12]. The standard proposes to derive them form the context of use, the needs of the user, existing standards, and usability requirements, and organizational requirements.

With focus of the practical implementation, the analysis of potential of industrial human robot collaboration various authors propose both ecological and ergonomic point of views [4, 7–9, 13, 14]. Also the operator participation from an early stage on is considered essential for a successful implementation [4, 15].

Two methods have been found in the literature for application of specific requirements. Ore et al [7] addresses the functional characteristic, quality criteria and geometrical characteristics in the first stage of the design of a human robot workstation. Also the necessity for a rough analysis of the potential form an ecological point of view is highlighted. Weber et al on the contrary focus highly on the safety of the workperson and address technological, medical and biomechanical requirements, ergonomic requirements and work organizational requirements that apply to the safety and wellbeing of the human worker [4, 7, 16, 17]

Both authors focus on safety of the working person as crucial requirement for the successful implementation. To achieve this, the application of applicate the standards EN ISO 10218 part 1 and part 2 defining the safety of industrial robots and the technical specification ISO/TS 150066 for collaborative robots is necessary [4, 14].

Apart from its potential for reducing the physical load, simply introducing a collaborative robot to a work system to take over some or all of the humans physical tasks, is not sufficient enough, to harvest the full potential of the synergies between human and robot [17]. Therefore, task allocation is one of the most important parts on the early development stages for a successful assistive robot [18]. The human performance is highly dependent on the workload, hence, if humans are supervisors without participation, their performance is poor [19]. Therefore, the workload, skills, aptitude and strain of the human needs consideration [4]. There is a wide research body on the strain that might be caused by the robot properties, for example the robots movement and position [20]. An Overview on the impact of robots on the human well-being is provided by Nelles et al [21].

However, these approaches focus on fixed workstations in production lines and cyclic tasks with limited tools and materials. Up to the authors knowledge, there has been no framework of requirements analysis for robots in mobile workplaces or frequently changing tasks. However, this mobility and flexibility needs to be addressed in order to implement a successful and accepted robot on construction sides.

4 Framework

The key objective of the framework is to help implementing human factors, into the technical design process in order to achieve a work system that enables human and robot work together effectively and efficiently on their tasks and to enhance the satisfaction and wellbeing of the human.

Therefore, the first step is to analyze the tasks that need to be fulfilled, the active elements of the work system, its purpose and the input and output of the system. Here there should be especially a focus on the stress that might be caused by the demands of the tasks and the strain and aptitude of the user.

The tasks need to be allocated between robot and working person. As mentioned above, this is takes careful considerations. However, task allocation will be not addressed in this paper.

The requirements that can be analyzed based on the work system are clustered in four groups: functional requirements and user related requirements, the physical environment and organization set requirements. The groups are displayed in Fig. 1. Safety needs to be addressed as foundation for a successful implementation and is related to all groups.

The user related requirements address the overall goal that the human should be able to work along the robot without restriction of his physical and mental well-being Therefore the demands of the working persons remaining tasks should be balanced and the impact of the robot on the strain and aptitude of the worker minimalized. In collaboration, the worker and the robot need to coordinate each other. Therefore, means of communication are necessary. These should have a high usability, especially regarding reprogramming and general control. It is important that there is no reduction of comfort or productivity if the worker is to accept the robot as an assistance system.

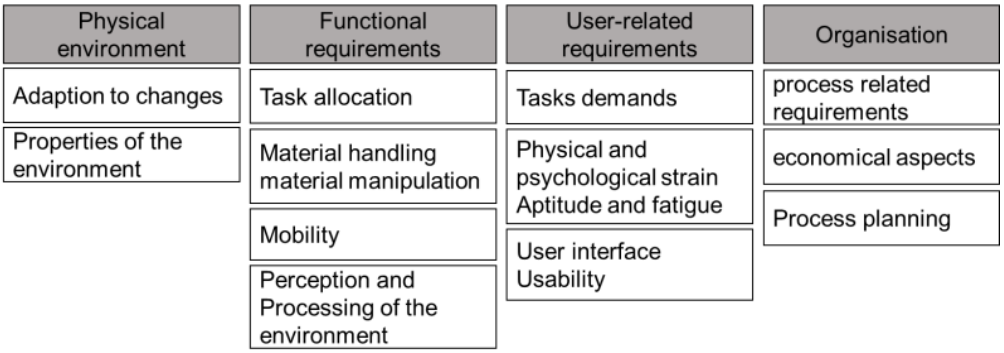

Fig. 1. Framework of topic groups for the Requirement analysis.

The functional requirements examine from a technical point of view the characteristics and the requirements of the robot directly related to his function. These include requirements that concern the handling of the materials as well as requirements which define the tools the manipulator needs to fulfill the tasks. On construction sides, the variety of jobs and their tasks need to be accessed. Also the materials that are often viscous can be challenging for the manipulator. In many cases it might be suitable to have a mobile solution, that can move independently within the work space. For this and also for safety, the robot's perception and information processing capabilities need to be dimensioned appropriately.

This leads to the third group the physical environment. As mentioned above, the construction sides are often distributed decentral. So the robot needs to be able to adapt to new environments. Also, the workspace is constantly changing, which is challenging the robot. The types of different situations need to be considered. The properties of physical environment also can be confounding factors- on construction sides there is often humility, dirt or dust, that can affect the system heavily. The robot should be design resilient against these.

The fourth group is summarizing the demands that arise regarding output of the work system and the overall planning. These concern the overall system efficiency, economical aspects, such as the price of the robot and the criteria for evaluation regarding to the standards.

5 Conclusion

With this framework the requirements for the robot as assistance and support system on a construction site can be examined. With the work system approach it is assured, that all aspects of the future workplace are considered. In future, the framework will be applied and evaluated on the example of tilers. Furthermore, more research should be carried out on the topic of task allocation in non -cyclic tasks and the impact of the robot on the strain and aptitude of the work person.

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Chapter 6

Business and Society

What Is This Thing Called Use Case Inheritance?

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Abstract.
In more than two 2 decades of use case modelling there has been a imprecisely defined notion in UML since v1.1 that has never been fully understood, namely use case inheritance (UCI). Therefore, this paper suggests a necessary reconciliation to achieve a broader acceptance and attractiveness in practice while reducing confusion, with a clear demarcation from the Include/Extend relationships. This is done based on implications from the author's completed PhD research, UCI suggestions found in research contributions, technical text books as well as literature about OO inheritance semantics, and the author's personal professional industry experience. Rather than being a typical formal research paper, the drivers of the presented solution proposal are to offer pragmatic and practical UCI application rules for the industry. This should offer a basis for further qualitative validation by requirements engineers in practice, and, also for future conceptual research.

Keywords: Use Cases, Use Case Relationships, Requirements Engineering, Inheritance, Specialization, Generalization, Subtyping, Polymorphism, UML.

1 Recollection of Use Case Basics

1.1 Actors, Goals, and Use Cases

An actor specifies a role that can be taken by a person, a piece of hardware, a component, or a software application [18],[17],[20]. Each actor has certain operational responsibilities imposed by the surrounding business processes and rules. In order to fulfil its responsibilities, the actor has to perform a number of operations. It wants some subset of these operations to be facilitated by a software application or hardware apparatus. Thus, it sets corresponding goals for the system to deliver. These goals lead to desired functional system requirements specifications, i.e. not internal design solutions, expressed by use cases [1],[10]. Each use case delivers a single go al (see Example 1). An actor instance processes only those use cases that the actor is connected to.

Example 1: Use Case Goal
"Register New Customer Order"

Basic Course:

1. Sales clerk enters customer ID.
2. System displays customer profile.
3. Sales clerk confirms that the customer's credit rating is sufficient.
4. System assigns an order ID.
5. Sales clerk registers the desired trade items and payment information.

Use Case Postconditions:

System has initiated an order, has documented payment information, and has registered the order with the customer.

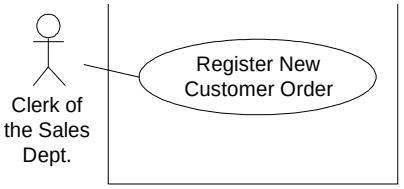

Fig. 1: Use case diagram for Example 1

Alternative Courses:

1a. Sales clerk wants to look up the customer:
.1 System shows all customers.
.2 Sales clerk browses the list and selects one.
Rejoin at 2.

3a. Customer's outstanding debts are above the threshold:
.1 System notifies the key account manager for mediation purposes.
Use case fails.

1.2 Use Case Pre- and Postconditions

From the goal of each use case a set of corresponding outcomes is derived to be established upon successful goal delivery [1],[10], i.e. successful use case completion. Each of these results is required by the business processes associated with the discussed use case and, therefore, is delivered to at least one primary actor or stakeholder [1],[4],[5],[10],[19],[20],[25]. The set of use case business results are also called *use case postconditions* [4],[5],[20],[30], In many cases, a use case requires some condition to hold *before* it can be triggered and executed by an actor instance. These are called *use case preconditions*. The view of use case goals, use case pre- and postconditions were considered a "contractual" specification [10],[20],[31] thereby seemingly resembling the Design-by-Contract principle in [25]. However, there is a fundamental difference: Design-by-Contract demands the caller of a service to guarantee the preconditions in order for the callee to deliver this service, the result of which is specified by postconditions. Clearly, for use cases an actor instance is the "caller". However, use case precondition checking is always a system responsibility, i.e. done by the callee but never by the caller [1],[4],[5],[10],[20],[30]. For example, the preconditions of an ATM's "Withdraw Cash" use case would include "Cash reservoir not empty". Therefore, use case pre- and postconditions do not correspond to Design-by-Contract.

1.3 Use Case Interaction

Accomplishing the goal-driven postconditions by the system might require active interaction with the actor instance at the *system boundary* [1],[4],[10],[17],[18],[19],[20]

1.4 The Extend- and Include-Relationships

The Include and Extend relationships have been defined and explained as *static* relationships for use case *restructuring* or *refactoring* of *specifications*, e.g. for removing redundancy or use case decomposition [1],[4],[5],[15],[14],[18],[19],[22],[23], [24],[32]. In this respect, Extend is explained as attaching to a base use case a description of a set of interaction steps that can be subject to a condition. On the contrary, Include is understood as attaching a description of a mandatory set of interaction steps. Therefore, an inclusion/extension use case always remains a *part* of a *static* system functionality *description*. In fact, in [24] it has been shown that Include and Extend follow whole-part (aggregation) relationship semantics.

If factored out by Include/Extend these interaction parts also form a use case, i.e. they receive a goal and post-conditions. It follows that this goal is a sub-goal of the base use case, i.e. the summarising goal for the factored-out interaction which is a *subset* of the base use case interaction. This is obvious for Include-attached interaction, and it is also true extension (and therefore conditional) use cases. Arguing that an extension use case may or may not be executed depending on condition evaluation is a *runtime* or at least a *scenario* perspective; in contrast, as shown above use cases are *static requirements descriptions* (see Section 1.1) prior to design, so talking about goals is a *conceptual* and *business semantics* perspective.

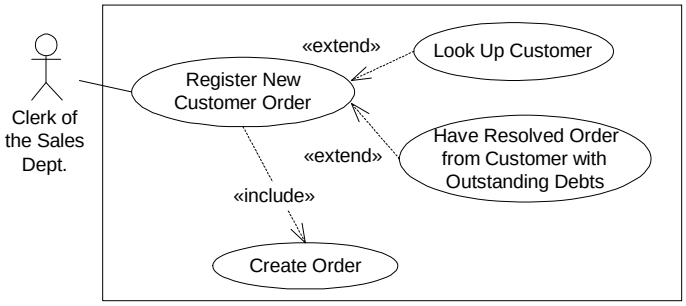

Fig. 2: Use case diagram of Example 1 showing the alternative courses, and interaction steps 4 and 5 factored out by Include and Extend, respectively

Hence, exclusion use cases hold sub-goals, i.e. either something additional, or a different approach to fulfilling a base use case interaction step [23]. See Fig. 2 as an example: the goal “Create order” would be a summarising goal of the interaction steps 4 and 5 in Example 1; the goals for alternative course 1a in Example 1 would be “Look Up Customer”, and its postcondition could be “Customer has been marked”. We see that goal-subgoal semantics are independent of model restructuring/refactoring through Include/Extend [1],[10].

2 Use Case Inheritance – Literature Review and Related Work

In practice, and in some literature e.g. [20], it is sometimes believed that Extend can be seen as a generalisation relationship. However, Section 1.4 and, also, references [22],[24],[32],[36] show that this view cannot be uphold. Furthermore, the fact that

to have the same semantics since otherwise this distinction would be meaningless.

It can often be observed that it is silently assumed, or even explicitly claimed, that UCI works the "same way" as with classes in the OO domain [17],[18],[19],[26],[27]. This view is probably fostered by UML's persisting foundation of use cases as Classifiers since v1.1, which yields object semantics [26], and also by former UML v1.4's statement:

> *"A generalization relationship between use cases implies that the child use case contains all the attributes, sequences of behavior, and extension points defined in the parent use case, and participates in all relationships of the parent use case. The child use case may also … add additional behavior into and specialize … behavior of the inherited ones."* [26].

Most authors avoid making any commitment and prefer to provide explanations like UCI is about "variations", "indicating commonalities", the child use case "doing a bit more" than the parent use case, or "adding to and redefining/overriding" parent interaction and properties [1],[3],[4],[5],[6],[19],[20],[28],[29].

In [18] Jacobson introduces the idea of "abstract use cases", i.e. a use case which contains generic interaction step placeholder to be expanded on in a child use case, a concept which is also supported by UML [26].

In [4],[17],[18],[27] it is claimed that a child use case must preserve the parent use case order of interaction steps. Apparently, this is driven by the assumption that use case inheritance should ensure OO behavioural conformity when substituting child entities for parent entities (see Section 3 for more explanation).

In [2] it is suggested that

> *"inheritance between use cases should be applied whenever a single condition … would result in the definition of several alternative courses."*

thereby making fuzzy the concepts of locally specified alternative interaction courses (*ScenarioPlusFragments* use case pattern in [1],[10] and the extracting of such alternative courses via Extend (*PromotedAlternative* pattern in [1]). Why creating a new use case instead of simply adding the new behaviour to the given use case?

To [1] Rawsthorne contributed the *CapturedAbstraction* use case pattern, which develops further Cockburn's idea of documenting Technology Variations [10]. This pattern suggests placing pure technology variations of given parent use case (e.g. interactions for blind people, voice control, loading of a keycard instead of money dispensing for a Withdraw Cash use case) into new child use cases instead of cluttering the parent use case up with a large number of alternative courses.

Cockburn [10] further suggests applying UCI in order to remove redundancy through parameterisation: consider the use case "Find Customer Order" in the sales domain. Further consider the use case "Find Insurance Policy" in the insurance domain.

these use cases will contain identical interaction logic with respect to "finding something". He suggests placing all identical interaction steps into the parent use case and adding placeholders at those places at which each child use case sets concrete concern-specific interaction (see Example 3, below). A notation for this is not proposed though. The same suggestion is made in [5] by Bittner/Spence and [16] by Hitz/Kappel.

In [30] it is claimed, without further explanation, that there is no UCI at all.

3 Consulting Object-Oriented (OO) Inheritance Semantics

Basically, in the OO domain inheritance is not only considered an implementation tool but also a general modelling and "thinking" concept. It addresses the creating of abstractions based on existing abstractions without modifying the latter (*Open-Closed principle*). Ideally, inheritance ought to represent *subtyping* which is also referred to as *conceptual specialisation*, or *strict inheritance* [35]. Subtyping demands true semantic correspondence of the child to its parents. A further goal of subtyping is the enabling of the processing of an object of a subtype on behalf of an object of a supertype (*substitutability*), thereby demanding *behavioural compatibility*, a term which is also referred to as *semantic conformance* or *behavioural subtyping*. This introduces *dynamic polymporphism*, as also called *subtyping polymorphism* or *dynamic typing,* that is realised by *late-binding*. Such behavioural compatibility has been addressed by e.g. Meyer's Design-by-Contract [25], the Liskov Substitution Principle (LSP) [21], or by Cook/Daniels [11], all of which guarantee the Open-Closed principle.

Inheritance further introduces the possibility of defining semantic abstractions with the decision about their properties' data types being deferred to instantiation time. This is called *parametric polymorphism* which does not require runtime concepts like late-binding [8],[34]. Today, in the programming domain this concept is often compared to *template classes* or *generic programming*.

In spite of the fact that subtyping was often regarded as the only legitimate reason for applying inheritance [35], the evolution of OO approaches, systems, languages, and concepts has shown that inheritance does not necessarily ensure subtyping. Rather, inheritance allows the modification of child properties in various manners by adding, redefining/overriding, and even removing properties, and by changing visibility of properties [35]. In the implementation domain, this is particularly exploited for pragmatic reasons such as saving coding effort (reuse), reducing memory needs, or introducing more efficient algorithms, all of which is not based on conceptual reasons. Furthermore, inheritance can be used as a pure *hierarchical structuring* tool by introducing *abstract classes* revealing *abstract operations*, i.e. having no methods; in contrast, *concrete* sub-classes provide such methods, thereby further supporting polymorphism. Pure abstract classes, i.e. having abstract operations only, equal to the concept of *interfaces*. This, in turn, has led to the concept of *interface inheritance* as opposed to *property inheritance* [35], i.e. inheriting operations vs. inheriting methods, attributes, constraints and associations. Due to the possibility of object concatenation (*delegation*)

which provides the ability for an object to change its parents at runtime [8],[33],[35].

All this makes it impossible to make the objective statement that the "very essence" of all types and variations of inheritance apparently is allowing *incremental modification* while following the *Open-Closed principle* [35].

4 My Proposal – Discouraged Use Case Inheritance Semantics

4.1 Use Cases Cannot be Treated Polymorphically "At Runtime"

I suggest that substitutability (see Section 3) should not valid for use cases. Why? Use cases are not programs but static requirements specifications (see Section 1.1). Hence, why would an actor instance need to process a more special or more general use case on behalf of the one that was specified for it based on its individual operational responsibilities, role definition, job description? Why would an actor instance perform a use case the postconditions of which would deliver more or even less than needed by the surrounding business process needs and business rules? Therefore, use case performances are *non-substitutable*, i.e. for use cases there neither is *runtime polymorphism* and *late binding* nor *dynamic inheritance*.

4.2 Multiple Use Case Inheritance Disregarded

UML allows multiple inheritance of use cases [26]. However, my opinion is that the idea of multiple UCI is not applicable because it violates the Separation of Concerns principle [12],[22]: as we know from Section 1.1 a use case is a goal-driven requirements specification of an *individual*, *independent*, and *behaviourally coherent* system functionality representing a system-supported part of *the pre-existing business processes*. In this respect, a use case is, in fact, a single business concern [22]. Consequently, the collapsing of two distinct business concerns, i.e. use cases, into one is in conflict with this principle (even if UC_3 in Fig.3 was adding further interactions). Would stakeholders and end users actually demand new a system functionality that consists of an assembly of two distinct already existing ones?

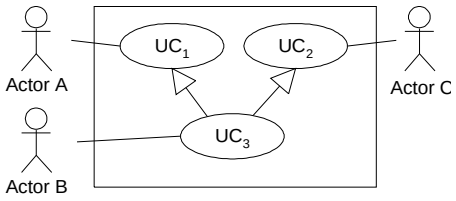

Fig. 3: Multiple use case inheritance

In fact, the existence of a use case child with multiple parents rather indicates the general confusing of inheritance and the employing of whole/part-like use case relationships, i.e. Include or Extend (see Section 1.4). A similar confusion has already been reported in the OO programming domain [34] where often *mixin classes* [7] are created where delegation, i.e. aggregating classes by associations, or single inheritance, respectively, would have been the appropriate tool [34].

5.1 Parametrization of Identifiers Within Interaction Steps ("Parametric Polymorphism")

I combine the existing idea of Cockburn [10], Bittner/Spence [5] and Hitz/Kappel [16], which represents *parametric polymorphism* as explained in Section 3, as follows:

Rule 1. Parameterizing Identifiers
Use case interaction steps contain identifiers (i.e. generic data placeholders) instead of concrete values, e.g. "customer name" instead of "John Doe". Now, for maximum reuse purposes and reducing redundancy, even such identifiers may be left unspecified (parameterization) in the parent, and in the child use cases only the expanding concrete identifier names have to be listed. The rest of the parent use case is valid also in the child use cases. E.g. a child use case identifier "customer name" could be abstracted to "search criterion" in the parent use case.

Example 2:

The following automotive domain example exploits the concept for propagating light signals to a hitch controller on a car driver's actions such as using the indicators or braking. In the parent use case generic identifiers are given in italics:

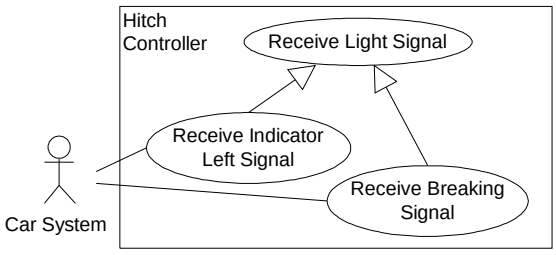

Fig. 4: Identifier parameterization

Goal "Receive Light Signal"

Trigger: `Edge change for <signal> detected`

Basic course:

1. `Hitch controller either activates <actuators> upon rising edge or deactivates <actuators> upon trailing edge.`

Postconditions:

`Electric contacts of <actuators> activated when corresponding car system <signal> activated.`

Goal "Receive Indicator Left Signal"

```
signal:   left indicator
actuators:  IndicatorRearLeft
```

Goal "Receive Braking Signal"

```
signal:    breaking
actuators: BrakingRearRight,
           BrakingRearLeft
```

I adopt Jacobson et al.'s original idea of "abstract use cases" [18] (see also [27],[28]) Rawthornes *CapturedAbstraction* use case pattern [1], and Cockburn's *Technology Variations* [10] by integrating in terms of the following rule:

Rule 2. Interaction step set placeholders
Even an entire set of interaction steps can be replaced by a generic placeholder, i.e. not providing concrete behaviour ("abstractness", "virtual" interaction step). This indicates that a child use case will later expand on this placeholder by providing concrete interaction steps.

Example 3:

Fig. 6 shows a simplified example from a real world requirements specification for 4th generation (GSM-based, i.e. no hardwired online connections) EFTPOS terminals (electronic funds transfer at point of sale).

Goal "Make EFTPOS"

Basic course:

1. Inserter inserts card and amount.
2. System validates card information remotely.
3. ***<interaction placeholder>***
4. System ejects card.

Postconditions: Card taken by inserter. Debit registered.

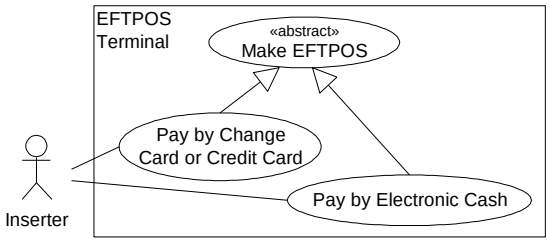

Fig.5: Use case inheritance for technology variations

Goal "Pay by Change Card or Credit Card"

Basic course:

At <***interaction placeholder***>

1. System asks for electronic signature.
2. Inserter signs with e-pen.
3. System debits card holder's credit card account.

Postconditions:

Credit Card or Change Card taken by inserter. Debit registered with credit card account.

Goal "Pay by Electronic Cash"

Basic course:

At ***<interaction placeholder>***

1. Inserter enters PIN.
2. System validates the PIN.
3. System debits card holder's bank account.

Postconditions:

Debit card taken by inserter. Debit registered with card holder's bank account.

Modification")

It follows from the general scientific principle of "Ockham's Razor" that it is is of little practical and scientific use if a new concept would only be an alternative to what can already be done with given modelling elements. Therefore, UCI semantics should be differentiable from Include and Extend in particular. Consequently, I discourage the suggestions in [2] (see Section 2). Further, I propose the following new detailed rules:

Rule.3 Strengthening Use Case Goals and Postconditions
This means that if Include and Extend carry *sub*-goals only then, in the spirit of the OO Design-by-Contract principle [25] and the LSP [21], UCI should be able to *either* maintain *or* strengthen the base use case goal; consequently, as postconditions must always support the goal, they need *either* to be held *or* strengthened, too.
Example 4 below shows a strengthening scenario, while in Example 3, above, the different wording of the goal and postconditions is only because of the different interaction step placeholder; from the business domain viewpoint they are actually equivalent.

Rule.4 Modifying Interaction Steps [1],[5],[19],[20],[28],[29]
In Section 2 we have seen that some authors claim that a child use case must not redefine the parent use case's order of interaction steps; apparently, this is to suggest that UCI shall ensure OO behavioural conformity when substituting child instances for parent instances. However, Section 4.1 explains why OO behavioural conformity should not be required for use cases. Further, from Section 1.3 we understand that interaction steps "connect" the use case goal with the postconditions. It thus appears that what solely governs the design of interaction steps are business rules (business domain semantics) and functional system requirements. For these reasons I suggest allowing a child use case to reorder and modify inherited parent use case interaction steps, and to add new ones. Correspondingly, guards of alternatives course may be adapted, and their branching points relocated, by the child use case. Further, inherited inclusions or extensions might need to be dissolved because former redundancy might vanish, or new inclusions or extensions ones introduced because of new redundancies. In a use case diagram, the dropping of a base use case's Include/Extend is represented simply by graphically not repeating them for the child use case. However, there are two constraints: any such modification must ensure consistency with the underlying business domain rules, and, also, must never cause the parent use case postconditions *and* the parent use case goal be *weakened* (i.e. Rule 3 shall apply). Let us look at Example 4 demonstrating the application of these rules.

- *Rule 3:* the goal "Register New Customer Order with Specials" is a stronger goal for "Register New Customer Order" (details given in Example 1) because the former adds price reduction for VIP customers. This is reflected correspondingly by the stronger child use case postconditions, i.e. the child establishes everything the parent does plus the recording of negotiated price reduction;

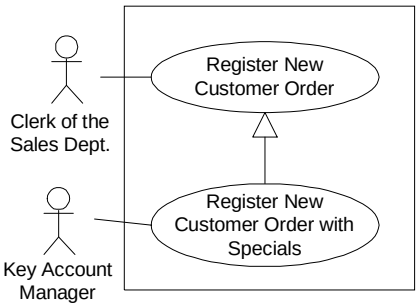

Fig. 6: Use case reuse

- *Rule.4:* correspondingly, the child use case goal reveals the new interaction step at label 6. It is also decided that the child use case waives the inherited step 3 (indicated by strikethroughs) as a VIP customer shall be attended to irrespective of their obligations. Correspondingly, the inherited alternative course 3a is no longer applicable either.

Goal "Register New Customer Order with Specials"

Basic Course:

1. Key account manager enters customer ID.
2. System displays the customer profile.
3. ~~Sales clerk confirms that the customer's credit rating is sufficient.~~
4. System assigns order ID.
5. Key account manager registers the desired trade items
6. Key account manager grants price reduction.

Alternative Courses:

~~3a~~. ~~Customer's outstanding debts are above the threshold:~~ …

Postconditions:

System has initiated an order for the customer, has documented payment information with price reduction, and has registered the order with the customer.

Rule.5 No Constraints for Use Case Preconditions

The Design-by-Contract principle in the OO domain [25] and the LSP [21] also require a subtype to either maintain or weaken the preconditions of a parent operation. As we know from Section 3 this is mainly for ensuring behavioural conformity when substituting child objects for parent objects. However, we have seen that for use case performances there neither is substitutability (see Section 4.1), nor does Design-by-Contract

by the triggering actor instance. Consequently, there is no need for use cases to enforce the same behavioural conformity semantics as desired for objects.

Please note, that the proposed Rules 3 to 5 still enable, but do not *necessarily enforce*, strict behavioural subtyping.

6 Critical Closing Remarks

6.1 UCI vs. Include/Extend Revisited

From the OO domain we know that any inheritance can alternatively be expressed by object aggregations, i.e. by whole/part relationships, and delegation (see Section 3). Therefore, a use case model employing Rule 4 can also be expressed via Include-relationships as shown in Fig. 7.

Fig. 8 shows the Include-relationships version of Fig. 6 (in Example 4, above).

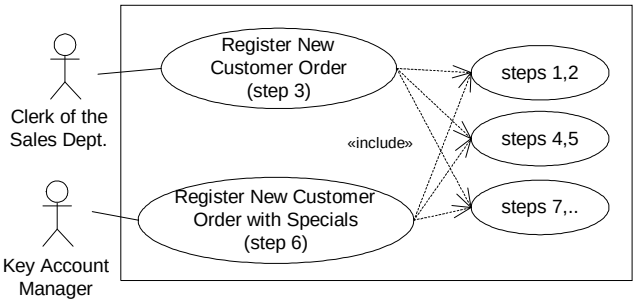

Fig. 7: Example 4 realised with Include. Numbers refer to interaction steps in 2

Even though that it is possible to solve a problem with Include where UCI appears appropriate it is obvious that an Include solution entails a greater graphical and textual complexity. This impacts on the reader's convenience and reading efficiency: in Fig.6 only one document (for "RegisterNewCustomerOrderWithSpecials") needs to be opened while in Fig.7 it would be four documents ("RegisterNewCustomerOrderWithSpecials" and three inclusion use cases), or at least 4 different document sections have to be looked up. Since size of use case models can be an issue in practice, UCI should contribute to keeping the use case model size at a minimum, and, therefore, ease reading and reviewing.

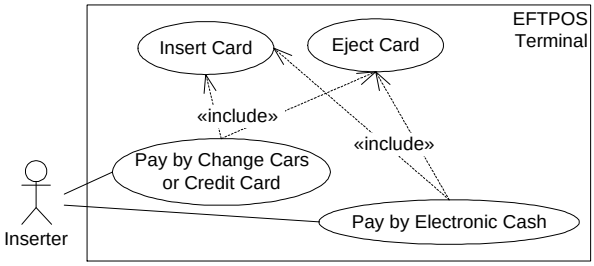

Fig. 8: Example 3 realised with Include

In any case, what cannot be expressed which Include or Extend is the idea of generic identifiers and generic interaction steps: neither Extend nor Include is an alternative in situations as shown in Examples 2 and 3 as these relationships do not support parameters and are not capable of *propagating* any type of "abstractness" [26]. Therefore, Rules 1 and 2 serve as further clear semantical distinction criteria.

6.2 Comprehensibility of UCI

One might argue that UCI only appears simple and understandable to software engineers, UML modellers and programmers since, historically, this audience has been mostly familiar with inheritance. Unfortunately, this audience is not the only one that deals with use case modelling: the use case calculus encompasses a requirements elicitation, modelling, and textual documentation technique and, thus, by definition, does require non-IT business domain experts to be involved. In my industry career as a requirements engineer I have experienced that the speaking in terms of *substituting placeholders*, *rewriting and adding interaction sequences*, and *appending more to goals and use case results* can be understood (and is often found helpful) by such stakeholders, in contrast to OO-related terminology like *Open-Closed*, *polymorphism*, *abstract classes*, or *subtyping* etc. However, UCI still remains a hard to understand concept in practice, irrespective of the added values identified and guidance provided by my solution proposals above. Without effective training, operational coaching, and industrial experience the benefits of UCI will not necessarily show.

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The Future of Innovation Coaching in Product Engineering: A Systematic Approach to Deriving the Future Competence Profile and its Development through Strategic Potential Identification

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Abstract
Innovation Coaches assist organizations in harnessing their innovation potential in order to operate successfully in a rapidly changing and challenging environment. Especially in the context of agile approaches and distributed development projects, the approach of innovation coaching is a valuable contribution to the successful accomplishment of innovation projects due to a process-oriented support. This approach will face a series of new challenges in the future. Development leaps in digital media such as Virtual- and Augmented Reality, Machine Learning and speech recognition create new challenges, but also new opportunities in in product development collaboration. Uncertain are the future competence requirements of an Innovation Coach and the corresponding impact on academic education. This paper presents the research results, which are based on qualitative studies as well as empirical investigations, conducted in an innovation project with 48 participants. The main responsibilities, tasks as well as key competences of the existing Innovation Coaching approach could be derived and applied in a profile. Furthermore, the application of a future scenario and a trend based approach leads to a derivation of future scenarios which implies not only required competences of an Innovation Coach, but also a development and training roadmap for the education of future Innovation Coaches.

Keywords: Innovation Coaching, Scenario-management, Product Engineering, Competence Profiles, Strategic potential identification

1 Introduction and Motivation

Especially in the early phases of product development, the work of product development teams is characterized by continuous decision-making in the face of uncertainty (Chursin/Tyulin, 2018). The challenges are intensified by the company's goal to act flexible and appropriate in a dynamic market by implementing agile approaches, particularly in the field of mechatronic systems development (Schmidt et al., 2017). As a

result, product development departments are forced to develop innovative ideas faster in order to cope with the huge competitive pressure. This is precisely where Innovation Coaches go into action to enable and motivate the product development teams and help to develop or strengthen the culture of innovation (Albers et al., 2016). Furthermore, studies show that decisions made in the early phase of product development fundamentally determine the success of the products on the market (Jahn/Binz, 2009) as well as their quality, cost and development time (Pache et al., 2001). However, the high importance of the early phase is contrasted with a lack of structure in the procedures and uncertainty of decisions due to the great scope for development in the future (Jahn/Binz, 2009). The aim of this research paper is to develop a competence profile for the innovation coach of the future. Therefore, a systematic approach proposed by Marthaler is used (Marthaler et al., 2019). This approach translates the findings of the derived future scenarios into short-term, medium-term and long-term recommendations for action in the form of a roadmap. In detail, this structured approach enables the development and validation of competences over several consecutive generations based on environmental scenarios (Marthaler et al., 2019).

2 State of the Art

2.1 Innovation Processes in Agile Product Development

Innovation forms the base for entrepreneurial success on the market and has great economic importance. An idea and technical solution leads to an Invention, which can become an innovation by a successful market launch. (Schumpeter, 1939) This implies the satisfaction of all relevant customer needs, which can be derived with a product profile to identify customer-, user- and provider benefit (Albers et al., 2018). Therefore, many innovation processes, especially agile approaches, start with a systematic problem definition and an empathy phase. Various methods and creativity techniques exist to identify and understand the customer's pain or demand situation. (Plattner et al., 2011) In order to merge external information about the demand and requirements, some companies even implement approaches as open innovation and co-creation within their processes (Chesbrough, 2006).

To achieve increased efficiency within the processes, existing knowledge should be made available and be considered by the developers. Building upon this knowledge, technical solutions with high innovation potential can be created by following situationally adaptable structuring and agile elements of the ASD – Agile Systems Design approach. It is operationalized in selected, iterative activities within a generic metaprocess of Analyze, Identifying Potentials, Conception, Specification, Realization and Release. ASD is an approach for the development of mechatronic systems. It is implemented within the model of PGE – Product Generation Engineering, which describes the holistic understanding that the development of new product generations always bases on references. (Albers et al., 2017). ASD supports self-working development teams with the right degree of structured and agile methods for the analysis and the synthesis of systems (Heimicke et al., 2018).

2.2 Competences Profiles in Product Engineering

Due to new requirements for development teams through higher quality, time and cost pressure, the implementation of new competence profiles in order to integrate interdisciplinary knowledge should be considered (Levin et al., 2011). Competences are defined as cognitive abilities and skills available to individuals, in order to solve certain problems, as well as the associated motivational, volitional and social readiness and abilities in order to be able to successfully and responsibly use problem solutions in variable situations (Weinert, 2002). This leads towards an integrated understanding of competence profiles for the problem-solving competence of development teams. Especially because the developer´s work is mostly characterized by teamwork, diverse competences need to join for a successful collaboration within interdisciplinary product engineering teams (Niever et al., 2018).

2.3 Innovation Coaching

As the organizational and human aspects in development projects increase in importance, the need for more emphasis arises, which can be complied by coaching (Berg/Carlsen 2007). To develop highly motivated and well performing development teams the approach of Innovation Coaching in product engineering projects was developed (Albers et al., 2016). Extinctive research show that Innovation Coaching is the process-oriented support of people in product development projects by a coach. Particular focus is placed on teaching best practices and empowerment for situation-appropriate application. The goal is the development and effective integration of disciplinary and social key competences and the creative potential of the people and, as a result, the development of the innovation culture of the organization. The role of the coach is to prevent or handle problems, to solve thinking barriers by means of early preventive measures, and to guide people with focused personal and critical questions. Independent solution development and the promotion of the self-reflection as well as perception of the team is of central importance (Hahn et al., 2017).

2.4 Foresight in Product Development

The three-cycle-model of Gausemeier places foresight as the first of three subprocesses of product development (Gausemeier et al., 2014). On this occasion, methods make it possible to estimate and handle future development, with which entrepreneurial decisions can be made under uncertainty (Gausemeier et al., 2014). The literature distinguishes between three basic types of foresight – scenarios, trends and forecasts. According to Gausemeier, a scenario is defined as a picture of the future, consisting of coherent combinations of possible developments of influencing factors (Gausemeier/Plass, 2014). Herby, scenarios provide the broadest temporal foresight and are suitable for long-term future planning. In contrast, a trend is a perceptible direction of development of the reference value and is suitable for a short to medium-term future forecast (Heinrich et al., 2012). The shortest view into the future is provided by the forecast, which describes a clear and expected picture of the future on the basis of a

linear time series analysis (Siebe/Fink, 2006). The development of the scenarios follows the phase model of Gausemeier and Plass. The phase model consists of five phases (Gausemeier/Plass, 2014). Current research indicates a lack of a consistent process model that combines the activities of foresight with the activities of product development. The basis for this is the model of PGE – Product Generation Engineering. In order to derive first methodical approaches of such a combination of foresight in the product generation development (Albers et al., 2018). For this purpose, a methodological process model was developed within a first iteration, which combines several successive product generations through strategic identification of potentials, especially foresight (Marthaler et al., 2019).

Based on that, a next iteration of future scenario and trend based product engineering was proposed (Marthaler et al., 2019). This approach provides insights from the derived scenarios which are transferred into short-term, medium-term and long-term recommendations for action. The systematic approach is based on seven consecutive steps, which contain three different variants which are carried out according to the development goal. The most detailed variant, which is based on the derivation of market environment scenarios and product scenarios is the most suitable for this research. This variant is primarily to be used if the product developer's focus needs to be resolved from the current product properties and if development scopes with a high proportion of principle variation are permitted. This variation is suitable for deriving new customer- experienceable characteristics. In the second step of the systematic approach, a reference product is identified. For this, the current predecessor generation is used in the following and examined with regard to existing customer- experienceable characteristics and evaluated with a five-level scale (--,-,0,+,++) depending on their relevance. The third step is to identify potential future environmental potential and to derive new, currently unknown, customer-experienceable product properties for the future. To this end, market or technology environment scenarios are derived and relevant trends and forecasts are identified. Based on the extended catalogue of characteristics product scenarios can be derived in the fourth step for finding innovation potentials by means of a consistency analysis or by using a morphological box. To gain knowledge about the future development and relevance of the individual customer-experienceable characteristics, the need for change and the future robustness, are defined in the fifth phase, the potential assessment. Using a formula to examine the robustness, the potential of each customer-experienceable characteristics can be assessed in the sixth step dependent on the calculated parameters. This step allows to identify the innovation potential and the need for change. In the seventh step - the implementation of potential - the identification of the relevant subsystems with their innovation potential is processed. Ultimately, a development roadmap can be derived that addresses specific development tasks in defined search fields with high innovation potential for the product developers (Marthaler et al., 2019).

3 Research Methodology

3.1 Research Questions and Research Environment

To explore the approach of Innovation Coaching as well as requirements in the early phases of product development an innovation project with 48 participants, named ProVIL - Product Development in a Virtual Idea Laboratory, was used as a research environment (Albers et al., 2016). During the innovation project, which is implemented as a project work in the education model, master students in mechanical engineering developed a product with an industry partner in a three-month period. Innovation coaches, who are students in the fields of business administration and international management, accompany them. Guided by the ASD approach and predefined activities the student-teams develop inventions with high innovation potential within a short time thanks to the agile approach.

The state of the art indicates that the future competence profile of an Innovation Coach is still unclear. This emphasizes the need to identify future competences of an innovation coach and leads to the following research questions:

1) What are the key activities and responsibilities for Innovation Coaching along the agile innovation process during the project in ProVIL 2018?
2) Which procedure is necessary to derive future-robust requirements for Innovation Coaching based on foresight methods?
3) How will the competence profile of innovation coaching develop in the future due to new technologies and trends?
4) Which training and development roadmap for Innovation Coaching arises from the strategic approach?

The Live-Lab ProVIL 2018 serves as a basis to analyze the current competences of Innovation Coaching. To answer the first research question, weekly surveys and participatory observations were carried out. Subsequently, the reports of the participants were analyzed and evaluated. As a result, actual competences are identified to examine the current tasks and responsibilities of an Innovation Coach. In order to answer the second question the future management tool, the scenario-method, was being applied. The scenarios provide a basis to investigate the future requirements and competences of an innovation coach. The development of the scenarios bases on a literature review, surveys with experts in the field of Innovation Coaching and a workshop with four experts in the area of innovation processes.
For the purpose of answering the third and fourth questions, the strategic approach for potential identification (Marthaler et al., 2019) for each competence was applied to develop a future-robust competence profile and roadmap for Innovation Coaching of the future. Instead of customer- experienceable characteristics of a product, competencies of an Innovation Coach are examined and assessed according to relevance and future-robustness. Thus, a development and training concept for the education of future Innovation Coaches was developed and significant need for research derived.

4 Results

4.1 Key Competences of an Innovation Coach

Within the empirical studies, all ProVIL participants – the product developer and the Innovation Coaches – were asked about an Innovation Coach's core responsibilities. Every Innovation Coach described his or her role during the innovation process in a comprehensive report, which was analyzed in detail. These sources served as a basis to identify Innovation Coach's necessary skills and their corresponding core responsibilities.

During the empirical studies seven core competences were observed. The core responsibilities are completed through process-organization, communication skills, professional and methodical competence, teamwork, socio-emotional competence, innovation competence and leadership.
An essential competence of an Innovation Coach is to convey process knowledge adequately along the phases of the innovation process and to consistently verify it. Process knowledge refers to the knowledge of individual tasks regarding responsibilities, time restrictions, phase sequences and requirements. Knowledge about the sequence and the goals of the different process phases enables the coordination of meetings, subsequent coordination of results, communication with the client and coordination of time management with the help of project management tools. The necessity of a broad field of expertise, especially in the initial phases of the innovation process, goes hand in hand with the importance of the Innovation Coach's professional competence. Professional competence includes knowledge regarding the economic feasibility and customer benefit of ideas through the creation of business models, market analysis and competitive analysis. The methodological competence of the Innovation Coach includes the ability to apply working techniques and procedures and thus the ability to convey and apply methods. This includes, for example, the teaching and implementation of creativity techniques. The ability to work in a team encompasses motivating the team members to work effectively and cooperatively through team building activities. By carrying out personality analyses right at the beginning of the process, the Innovation Coach is able to identify the strengths and weaknesses of individual team members. This guarantees the minimization of possible barriers and conflicts during collaboration. Another key competence is the ability to facilitate communication by creating an open-minded culture, in which problems and suggestions can be addressed directly and effectively. This includes activities such as promoting communication between individual team members and facilitating creativity sessions. In order to recognize problems and conflicts the Innovation Coach needs a socio-emotional competence, namely, the ability to recognize and counteract problems in an early stage. Intercultural skills are also part of socio-emotional competence. This encompasses, recognizing and minimizing language barriers, promoting mutual understanding of different values, working methods and promoting self-reflection. Furthermore, the Innovation Coach promotes the innovation culture within the team by recognizing mindset barriers. Leadership skills are required in order to achieve the goals effectively and efficiently to influence team members'

behavior. This encompasses, for example, initiating conflict solutions and giving reactive feedback.

4.2 Scenarios of Future Innovation Coaching

A literature review, workshop and a qualitative survey serve as valuable inputs for Gausemeier's scenario-method (Gausemeier et al., 2014), which consists of five phases. The method starts with the preparation of the scenario field and its analysis through the identification of influencing factors followed by the development of key factors and projections. The fourth phase consolidates the dominant projections to scenarios which are then interpreted in the last phase. On this occasion, influencing factors have been collected, examined and prioritized resulting in key factors with the subsequent execution of projection development. Thus, the projection portfolios have been transferred into a consistency analysis to conduct the phase of scenario building. Applying the scenario-method, four possible scenarios result:

Scenario1: Inflexible and centralized end-to-end collaboration
Consistent, inflexible end-to-end (E2E) process organization and support by the Innovation Coach in central and permanent teams based on experienced knowledge under strict data protection requirements.

Scenario 2: Agile and centralized E2E collaboration
Consistent, agile and interdisciplinary process organization and support by the Innovation Coach in central and permanent teams based on open innovation approaches and influence through other interfaces with corporate divisions of a company.

Scenario 3: Smart, virtual and partial process organization
Agile and process-driven product development in central teams with partial involvement of the Innovation Coach and simultaneous implementation of smart methods based on intuition and artificial intelligence.

Scenario 4: Dynamic, virtual and with a holistic network
High innovation culture with agile processes and holistic networking of the team members through increased use of smart technologies and man-machine-collaboration. The team composition is dynamic and thus the involvement of the Innovation Coach is only partially required along the process.

4.3 Foresight Methodology to Derive Future Competences

The competence and scenario development is illustrated in a flow diagram in Figure 3, describing how to derive future competency profiles. In order to answer the third and fourth research questions, the methodology for strategy potential identification, which is outlined in 2.4., is applied to identify future competences (Marthaler et al., 2019). In the following figure the method is adjusted to the topic of Innovation Coaching.

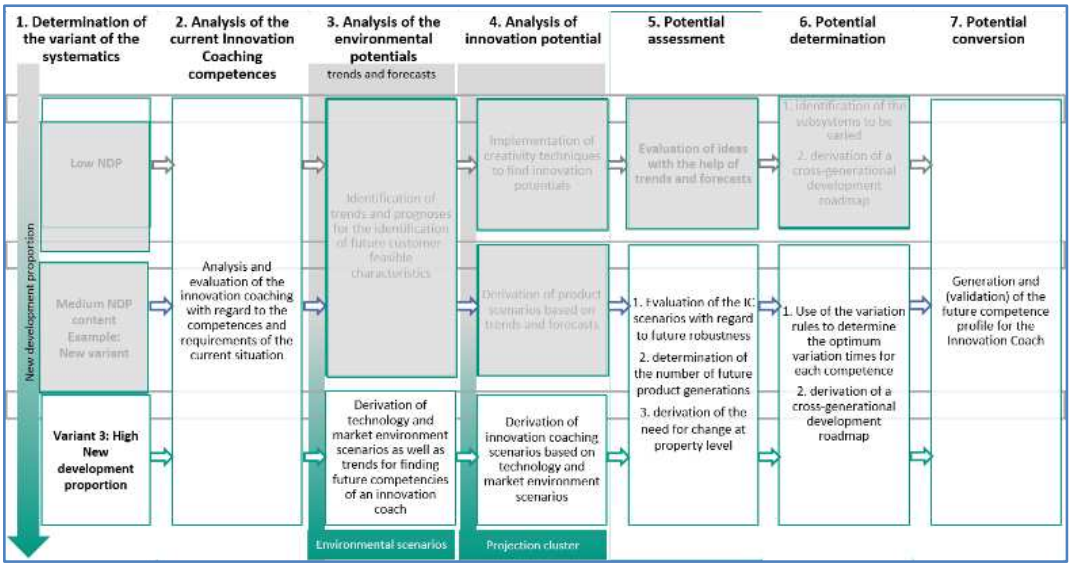

Figure 1: Systematic approach for strategic potential identification (Marthaler et al., 2019)

The definition of the variant (in step 1) was defined and specified as a premise. In the step 2 the actual competences of an Innovation Coach were identified (see chapter 4.1) and the results are illustrated in Figure 1. After determining the actual competences, the evaluation of the competences follows on a five-step scale (--, -, 0, +, ++). The third and fourth step serve to identify future environmental potentials in order to derive new future requirements and competences for the Innovation Coach. The scenarios illustrated in chapter 4.2 are examined and compared with the actual competences. Furthermore, trends are identified to consider not only the long-term development through scenarios, but also the short-term development. In order to determine which competences will be obsolete or relevant in each scenario, each competence is compared to the dominant and characteristic projections of each scenario. In the fifth step, the strategic potential is assessed by defining the two parameters, which describe the need for change and the future robustness. These parameters enable the regular monitoring of the future development and relevance of the tracked competences of the Innovation Coach and furthermore result in variation rules. In this way, the competences are examined with regard to their variation in a short-term, medium-term and long-term manner. This makes it possible to see which competences will remain unchanged in the future and which will need to be adapted in the next step through new training courses so that the Innovation Coach can continue to meet the requirements in the future. In the last step (step 7) of the potential implementation process, the results are discussed in form of a feedback discussion with doctoral candidates.
Applying this method, new competences are identified, which are to be outlined in section 4.4. The resulting findings are validated through research by comparing given findings to expected results, which are outlined in literature.

Openness competence
The Innovation Coach should ensure that the innovation process is not hindered and that the most important information is revealed. The main goal of open innovation is to promote awareness of the need to open up to external participants and transfer knowledge to innovation partners (Wagner/Piller, 2011).

Integration competence
Particularly in the context of open innovation, companies must integrate co-produced knowledge. This requires integration competence, which includes the transfer of heterogeneous knowledge from participants into a product solution, i.e. combining existing knowledge with new knowledge (Habicht/Möslein, 2011).
Digital literacy
Basic digital literacy refers to careful handling of personal data, usage of common software and interaction with artificial intelligence. The main goal is to strengthen digital interaction (McKinsey, 2018).
Networking competence
Networking and interacting with team members as knowledge carriers inside and outside the company is a decisive way to find innovative solutions. The implementation of innovations always requires target-oriented information and persuasion of different groups of people resulting in the ability to build and use networks (Schültz, 2014).
Overview competence
Overview competence compromises (technical) knowledge, experience and the competence to monitor different ideas of the involved people (knowledge and experience carriers) as well as the ability to assess the innovation potential (Ridder et al., 2005).

4.4 Derived Competence Roadmap

Applying the strategic approach (Marthaler et al., 2019) a future-oriented competence profile and roadmap for Innovation Coaching of the future can be derived through the calculation of the two key figures robustness and the need for change. Thus, a development and training concept for future Innovation Coaches serves as a basis for future research.
Figure 2 provides an overview of the potential of each competence throughout the next 10-15 years and the time to take action for training concepts. Furthermore, it illustrates the set of variation rules for each individual competence resulting from the calculation of the key figure future robustness and the need for change. The potential of a competence is particularly high if there is a high degree of robustness on the one hand and a high need for change on the other.

Competencies ↓	5 years	5-10 years	10-15 years
Prozess organization		middle-term variation	
Networking competence		middle-term variation	
Overview competence		middle-term variation	
Communication skills		middle-term variation	
Integration competence	early variation		
Digital literacy	early variation		
Professional and methodical competence			late variation
Collaborative skills	no variation		
Socio-emotional competence	no variation		
Innovationcompetence	no variation		
Leadership		middle-term variation	
Openness competence		middle-term variation	

Figure 2: Development and roadmap for Innovation Coaching competences

The ‘collaborative skills’, ‘socio-emotional competence’ and ‘innovation competences’ are not subject to any variation. This goes hand in hand with a low need for change and a high degree of future robustness. This means that the competences will last in the future as they are defined until now. The need to change, train or vary the competence is particularly low. When consolidated along the scenarios, the competences show a high degree of future robustness. Thus, the Innovation Coach is well equipped for future developments. The ‘process organization’, ‘network competence’, ‘overview competence’, ‘leadership’ and ‘openness competence’ show a medium-term variation. This indicates that in 5-10 years the competences need to be reviewed and revised. Since the network and overview competences were identified from an inconsistent evaluation of the process organization along the scenarios, it illustrated that process organization as it is defined in the actual competences can no longer be trained the same way in 5-10 years and thus requires different training concepts in the medium-term. Furthermore, the ‘integration competence’ and ‘digital literacy’ correspond to an early variation. That means that for the two competencies a valid training concept for the Innovation Coaches must be examined in the next step so that the Innovation Coach can face the challenges of the illustrated scenarios in a future-proven way. Professional and methodological competence are subject to late variation. The consequence is that the technical and methodical knowledge of Innovation Coaches - as it is defined now - will not be sustainable in the long-term. This implies to rethink the training process of both competences and to analyze what methodological competence will be needed in the future.

5 Conclusion and Outlook

Important driver for a corporate innovation capability are the skills, behavior and knowledge of the product developer. Due to this, the concept of Innovation Coaching supports the human in agile innovation process within the model of PGE– Product Generation Engineering by the mediation of problem-solving skills, supporting the application to situation appropriate methods and the conscious management of the team-development. Several technical, economic and cultural influence factors lead to dynamic requirements towards the competence of an Innovation Coach. Therefore, there is a need to examine which competence are required to cope with future challenges.

Applying the future scenarios and trends based approach for strategic potential identification of (Marthaler et al., 2018) a future-robust competence profile and roadmap for Innovation Coaching of the future results. Additional competences of a future Innovation Coach will be the *openness competence*, *Integration competence*, *digital literacy*, *networking competence* and the *overview competence*. The further goal is to develop a training concept for future Innovation Coaches. The development roadmap instructs which competences to develop, illustrates a systematic guide and gives short-term, medium-term and long-term recommendations for action. Pursuing research will focus on an adaptive teaching model to guide the training of the identified skills by applying the compiled development road.

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A Survey of Automated Information Exchange Mechanisms Among CERTs

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Abstract. Nowadays innovative computer related exploits are released every single day, which makes researching about those exploits a significant task. A CERT (Computer Emergency Response Team) is an expert group that is responsible for handling cyber security incidents and for issuing feasible advisories and countermeasures for new vulnerabilities. There exist national CERTs and CERTs that belongs to large organizations; and the coordination among them to share knowledge of new threats and countermeasures is very essential for a timely emergency response. This can be done by a systematic information exchange process among different CERTs. The purpose of the present research paper is to give a review about automated information exchange mechanisms at CERTs. Furthermore, issues, challenges and various technologies used to automate information exchange are discussed.

Keywords: CERTs · Information Exchange · Autonomous

1 Introduction

In the field of cyber security latest vulnerability and malware signatures are detected by CERTs on daily basis. Exchanging the information about various signatures is essential for effective defense strategy. However, in the view of latest cyber crime events [1][2], the effectiveness of information sharing process among CERTs is questionable. Thus, the present research will analyze how automation will makes information sharing process more effective and reliable and how to maintain threat detection in organizations at the root level. The researcher would briefly present the available research related to information exchange processes between different CERTs. The present report seeks answers to the following research questions.

- What is the current state of the art of information exchange mechanism used by CERTs?
- What are the automated information sharing processes presently working in CERTs?
- What mechanisms are present to avoid crossing the boundaries of information sharing between CERTs?

- What are the control filtering mechanisms between CERTs?
- What are the limitations and problems present in automated information sharing between CERTs?

The rest of the paper is organized in the following sections. Firstly, the authors states a brief introduction of the automated information exchange processes used by CERTs. Secondly, the literature related to the automated information exchange mechanisms at CERTs is stated. Thirdly, the current status of information exchange mechanism at CERTs is stated. Then, the authors would reflect upon the automated information sharing process, infiltrating the boundaries of information sharing, control filtering process and the discussion about limitation and problems in the process of information sharing between CERTs would be analyzed. Finally, the researcher would then conclude the paper.

2 Related Work

Skopik et al. in 2016 [3] stated in *a survey on the dimensions of collective cyber defense through security information sharing* the brief description of information exchange mechanisms formulated by authentic bodies. The authentic bodies and the related enterprises consist of such product significance such as how to produce reliable security exchanging networks. Some of the examples are given as follow

- NIST guideline "Framework for Improving Critical Infrastructure Cybersecurity".
- ENISA documents "Cyber Security Information Sharing: An Overview of Regulatory and Non-regulatory Approaches" and "Cybersecurity cooperation: Defending the digital frontline".
- ISO/IEC standard 27010 "Information technology - Security techniques - Information security management for inter-sector and inter organizational communications".
- EU Network Information Security Directive.

Creating a reliable and secure cyber atmosphere is a priority for all member states of EU (European Union). This also include key internet enablers, critical infrastructure operators, such as e-commerce platforms, social networks, and operators in energy, transport, banking and health care services operating within EU. EU uses the ENISA (European Network and Information Security Agency) to help the member states and the commission by catering them with professional help and guidance. The structure of cyber security information for the purpose of information exchange between different networks can be formed by considering the following factors.

- Recognizing and finding out about cyber security information and bodies. Forming reliable and information exchange policy between exchanging CERTs.
- Pledging and reacting towards cyber security information; Ensuring the security of the cyber security information exchange.

– Suggesting the security and quality of shared reports about cyber security in information sharing data format, protocols and standards.

After discussing the above factors of information sharing, a research centre is formed as a reliable body consisting of security specialists, from enterprises belonging to various information technology industries, devoted to secure the information technology process by identifying the threats and risks in it, and propose countermeasures. Seeking recurrent structures from event log data sets and marginal reporting from various equipment across different locations ensure the consideration of information across hundreds of users, applications and protocols. It joins the given data, enabling the user to have an overview of network activity combining log management, asset management, information from security controls and detection systems. The EU motivates the enlargement and the related usage of synergies between civilian and military facilities for securing the important cyber assets by producing research and development programs and by fostering coordination between governments, private sector and academia in EU.

Franke et al. in 2014 [4] investigated *Cyber situational awareness.* A research on cyber situational awareness was presented in eleven groups. Accordingly, the cyber situational awareness is mostly about knowledge regarding cyber issues. Such cyber issues need to be studied along with relevant data to get the complete realization of a situation. Instead of talking about the complexity of situational knowledge, majority of the available data is focused on cyber issues such as how cyber sensors can play a part in the complete understanding of the situation, or by focusing on the relations among particular cyber sensors in threat information acquisition, handeling and processing. The similarity among cyber sensors and their role in the overall situational awareness are studied, however the antonymic similarity in which the routine sensors have got the potential to play part in the cyber event is not covered fully. The eleven theme-based groups are discussed as follow.

– General cyber situational awareness
– Tools, architectures, and algorithms
– Information fusion
– Cyber situational awareness for industrial control systems
– Cyber situational awareness for emergency management
– Visualization for cyber situational awareness
– Human-computer interaction
– Nation-wide, large scale cyber situational awareness
– Exercises relating to cyber situational awareness
– Information exchange for cyber situational awareness
– Military cyber situational awareness

According to researchers in [4] given the prominent role of high-level cyber situational awareness in national cyber strategies, it seems that more attention should be directed to the risk of deception. On the rather liberal interpretation of a non-trivial empirical contribution slightly below 45% of the articles reviewed

were classified into this category, but it is noteworthy that only 3 out of 102 articles were found where exercises were used as vehicles to gather empirical data on cyber situational awareness. Cyber security exercises of various kinds offer a particularly interesting source of data on cyber situational awareness

Tounsi et al. in 2017 [5] stated that there is a particular interest in the favor of threat detection, when organizations nowadays are investing to procure different types of threat detecting tools, largely concentrating on the Technical Threat Intelligence(TTI). The researchers have concluded that in comparison to what was identified earlier, the quick exchanging of TTI is not enough to get rid of persistent attacks. Security lies in effective exchange of threat information among organizations. A standardized way for exchanging TTI reduces the risk of losing the quality of threat data, thus enables applying automated analytics on large bulks of TTI and the selection of the threat intelligence tool depends upon the objectives of the organization, as in some organizations the information processing and automatic analytics is desired. Majority of organizations motivate the threat information exchange by enhancing support between threat defenders. The benefits of exchanging data also consist of a good knowledge of the situational awareness of the threat scenario. The format of threat intelligence libraries or platforms are fabricated in such a way as that their main purpose is to overcome the bulk of problems of TTI and to help in exchanging the threat information with other organizations in the threat intelligence arena.

Bartnes et al. in 2016 [6] investigated *The future of information security incident management training* and concluded that the practice for reacting to information security events is treated with less enthusiasm and also various bodies like business managers and technical professionals have diverse opinion about information security. The aim of the information security incident management training is to give resilience to the potentials of the company in response to the events that could be helpful for business operations continuity. The human resource element acts here as a factor for the domain of resilience engineering, and the relation between the incident management process and resilience engineering activity. When their is no major security events limiting the preparatory activities, then a mark of preparation and importance is limited to event management planning and preparation activities between cyber security officials are restricted, specifically in comparison to the suggestions by ISO/IEC 27035. The recommendations from the cyber security officials stated that no prodigious information security events had been noticed that had affected their business endeavors. Probing into information security incidents is never given much attention as compared to other items, although the information and training are giving more importance than the written material in the wake of an event. Getting experience from previous events and getting ready for the upcoming events would help to device more strategies against the threats. The experience for getting knowledge about different tasks consists of security specialists, acquiring new perceptions on how to solve the problems, how to make better methods, performing the threat analysis, finding out direct causes, discussing new security measures that are desirable, and up-gradation the risk assessments.

3 Methodology

In order to understand the literature review of the present research paper, a keyword-based research is employed. The researcher started with *CERT* and *Information Exchange* with *automated*. The researcher investigated the following keywords in academic databases like Google scholar, IEEE and ACM to acquire the better understanding of the given terms [7]. The researcher also made himself familiar with the related literature on the given topic. The researcher spotted a lot of related information but employed them in indexed research articles only. The researchers conducted a thorough research and collected good amount of relevant literature in an organized manner, but the repetition of literature gathering process may yield slightly different results [9]. Hence, the researchers are including only the inclusion and exclusion criteria in the paper to lessen the variation of results in other literature reviews.

3.1 Inclusion Criteria

The researchers have followed the following inclusion criteria for the survey:

- Articles which are published in English.
- Articles which are directly related to CERTs.
- Articles that discusses Information exchange mechanisms in CERTs.

3.2 Exclusion Criteria

In respect of the huge amount of related data, the researchers have followed the following exclusion criteria:

- Articles that mention CERTs to some extent but are not directly related to it are not taken into consideration.
- The researcher also excluded conference abstracts, book reviews, conference information, discussions, editorials, mini reviews, news, and short communications for the survey .

3.3 Quality of Articles

The researchers have carefully gathered the relevant research articles for the present survey. The main purpose of this exercise was to build a stance for the survey and to extend it in the light of a specific research framework. The researcher evaluated the related articles with the help of a pre-defined criteria containing five quality assurance factors. The points are allocated on the scale of one to five, in which five is considered the highest value and one the lowest. The articles whose score topped the chart were given priority in the survey. The researchers have employed the following criteria.

- Reputation of publication channel, the publication channels which are well known and recognized by academia scored higher in our criteria.

- Citation of article, the articles which consist of more citations were given higher score in our criteria.
- The relevance of article, content in relation to survey topic were also given high score.
- Publication date of articles, the articles which are published recently received higher score as compared to older articles.
- The articles in which there was more number of references used to build the argument scored higher .

4 Information Exchange Mechanisms Among CERTs

During the survey we identified multiple information exchange mechanisms among CERTs details of which is as follows:

- CybOX [8]
  The first mechanism is The Cyber Observable expression cybox language, produced by a wide range of industry, academia, and government organizations all around the world. It standardizes the encoding and communication of highly confidential information about cyber observable, whether they are dynamic events or stateful measures observable in the operational cyber domain. The cybox Language consists of three overarching principal objectives: Firstly, to develop a common solution for all relevant usage cases. Secondly, to support multiple cyber security use cases. Thirdly, to develop it in a form that is flexible enough to offer a common solution for all cyber security use cases requiring the ability to deal with cyber observable. The Cybox language is defined within a set of specification documents as follows: cybox Language Core Specification specifies the purpose, approach, conventions and usage of the cybox language as well as the detailed language data models for the language core and set of common types. Cybox Language defined objects Specification restates some language basics from the Cybox Language Core Specification as well as specifies the detailed language data models for the official set of Cybox defined objects.
- TAXII [12]
  The researchers stated that the present cyber threat information sharing is either a time-consuming, manually processed or automation effort have limited scope and are tied to a particular cyber threat information sharing community or technology. As the value of cyber threat information sharing has increased, the number and kinds of cyber threat information sharing communities has also grown.The goals of TAXII (The Trusted Automated exchange of Indicator Information) are to enable timely and secure sharing of threat information both within and between cyber defender of multiple organizations. Leveraging consensus standards to enable the sharing of actionable indicators and more across organization and product/service boundaries extend indicator sharing to enable robust, secure, high-volume exchanges of significantly more expressive sets of cyber threat information. It supports a broad range of use cases and practices common to cyber threat information

sharing communities. Leverage must be given to existing mature standards, where appropriate eventual adoption by one or more international standards organizations is required. In order to enable the automated sharing of a wide range of threat data beyond simple threat information, atomic indicators are also employed. Thus it requires fewer analyst-eyes needed to screen and enable cross organization analyst collaboration on the truly challenging issues. Standardized threat data formats and sharing implementations will achieve these goals. As noted in the *Roadmap to Intelligence-driven Information Security*, Automated data-exchange systems need to be established to remove the dependency on specific bodies. In addition, "harmonized standards for representing attack information in machine-readable format, delivering it securely, and consuming it in real time would help to enable automation." Additionally, as noted in *Breaking Down Barriers to Collaboration in the Fight Against Advanced Threats* [12]: "There is a Lack of inter-operable standards to describe advanced threats - The security industry has yet to align behind a set of uniform, machine-readable standards to capture, integrate and communicate threat information".

– STIX [10]
  STIX (Structured Threat Information Expression) provides a single architecture tying together a diverse set of cyber threat information including: cyber observables indicators, incidents adversary tactics, techniques, and procedures. It exploits targets courses of action cyber attack campaigns by cyber threat actors. To enable such an aggregate solution to be practical for any single use case STIX is both flexible and extensible. The core use cases targeted by STIX analyzing cyber threats a cyber threat analyst reviews structured and unstructured information regarding cyber threat activity from a variety of manual or automated input sources. By specifying indicator patterns for cyber threats, a cyber threat analyst specifies measurable patterns representing the observable characteristics of specific cyber threats along with their threat context and relevant metadata for interpreting, handling, and applying the pattern and its matching results. For managing cyber threat response activities, cyber decision makers and cyber operations personnel work together to prevent or detect cyber threat activity and to investigate and respond to any detected incidences of such activity. Cyber threat detection operations personnel apply mechanisms to monitor and assess cyber operations in order to detect the occurrence of specific cyber threats whether (1)in the past through examples, (2) currently ongoing through dynamic situational awareness, or (3) through predictive interpretation of leading indicators. A core requirement for maturing effective cyber threat intelligence and cyber threat information sharing is the availability of an open-standardized structured representation the cyber threat information.
– CYBEX [11]
  CYBEX (Cyber Security Information Exchange) researchers argued that previous research did not consider any specific type of information to share and the range of information sharing amount varies between 0 to 1.The re-

searchers have adopted a 2-stage Bayesian game considering the information as the number of bugs and by using backward induction from previously shared information of bugs they have derived the optimal investment quantity and a number of bugs to share with the other firms participating in information sharing. A dynamic cost of participation mechanism is necessary to let both CYBEX and information sharing firms coexist in a sharing market such that firms can take the advantage of information sharing and CYBEX can manage the participation as well as CTI(Cyber-Threat Intelligence) sharing. The researchers assumed that every participating firm in CYBEX shares a constant amount of CTI. However, realistically some rational firms may share less whereas some firms share more based on their best interest. CYBEX introduces two different incentive parameters for two different sharing levels that researchers called as high sharing strategy and low sharing strategy. Differentiated sharing gain when a firm is not participating in the sharing framework, then researchers can infer that the firm is not interested in sharing its CTIs with others and decides to tackle cyber security issues solely. Low sharing strategy is only favorable in two scenarios, (1) when the firms do not get the value of their truthfully shared cyber-threat information, and (2) when firms decide not to share all of their information and free-ride on others' CTIs, so that the cost of information sharing is reduced.

– MISP [13]
  In MISP (Malware Information Sharing Program), a user can describe an event with multiple attributes while providing as much information as possible, or one can only put a minimum of information for an event. The pull mechanism allows a MISP instance to discover available events on a connected instance and download any new or modified events. It automatically goes through each of the event IDs that are eligible, converting them to MISP's JSON format and POST them to the event creation API of the remote end. The event already exists and can be edited, while the remote side will match the event by UUID to a local event and return the URL that could to be used to update the event. It shows an index, description, events, attributes, correlations found, proposals, active users, organizations, discussion threads, discussion posts, number of instances to ease the usage of MISP. The CIRCL (Computer Incident Response Center Luxembourg) provides a feed of events that can be easily shared; such as OSINT events and attributes that are classified as unclassified information that can be distributed without any restrictions.

– Traffic Light Protocol [19]
  The TLP (Traffic Light Protocol) was created by UK (United Kingdom) in early 2000 to control the flow of information withing or outside the organization. The protocol mark the information with 4 colors red, amber, green and white. Information marked as red should not be shared by the recipient of the information. Information marked as amber can be shared by the recipient with the member of its own organization. Information marked as green

can be shared with affiliated organizations. Information marked as white can be publicly shared.

4.1 Automated Information Sharing

The multinational alliance for collaborative cyber situational awareness's for information sharing framework was formed to describe how sensitive information should be shared across organizations and governments. Content consumers can generate security reports after automatically assessing devices based on automated security content, and security information can be exchanged automatically. The TAXII [12] information exchanged is represented in the XML-based structured threat information expression language. The US DISA(Defense Information Systems Agency) fields XCCDF (xtensible Configuration Checklist Description Format) [14] with CPE (Common Platform Enumeration) and OVAL (Open Vulnerability Assessment Language) [17] to publish security technical I implementation guides, which are the configuration standards for the US Department of defense IA (Information Assurance Division) and IA-enabled devices and systems. INCH WG (Extended Incident Handling Working Group) goal is to define a data format, information model, and messaging format to exchange security incident information used by CSIRTs. ICSG (Industry Connections Security Group) work is to efficiently describe and share threat information, which is studied in ICSG's MMDEF (Malware Meta Data Exchange Program), Malware, and Stop eCrime WGs [16]. MMDEF WG. The MMDEF WG's goal is to standardize and enrich captured and shared malware information. The RESTful architecture style can be used for resource discovery and exchange of information represented by various data models. Even though it's flexible, the resource-oriented architecture is still a pull model in which threat information can't be distributed only to interested parties. For some countries with different privacy laws for personally identifiable information, information collection and sharing methods will need to be designed carefully.

4.2 Crossing the Boundaries

Classified information such as undersigned unclassified data and personally identifiable information may be faced when an expert is checking cyber threat data. The data from the intelligence are mostly written papers that discuss about the TTPs, actors, types of systems and data being targeted, and other threat related knowledge that are worthy of importance for a company. In order to describe the significance of data sharing activities, companies must narrate the extent of their data sharing activities by describing the kinds of data available for exchange, the environment under which exchange of this data is allowed, and the bodies with whom the data could be exchanged. A company may set regulations that could narrow down the sharing of highly classified data with infiltrated groups, which could permit the exchange of medium classified data with particular reliable users, and also that allow data of less classified information to be highlighted in the range of packed sharing group, and also that permit the unhindered sharing

of non-classified data in national data exchanging platforms. The secrecy effect level as described in NIST SP 800-122 [18] and 800-150 [19] is a productive tool for getting the classified data to be secured.

4.3 Control Filtering Mechanism between CERTs

When a company signs a pact for data exchanging policy, earlier it must get the approval from the administrative team, who should must have a specific system for checking the data sharing activities and for handling the tools essential for the company's data exchanging assist. NIST SP 800-150 [19] *GUIDE TO CYBER THREAT INFORMATION SHARING* discusses the control filtering process for the judicial team and the one with the authorization to come into contact with the privacy officers and other significant stakeholders who play their part in the collection, ingestion, storage, analysis, publication, or protection of threat data. Majority of companies can get threat data by the channels of email lists, text alerts, and web portals in the absence of autonomous mechanism related to data sharing. Though the material obtained by these production ways could also be handed manually. A creator of exchanged threat data could make his mind what device could be used in case any metadata is assisting exchanged data, what data patterns could be used, how the classified data could be handled, and in which way data exchanging regulations can be upgraded with the passage of time. A measured non-sensitive data is the one for which the laws, regulations and government policy need to have ways of protection or disintegrating controls, that are taking out the data which are sensitive.

4.4 Limitations and Problems

Innovative researches in the field of technology play a significant part for CERTs, and the method is also important by which specifically nation-wide CERTs have to work and the way they react with other bodies. International cyber security rules can be viewed as a method of lessening the threats of cyber security events, and the progress of event responses as well. The Internet is a huge system and it shows that CERTs must establish contacts to perform their task of incident reporting. The first ever CERT, CERT/CC was made to undergo coordinating role, afterwards CERTs have a way of establishing contact that is also strengthened by the RFC 2350 [20], which illustrates a mini design to show the activities of a CERT. Different helpers are present to discuss how to set up a CERT e.g. from ENISA or the NIST publication Security Incident Handling Guide, where the communication area is also discussed briefly. The complete new method is that the part of CERTs, especially national CERTs is limited in a narrow connecting manner. An eye catching dimension of CERTs is that not only the national CERTs might be taking into consideration but all CERTs are held responsible for important security incidents and digital service providers. CERTs need to maintain contact to fulfill their compulsory supporting process. Helping this communication should be according to the political arena. There are several hindering elements in this regard as well. The new part that CERTs assume in

national and international cyber security strategies puts forward tough questions in regard to the support of national security interests versus the interest of global cyber security. The handling of this situation cannot be completely overcome by technical support measures alone, it also needs a strategic approach to encounter it as well.

5 Conclusion

The conclusion drawn from the above survey is that there are various information exchange platforms already existing among different CERTs. But the exchange of data is dependent upon the significance of the data and the importance of the strategic data for the receivers. For a collective defense mechanism, political obstacles should be removed so that nationwide CERTs could cooperate with each other in a productive manner in the wake of political conflicts. The new processes reflect that categorizing the data independently will enhance the performance of present automatic information exchange process among CERTs. This would make the exchange of data easier which would lessen the risk of threat exploiting and vulnerability and would increase the defense power of information sharing CERTs collectively.

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“Pricing Game” for tacit collusion and Passive Investment

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Abstract. This paper aimed to figure out the structural factors of tacit collusion from the perspective of the oligopolistic market. A two-step approach is adopted to analyse this phenomenon. As pricing mechanisms shift from traditional method to computational algorithm, herein termed the “pricing game”, new forms of collusion are expected to emerge. First, game theory is applied toward an understanding of this unspoken collusion, which involves interaction between different parties. A potential new form of collusion is identified as having been created by information signals in the price networks. Second, firms are owned by overlapping sets of investors (passive investors), and their incentives to compete are thereby reduced. Investors are rapidly shifting their investment allocations from active to passive management (ETF; Exchange Traded Funds), in response to the complexity of asset management and the excess liquidity from central banks around the industrial world. This trend has accelerated during the last decade. A potential solution for this situation may be found in family ownership, as a countervailing power for healthy competition.

Keywords: Tacit Collusion, Oligopoly, Pricing Algorithm, Game Theory, Passive and Active investor,

1 Introduction

“Googling”, “Hotel and Flight Booking”, and other modes of accessing information are now commonplace in our everyday lives. They have been described as “algorithms-as-institutions” (Robyn, et al., 2018). Raising questions about the extent to which human decision-making processes will ultimately be replaced, in certain cases, by machines (OECD, 2017). However, there are a growing number of companies using a computer algorithm for improving their pricing models, tailored services and predict market trends, not simply for customers but, particularly, to maximize profit. The pricing model is not only constructed by traditional supply and demand, but also using an ever faster, cheaper, and more powerful computer, which can fully automats to optimise a particular interaction between parties.

This study discusses a price which shows their product value, cost structure and their competitiveness. For example; Flight ticket prices are approximately 3% to 7%

higher in the American airline route than would be the case under special condition of ownership (Azar, et al., 2017). Also, many fees for banking services are recorded at historical highs in America despite offering the lowest interest rate in recent time (Jose, et al., 2016). For example, the price of eating or drinking at an amusement park or high prestigious restaurant is higher than downtown, of course, because the price is affected by location (i.e. a special condition). Galbraith, K. notes the dependence effect. Demand for goods and services is organic if the consumer suffers a privation. However, the new demands are created by advertisers who benefit from increased consumer spending and to provides a less urgent supply. The goal is to fight against those affirmations based on "conventional wisdom" (Galbraith, 2010), so-called "institution".

Generally, firms compete with one another by offering the best prices in a particular market. The "pricing game" can lead to cartels. *Industries using sophisticated computer algorithms can promptly calculate interactions with competitors and update their prices while also considering their next move* (Ezrachi , et al., 2015). This computer algorithm may represent a signal for the counterpart; however, it tends to remain undetected, most notably by antitrust authorities.

This research aimed to identify the structural factors of tacit collusion, which is when two firms agree to play to a particular condition without explicitly stating an exact price. For example, Company A holds more than 50% of the market share and sets the price at 100. There is then the question of how counterpart Company B should behave under the condition (Figs. 1 and 2). If Company A is a price leader, Company B usually follows it. Both companies depend on the action of their competitor, here Company B. When company B reduces the price to 80, it can gain market share. The normal reaction of company A would be to reduce its price to 80 also. The overall response is good for the consumer. However, there is a way to avoid reducing their price yet keep their profit; this is called "tacit collusion".

The price mechanism is shifting from the traditional method to a computational algorithm. New collisions can form via computational signals. Also, in general, shareholders are becoming decentralised and institutionalised. A shareholder's money is in trust with institutional investors who are interested only in high and stable dividends and dislike issues that could reduce these dividends. Furthermore, a money manager can create a smart investment approach, such as an exchange-traded fund (ETF). Holders of ETFs are shareholders who desire high and stable dividends but are not keen to be directly involved with company management. Galbraith suggests a countervailing power, which optimises stakeholders under certain conditions. Family ownership can provide such countervailing power because it imposes identity onto a company's culture and strategy.

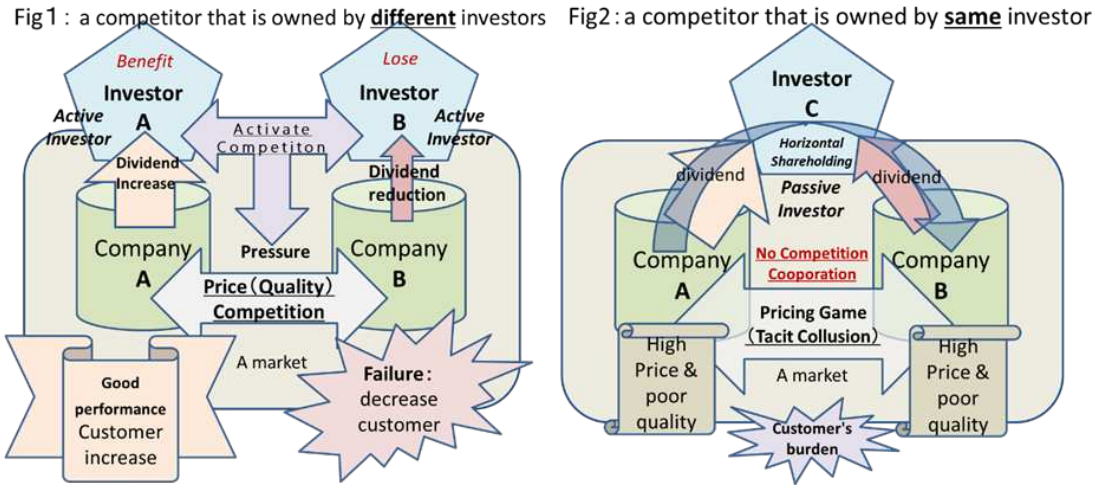
2 Game theory

The "game" in game theory denotes the interaction between parties that are acting in their own interests. It could, therefore, also be called "interaction theory", and is

applicable to the phenomenon of tacit collusion in the oligopolistic market. Two types of game are distinguished: cooperative and non- cooperative.

- *Cooperative game*; A game is cooperative if the players can form binding commitments that are externally enforced (e.g. through contract law). Cooperative game theory model scenarios, when agents can benefit from cooperating, and binding agreements are possible. In cooperative games, actions are taken by groups of agents, coalitions (Fig. 2). This diagram schematically shows investor C who holds both shears of company A and B. Investor C player plays a role as a horizontal investor, as explained below (OECD, 2017).
- *Non-cooperative game* (Competition on the market); A game is non-cooperative if players cannot form alliances or if all agreements need to be self-enforcing. The traditional non-cooperative game focuses on predicting individual player's actions. Also, the critical feature of a non-cooperative game is the absence of an external authority to enforce rules. For example; A sharing of information between competitor A and B is not permitted under the Sherman Act and the U.S. federal antitrust law (Department of Justice) or "Gesetz gegen Wettbewerbsbeschränkungen (GWB) [Bundesministerium der Justiz und fur Verbraucherschutz]" and "Japanese Act on Prohibition of Private Monopolization and Maintenance of Fair Trade [Japanese Law Translation]".

Figures 1 and 2 schematically illustrate a common non-cooperative situation [Mizuta, 2018]. Company A and B are competing for each other. There are several types of competition, which act for and against each other, such as a Joint venture, cooperation, alliance, original equipment manufacturer (OEM) and Japanese "Keiretsu". The degree of connection between companies A and B will crucially affect how their specific resources will be exchanged in the combined situation. Here, both companies are rational economic agents who separately achieve their own goals. Usually, companies are owned by investors, here designated as unrelated investors A and B. Their behaviour will be that of their respective company A or B.



Figures 1 and **2.** Conceptual diagram for **different** and the **same** investor.

Generally, a shareholder can influence a company's activities. Notably, a majority shareholder, who usually owns more than 50% of a company's shares, can play an important role. This majority shareholder has more power than all of the other shareholders combined, and has the authority to do things that other shareholders cannot, such as replacing a corporation's officers or board of directors. However, the attribution of these majority shareholders gradually changes into horizontal shareholding, which is discussed in Section 2.1 below.

In the context of corporate governance, separation of ownership and management means that the management of the company can authorise its activities under dispersed ownership; no one shareholder has enough shares to be able to control the company. There is also the stakeholder's view of a firm. In defining "Stakeholder Theory" Freeman (2010) states: "The firm is a system of stakeholder management within the larger system of the host society that provides the necessary legal and market infrastructure for the firm's activities" (Freeman, et al., 2010). Business is about how customers, suppliers, employees, financiers (e.g. stockholders, bondholders, banks), communities and managers interact and create value. Therefore, "Stakeholder Theory" and a cyber-platform can deal fairly well with "Game Theory".

Figure 1 shows a competitor that is owned by **different** investors. These are investors who are actively involved in formulating strategy for companies A and B, so-called active investors. Figure 2 shows a company that is owned by the **same** investor. The investor is not involved in strategy formulation, and is thus called a passive investor (here, investor C).

Figures 1 and 2 illustrate the analysis for maximum profit (dividend) for investors A and B, and investor C, in the two scenarios. The active investors in Fig. 1 are expected to promote competition between companies A and B and within the market at large. In contrast, investor C (in Fig. 2) reduces risk through passive investment, in comparison to the reduction of dividends by competition between companies A and B. Investor C, therefore, creates a stable profit condition. For example, ETFs track stock indexes. A stock index is computed from the prices of selected stocks (typically a weighted average). The selected stocks are chosen according to many factors such as a market-cap, free-float and other portfolio-related criteria.

- *A passive investor* (investor C in Fig. 2) invests for the long haul. Passive investors are based on a "random walk", which is a statistical phenomenon. The passive investor believes a variable follows no discernible trend and moves seemingly at random. Malkiel's random walk theory points out that the price of securities moves randomly, therefore, it is impossible to predict future price movement, either through fundamental or technical analyses. One type of passive-investor style involves a buy-and-hold mentality (Malkiel, 2019).
- *An active investor* takes a hands-on approach and requires that someone act as portfolio manager. The goal of active money management is to beat the stock market's average returns such as that of the DAX30 or other leading indexes. A hedge fund uses this investment style. A portfolio manager usually supervises analysts who examine qualitative and quantitative factors.

2.1 Horizontal shareholdings

Horizontal shareholdings have overlapping ownership by financial investors. It exists when a standard set of investors own significant shares in corporations that are horizontal competitors. Institutional investors have become leading shareholders in the airline, banking, computing and pharmacy markets. Several empirical studies have confirmed that these horizontal shareholdings have anticompetitively affected airline and banking markets (Einer, 2017).

Institutional investors are specialised financial institutions that invest capital from a large number of investors on their behalf, pursuing the goal of maximising returns at a reasonable risk. Institutional investors include insurance companies, asset managers, investment and pension funds, as well as banks and sovereign wealth funds. The German Monopolekommission focuses on investigating equities and differentiating between active and passive investment strategies (Table 1). Active investors may choose between value, growth and combination strategies (e.g. growth at a reasonable price (GARP)). Passive investors seek the performance of an index, such as using ETFs. In the context of the DAX, the most important German stock index, the share held by institutional investors in 2017 represented 61.8% of the free float, while private investors accounted for 17.2% and strategic investors 18.4%. Strategic investors are anchor investors such as families (companies), foundations and strategic participations of the Federal Republic of Germany (Table 1) (DIRK, IPREO, 2018). The Top 10 investor group of the DAX 30 index shows the value held by specific institutional investors, e.g. BlackRock, which accounted for 10.1%. Notably, the Top 10 investors collectively held more than one-third of the value of the DAX30 index.

Table 1. Top 10 Investor group of DAX 30 index

Rank	Group	Value on DAX in 2017（Mio $）	Account of DAX ％	Passive or Active	Country
1	**BlackRock, Inc.**	72,152.00	10.10%	Aktive&Passive	USA
2	**The Vanguard Group, Inc.**	29,802.50	4.20%	Passive	USA
3	**Deutsche Bank AG**	29,254.20	4.10%	Akive	Germany
4	**Norges Bank (Norway)**	25,905.00	3.60%	Aktive	Norway
5	**State Street Corporation**	23,417.80	3.30%	Passive	USA
6	Credit Agricole (Amundi)	17,529.80	2.50%	Aktive&Passive	France
7	Societe Generale (Lyxor)	15,904.60	2.20%	Passive	Germany
8	BPCE S.A. (Harris Associates)	15,541.20	2.20%	Aktive	Swiss
9	UBS AG	15,470.60	2.20%	Aktive	France
10	Allianz SE	14,826.70	2.10%	Aktive	Germany
	Total	259,804.40	36.50%		

参照: Deutscher Investor Relations Verband und Ipreo

3 The several Signals (Artificial intelligence, Machine learning and Deep learning)

Regarding the use of computer techniques below will create more secret collusion, and as a result, manipulates a price setting. The stronger, more powerful algorithms will likely prevail and dominate the market. A simple scenario, we use computers to execute their instructions directly. Firms are owned by overlapping sets of investors (passive investors), and their incentives to compete are thereby reduced, explained about 2.1 Horizontal shareholding. The computer techniques are developing step by step see 1 to 3 below.

1. Artificial intelligence (AI)

Chaos data (now referred to as 'big data') are generated through our daily experiences. Norbert Wiener first suggested that chaos data could be regulated and organised using cybernetics as an approach to controlling the chaos (Norbert, Wiener, 1950) and he now considered to have been a pioneer in artificial intelligence (AI). The signals involve the following concepts: artificial intelligence (1950s-), machine learning (1980s-) and deep learning (2010s), in chronological order.

2. Machine learning

The machine is "trained" using large amounts of data and algorithms that enable it to learn how to perform a task. There are several types of learning pattern: 1. Supervised learning; the computer learns a general rule. 2. Unsupervised learning; no labels are given to the learning algorithm so that the hidden structures or patterns in the data may be discovered. 3. Active learning; the computer can only obtain training labels. 4. Reinforcement learning; feedback is given to the program's actions in a dynamic environment, such as a self-driving vehicle.

3. Deep learning

As you know, Go is a strategy board game for two players. The game was invented in China more than 2,500 years ago. Alphabet Inc. (Google DeepMind) developed AlphaGo what is a computer program for playing the game of Go. AlphaGo has beaten a human professional Go player, who is the world No.1 ranked player, Ke Jie in 2017. AlphaGo's algorithm uses a combination of machine learning.

3.1 Pricing Game

An agreement may be established as humans collude through the medium of computers (Table 2). The computer algorithms serve as the messengers in the sense that the cartel members program the computers to help the cartel. Table 1 shows three types of collusion: "messenger", "hub-and-spoke" and "autonomous machine". However, these are only recognised behind closed doors (tacitly).

- *Messanger;* This type of collusion occurs when a competitor agrees to use the same pricing algorithm under the same conditions, even if there is no agreement on direct price. As with the agreement to use the formula, the cartel is also established under the traditional cartel concept.
- *Hub and Spoke;* If a competitor happens to use the same pricing algorithm provided by a third party, it does not immediately cause a problem with respect to antitrust law. However, in the case where competitor price data themselves are shared through third parties and they are mutually recognised, a hub-and-spoke type of cartel may result.
- *Autonomous Machine*; When autonomous pricing algorithms make price adjustments irrespective of the intention of the operator, there is no artificial interaction between competitors. The cartel concept can be difficult to apply in such a situation.

Table 2. Computer collusion scenario (Ezrachi , et al., 2015 p. 1784)

Model of collusion	Usage/Type/ characteristics of	Evidence of agreement
Messenger	Competitive companies use the same pricing algorithm	Strong evidence of horizontal agreement
Hub and Spoke	Machine Learning	likely effect
Autonomous Machine	Deep Learning	Unclear

4 Asset under Management

"Horizontal Shareholding", mentioned above section 2.1 based on respect to passive funds. Horizontal shareholding means that funds investing in shares will be majority shareholders of many companies in one industry. Usually, investors will apply pressure on corporate managers to increase the competitiveness of the holding company, which will win market share and the corporate value will rise. This will drive up the stock price and improve profit.

However, the situation will be different for the investor who holds shares of many companies in the same industry. A highly competitive market will lead to price reductions and, thereby, a loss in value of the company. There is a possibility that the total profits of both companies could actually be higher in such a situation, not because of price competition but, rather, because of “tacit collusion” in a low-growth market.

The shareholding structure may support such tacit collusion. Global assets under management are expected to rise from US$84.9 trillion in 2016 to US$145.4 trillion in 2025 according to PricewaterhouseCoopers (PwC). This firm predicts a compound growth rate of almost 6%. Figure 3 shows the share of active, alternative and passive global assets under management. Traditional active management will continue to be

the core of the industry in 2025. However, it will grow at a less rapid pace than the passive and alternative strategies.

PwC forecasts that active management will decrease from 71% in 2016 to 60% in 2025. Passive investment will gain significant market share, rising ***from 17% to 25%***, while alternatives will increase from 12% to 15% over the same period. Passive investment will more than double, from US$14.2 trillion to US$36.6 trillion because of cheap passive ETFs. Alternatives will increase from US$10.1 trillion to US$21.1 trillion.

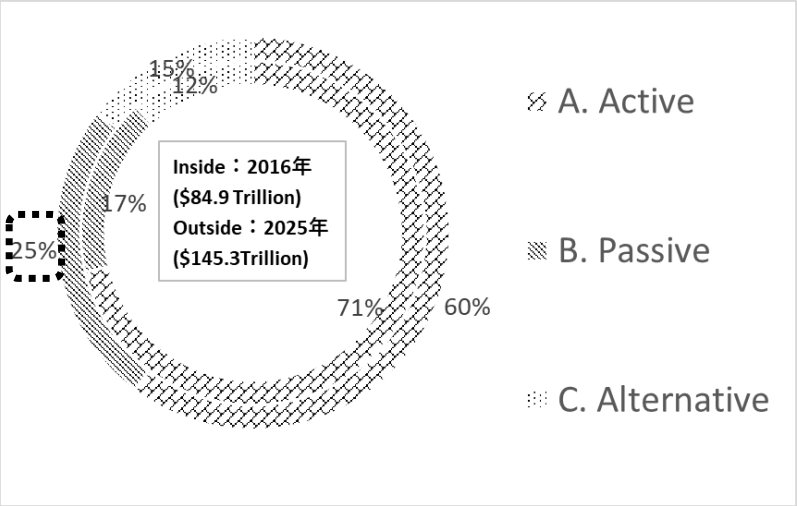


Fig. 3. The active, alternative and passive shares within global assets under management (PwC, 2017).

5 Conclusion and Solution

In this paper, a structural investigation of tacit collusion was presented by adopting a two-step approach. **First,** pricing mechanisms are slowly shifting from traditional techniques to a new "pricing game". Moreover, new forms of collusion have emerged, including horizontal agreement, as a result of computer algorithms that exert their influence covertly.

Second, firms are owned by passive investors, such as the "Big Three" institutional investors (BlackRock, Vanguard and State Street). Investors are shifting their money into ETFs, particularly as they can offer lower operating costs, flexible trading and superior risk diversification. ETFs are also a favourable counterbalance to the excess liquidity that has afflicted central banks since the financial crisis began in September 2008. However, despite the convenience of ETFs, their character can accelerate the hollowing-out of voting rights (corporate governance). Corporate governance is defined as the relationship between a company's stakeholders, management and board of directors, and has a significant influence on that company's operation. The Big Three are incapable of executing their voting rights without their workforce.

BlackRock continues to be an important and very large investor in Germany (Deutschland-AG) with an actual share of 6.1% of the institutional free-float. BlackRock holds $2.1 Mrd in the DAX (German stock index; $2,1 Mrd.) (DIRK, IPREO, 2018). They also have $4.7trn assets under management. The NYSE market

capitalisation will be around $19trn, that is, almost one-quarter of the entire market (Azar, et al., 2017).

*Family ownership may offer a **possible solution** and to offer a countervailing power against this situation, for healthy competition. The motivation for the family-shareholding is focusing on the company's governance, rather than the intention of profit maximisation of institutional investors.* For example, according to Fig. 4. the historical shareholding structure of DAX30, family ownership holds a share of 19.01% compared to that occupied by overseas investors at 16.58% (Monopolkommission, 2018).

The shareholding structure categorises identifiable capital shares exceeding one per cent according to the nature of the shareholder. It identifies whether the equity interests of shareholders are held by the Top 100 companies, foreign investors, the public sector or individuals, or families or family foundations. Figure 4 shows the historical shareholding structure from 1982 to 2016. The shareholders fall into the following six categories:

1. ***Free-float***; This refers to the number of outstanding shares that are available to the public for trade. Free-float market capitalisation is calculated by multiplying the equity's price by the number of shares in an index, such as the DAX30. It is important to identify all of the active and inactive shares for the calculation. The free-float excludes locked-in shares such as those held by the Top 100 companies, and shares owned by families, the general public and governments as below.

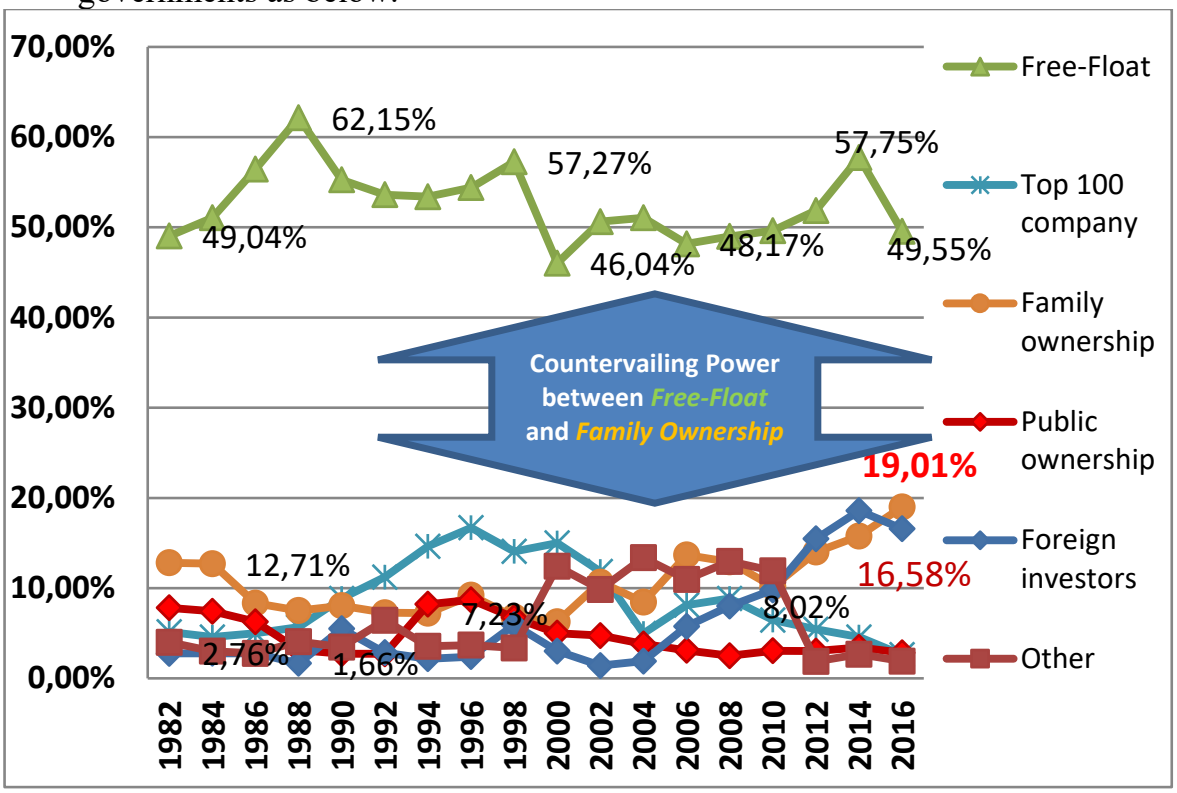


Fig. 4. Historical shareholding structure of the DAX30

This Free-float ownership, held by institutional investors, need to be countervailed by family owners (19.01%) against this free-float (49.55%), see Fig. 4

below. Free-float is applied by especially passive investors for grounding their precondition what explained in Fig. 3. before.

2. ***Family ownership***; This category includes ownership by individuals or family foundations. Family ownership has a direct or indirect majority (in the sense of the regular majority of capital or voting rights in shareholders' meetings); one or more families can be involved. Also, family ownership must (in some way) influence the company's strategy (Prof. Dr. Kirchdörfer, 2011). Fig. 4. shows that the family ownership (19.01%) is exceeded the overseas investors (16.58%) in throughout the 2000s when globalization progressed. In addition, family ownership is favoured by regulators because of their creation for attractive employment opportunities.
3. *German Top 100 company*; These companies create significant economic value and employment. Fig. 4. illustrates the ownership ratio of the Top 100 companies has decreased slightly over the past 15 years.
4. *Public ownership*; Figure 4 shows that public ownership has also decreased markedly over the past 20 years. However, the public sector plays a very important role from the socio-political perspective. It comprises the governing bodies that are political decision-makers. Public sector representatives as policy-makers are predominantly found in the boards of directors of companies in which the public sector also holds shares of capital. The importance of this category has also diminished, due to the privatisation of major energy suppliers such as RWE AG in Germany. The public sector offers a certain framework to create a countervailing structure between the free-float and family ownership, as noted above.
5. *Foreign investors*; An allocation to the "identifiable foreign investors" category only takes place insofar as the available data sources explicitly include investments by foreign investors, which in each case must exceed one per cent.
6. *Other*; Shares of companies outside the German Top 100 companies and institutional investors in Germany as well as capital shares of co-operatives and unidentifiable participations are included in this category.

It could be a very natural step toward setting up a foundation for a big family-owned corporation for Tax reason, primarily a social responsibility for the public.

Between 2006 and 2014, the domestic employment figures for the 500 largest family firms in Germany increased from 2.67 to 3.17 million to almost 19%. In comparison, the 27 DAX-listed companies recorded only a 1.5% growth in employment over the same period (Dr. Gottschalk , et al., 2017). Also, A variety of the corporate form is also helping to increase family businesses such as the foundation for public interest. For example, Volkswagen AG is governed heavily from the foundation of the Porsche and Piëch families, such as the Ferry Porsche foundation. This foundation sacrifices only their dividend from their shareholding but keeps Governing power to the company.

The branding strategy (a dependence effect) of those family-owned companies will also be the research subject, which is heavily causing a vertical and horizontal inte-

grated structure not only for their physical production but also their virtually created brand-image.

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Digital empathy secures Frankenstein's monster

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Abstract. People's worries about robot and AI software and how it can go wrong have led them to think of it and its associated algorithms and programs as being like Mary Shelley's *Frankenstein monster*. The term *Franken-algorithms* has been used. Furthermore, there are concerns about driverless cars, automated General Practitioner Doctors (GPs) and robotic surgeons, legal expert systems, and particularly autonomous military drones. Digital Empathy grows when people and computers place themselves in each other's shoes. Some would argue that for too long people have discriminated against computers and robots by saying that they are only as good as what we put into them. However, in recent times computers have outperformed people, beating world champions at the Asian game of Go (2017), Jeopardy (2011) and chess (1997), mastering precision in medical surgical operations (STAR) and diagnosis (Watson), and in specific speech and image recognition tasks. Computers have also composed music (AIVA), generated art (Aaron), stories (Quill) and poetry (Google AI). In terms of calling for more Digital Empathy between machines and people, we refer here to theories, computational models, algorithms and systems for detecting, representing and responding to people's emotions and sentiment in speech and images but also for people's goals, plans, beliefs and intentions. In reciprocation, people should have more empathy with machines allowing for their mistakes and also accepting that they will be better than people at performing particular tasks involving large data sets where fast decisions may need to be made, keeping in mind that they are not as prone as people to becoming tired.

We conclude that if digital souls are programmed with Digital Empathy, and people have more empathy with them, by doing unto them as we would have them do unto us, this will help to secure Shelley's monster.

1 Introduction

In recent times the fears and anxieties about robots and AI have come to the fore again with academics, but particularly industry and the military-industrial complex, working on conversational chatbots, healthcare assistants, driverless cars, humanoid robots including sexbots and military robots including autonomous drones. Many would argue that the fears are unfounded as these systems are currently no where near the level of human intelligence envisaged in *strong* AI and are more at the level of *weak* or now *narrow* AI, solving fixed problems in limited domains [1]. However, in response to people's fears and a need for ethics in design and production of AI we have seen a rise in the formation of institutes addressing ethical matters in respect of AI such as the *Future of Life Institute* [2], championed and funded by Elon Musk.

What appears to make people anxious about robots and AI is the possibility of robots displacing employment and putting people out of jobs, the fact that robots may get *too big for their boots* and control people who become their slaves, and that building robots that are like people should only be the work of *God*. In effect, the fears that people have is that in the strive to create lifelike machines, monsters like Dr. Frankenstein's [3, 4] (Figure 1) will inadvertently be created.

In this paper we explore people's fears on the rise of AI and how more *digital empathy*, where people and robots can put themselves in each other's shoes and work in harmony, will help to secure AI from becoming Frankenstein's monster. In section 2 we discuss some historical background to the field of robots and AI exploring people's relationship with it in philosophy and literature. Section 3 discusses people's fears leading to possible silicon discrimination. Successes and failures in AI which have added fuel to people's fears are discussed in Section 4. Section 5 discusses key efforts to bring ethics to bear with AI and robots. Section 6 discusses how digital empathy can help to secure people's fears and finally section 7 concludes with avenues for future work.

2 Historical background and related work

People's fears about scientists inadvertently creating monsters in trying to create life run right back to Mary Shelley's, *Dr. Victor Frankenstein* [3], from 1818. In her novel the monster is referred to as *creature*, *monster*, *demon*, *wretch*, *abortion*, *fiend*, and *it*. Speaking to Dr. Frankenstein the monster states: "I ought to be thy Adam, but I am rather the fallen angel." Dr. Frankenstein, whilst based at the *University of Ingolstadt*, excels in chemistry and other sciences and develops a secret technique to impart life to non-living matter and then creates the humanoid which is 8 feet in height and large. The creature escapes and lives alone in the wilderness finding that people were afraid of and hated him due to

Fig. 1. Frankenstein's monster, Boris Karloff, 1931 [3]

his appearance which led him to fear and hide from them. The creature learns to speak and read and when seeing his reflection in a pool realised his physical appearance was hideous and it terrified him as it terrifies normal humans. The creature demands that Dr. Frankenstein creates a female companion like himself and whilst doing so he suffers fears that the two creatures may lead to the breeding of a race that could plague mankind and so destroys the unfinished female creature. In the end Victor dies and the creature drifts away on an ice raft never to be seen again. Shelley travelled through Europe in 1814 and along the Rhine in Germany with a stop at Gernsheim which is 17 km away from the Frankenstein Castle at Pfungstadt, where an alchemist and theologian, Johann Conrad Dippel, was born on 10 August 1673 and was engaged there in experiments on alchemy and anatomy performing gruesome experiments with cadavers in which he attempted to transfer the soul of one cadaver into another. He created an animal oil known as *Dippel's Oil* which was supposed to be an *Elixir of Life*. Soul-transfer with cadavers was a common experiment among alchemists at the time and Dippel supported this theory in his writings [5]. It is rumoured that he dug up bodies and performed medical experiments on them at Frankenstein Castle and that a local cleric warned the parish that Dippel had created a monster that was brought to life by a bolt of lightning.

The title of Shelley's book also makes a reference to *Prometheus*, in Greek Mythology a Titan culture hero and trickster from 800 BC who is credited with creation of man from clay and who defies the gods by stealing fire and giving it to humans. He is then punished by eternal torment and bound to a rock where each day an eagle feeds on his liver which grows back but is then eaten again

the next day. In Greek Mythology the liver contains emotions. Hence, it is clear that Shelley is bringing into our consciousness, that in man's overreaching quest for scientific knowledge, there is the inadvertent or unintended consequences of tinkering with the work of the Gods. In Shelley's novel there is also the gender theme of man attempting to create life without involvement of woman and Shaw's play *Pygmalion* [6] also investigates gender in how man (*Professor Henry Higgins*) attempts to transform a poor flower girl (*Eliza Doolittle*) so she can pass as a duchess by teaching her to speak properly the Queen's English, which also has an unhappy ending. Pygmalion is a reference to the Greek story of *Pygmalion*, catalogued in *Ovid's Metamorphoses* from 8 A.D., who fell in love with one of his sculptures which then *Aphrodite* brought to life. The story of breathing life into a statue has parallels with Greek myths of *Daedalus* using quicksilver to put voices in statues, *Hephaestus* creating automata and *Zeus* making *Pandora* from clay. Gender power matters are also explored again in Greek Mythology in 400 B.C. the *Gorgon* monster *Medusa*, a winged human female with venomous snakes in place of hair, has a power where gazers upon her face would turn to stone.

Der Sandmann (*The Sandman*) [7] is a short story in a book titled *Die Nachtstücke* (*The Night Pieces*) which appeared in 1816, around the time of Shelley's Frankenstein. In *The Sandman*, *Nathanael* tells of his child terror of the sandman who stole the eyes of children who would not go to bed and fed them to his own children who lived in the moon. Nathanael calls his fiancée *Clara* an "inanimate accursed automaton" and Nathanael's Professor, *Spallanzani*, creates a daughter automaton called *Olimpia*, who Nathanal becomes infatuated with and is determined to propose to, where there is also the gender matter of no mother or woman involved. In 1870 elements of *The Sandman* were adapted as the comic ballet *Coppélia*, originally choreographed by *Arthur Saint-Léon* to the music of *Léo Delibes* with libretto by *Charles-Louis-Étienne Nuitter*. *Die Puppe* (*The Doll*) [8] is a 1919 fantasy comedy film directed by Ernst Lubitsch also inspired by *The Sandman*. Objections to machines displacing employment go back to Leviathan [9] in 1651 which discusses humans as being sophisticated machines. Then we have the *Luddites* of 1811, English workers who destroyed machinery mainly in cotton and woollen mills which they believed was threatening their jobs. *Marx* and *Engels* also objected to the weaving automota upset by sights of children's fingers being chopped in machines and visions of them being eaten by these machines. The related theme of slaves and masters between machines and humans comes leads back to slaves in ancient Egypt where we find some of the first automata in the form of moving statues. Egyptian Kings, and kings throughout the ages, displayed their power by demonstrating moving statues, clocks and fountains at public entertainment events [10–14] such as *Jacques de Vaucanson's* mechanical duck (1739) which could eat, drink and go to the toilet. This theme of slavery comes up again *in Fritz Lang's Metropolis* [15]. Alternatively, others have argued that machines will do all the hard work liberating people to pursue creative pursuits and leisure, a kind of Utopia [16].

There have always been religious objections to AI and robotics, man of them based on the fact that creating life is the work of God and only people can have souls. Descartes [17, 18] who focused on rationalism and logic whilst watching through his Amsterdam window Dutch people walking in street saw no difference between them and automata and produced his well known statement: "Je pense, donc je suis" ("Cognito ergo sum"; I think, therefore I am). He emphasized that people are rational and only they can have souls, not animals or automata which are mechanical. Leibniz, another rationalist, and Hobbes an empiricist, had similar views. However, religion has also used statues to demonstrate God's power where at the *Cistercian Boxley Abbey* in Boxley, Kent, England there were moving and weeping statues with nuns inside manufacturing the tears. There have also been arguments that the design of people's hands is proof of the existence of God.

3 Silicon discrimination?

People's fear of AI and robots has led to what could be called *discrimination* against them with common colloquial sayings such as *computers are only as good as what we put into them.* In 2017 Jack Ma, the founder of Alibaba said that there is IQ (Intelligence Quotient), EQ (Emotional Intelligence) and LQ (Love Intelligence) and that people have all three of these but robots cannot have LQ. However, Ma does not take into account a particular type of humanoid robot that we will visit below in Section 4. People also say that robots have no creativity and no soul as they are not created by God.

Searle [1, 19, 20] makes the distinction between human level intelligence envisaged in *strong* AI and *weak* or now *narrow* AI where programs are solving fixed problems in limited domains. In arguing against strong AI, Searle proposed the *Chinese Room Argument* [1, 19] GedankenExperiment arguing that AI programs are like a person inside a room who uses a large rule book to handle messages with written Chinese instructions and responds to them, but has no understanding of Chinese at all. There is also Harnad's *Symbol Grounding Problem* [21], asking the question how symbols in AI programs are grounded in the real world. Dennett in the *Intentional Stance* [22] discusses a *Ladder of Personhood* where computers can have the ability to perform language processing, reasoning, but cannot have stance (ascribing intentions to others), reciprocity and consciousness, which only people can have. However, Ballim & Wilks [23] discuss in detail how computers can have beliefs and nested beliefs about other people's beliefs. Dreyfus [24, 25] points out that computers cannot have common sense like humans. Weizenbaum, an AI researcher, explains the limits of computers and that anthropomorphic views of them are a reduction of human beings and any life form [26]. Penrose [27] argues from the viewpoint of Physics, that AI cannot exist.

In terms of employment displacement fears, in many states there is fair employment discrimination legislation enabling tribunals based on religious, sexual orientation, nationality, race, and gender discrimination. In a future where in-

telligent robots do exist will they request legislation on silicon discrimination? and could there be robots sitting on Tribunal panels?

4 AI successes and failures

There have been successes with AI and robots over the years. There was the checkers (draughts) playing program developed by Arthur Samuel at IBM in 1961. IBM also built Deep Blue which beat the world chess champion Gary Kasparov in 1997 and in 2011 IBM's Watson beat the world champions at the quiz show game of *Jeopardy!*. Google's *AlphaGo* beat the world champion in Korea at the Asian game of *Go*. However, there have also been failures with Driverless cars and particular image recognition tasks.

4.1 Conversational chatbots

One of the popular areas of AI is the development of natural language processing conversational AI programs which can interact in, usually typed and not spoken, dialogue with people. These chatbots have been applied in many areas including pychotherapy, companions, call-centre assistance, and healthcare. One of the first programs developed at MIT by Joseph Weizenbaum in 1964 [26, 28] was *ELIZA*, named after *Eliza Doolittle* discussed in Section 2 above. ELIZA simulated conversations by using pattern-matching that gave users an illusion of understanding by the program. Scripts were used to process user inputs and engage in discourse following the rules and directions of the script. One of these scripts, *DOCTOR*, simulated a Rogerian psychotherapist. Many individuals attributed human-like feelings to ELIZA including Weizenbaum's secretary, with users becoming emotionally attached to the program forgetting that they were conversing with a computer. In 1972 ELIZA met another conversational AI program named PARRY developed by Ken Colby [29] where they had a computer-to-computer conversation. PARRY was intended to simulate a patient with schizophrenia. Since ELIZA there have been many chatbots developed and *Hugh Loebner* launched the *International Loebner Prize* contest in 1990 for chatbots which could pass the *Turing Test* [30], a test proposed by Alan Turing where programs which could fool human judges that they were humans would be deemed to be intelligent. The most recent winner in 2018 of the annual bronze medal for the best performing chatbot is *Mitsuku*, which has now won the contest four times (2013, 2016, 2017, 2018). No chatbot has won the Loebner Gold Medal Prize, where it fools all of the four judges that it is human.

4.2 Medical assistants

Chatbots are being used in healthcare and last year *Babylon*, a healthcare chatbot with the goal of making healthcare universally accessible and affordable, giving online consultation and advice effectively acting as a General Practitioner

Doctor (GP), has received a £100 million investment in September, 2018 creating 500 jobs in London. Babylon caused controversy by claiming that in tests it performs medical diagnosis on a par with GPs achieving medical exam scores in the MRCGP (Royal College of General Practitioners) exam.

IBM's *Watson* mentioned above is also being applied to a number of application domains including healthcare. Watson uses natural language processing, hypothesis generation and evidence-based learning to support medical professionals as they make decisions. A physician can use Watson to assist in diagnosing and treating patients. Physicians can pose a query to Watson describing symptoms and other related factors and then Watson identifies key pieces of information in the input. Watson mines patient data and finds relevant facts about family history, current medications and other conditions. It combines this information with findings from tests and instruments and examines existing data sources to form hypotheses and test them. Watson incorporates treatment guidelines, electronic medical record data, doctor's and nurse's notes, research clinical studies, journal articles and patient information into the data available for analysis. Watson provides a list of potential diagnoses along with a score that indicates the level of confidence in each hypothesis.

DeepMind was founded in London in 2010 and acquired by Google in 2014, now part of the Alphabet group. DeepMind is a world leader in AI research and its application. DeepMind Health is focused on helping clinicians get patients from test to treatment faster. DeepMind Health works with hospitals on mobile tools and AI research to help get patients from test to treatment as quickly and accurately as possible. *Streams* is an app developed and in use at the Royal Free London National Health Service (NHS) Foundation Trust using mobile technology to send immediate alerts to clinicians when a patient deteriorates. Nurses have said that it is saving them over two hours each day meaning they can spend more time with those in need.

The STAR (Smart Tissue Autonomous Robot) in 2017 [31] beat human surgeons at a flesh-cutting task in a series of experiments. It made more precise cuts than expert surgeons and damaged less of the surrounding flesh. Previously, in 2016 STAR had sewed together two segments of pig intestine with stitches that were more regular and leak-resistant than those of experienced surgeons.

The SenseCare (Sensor Enabled Affective Computing for Enhancing Medical Care) [32, 33] project is developing a new affective computing platform providing software services applied to the dementia care and connected health domain providing intelligence and assistance to medical professionals, care givers and patients on cognitive states and overall holistic well-being. Data streams are integrated from multiple sensors fusing these streams together to provide global assessment that includes objective levels of emotional insight, well-being and cognitive state where medical professionals and care can be alerted when patients are in distress. A key focus of SenseCare is to detect the emotional state of patients from their facial gestures and a web service has been developed which outputs emotional classifications for videos [32, 33]. A sample screenshot of the application is shown in Figure 2. Results from analysed emotions giving senti-

ment (positive, negative) and timestamps are shown in Table 1. The MIDAS (Meaningful Integration of Data, Analytics & Services) [34] project is also addressing connected health from the point of view of data analytics and services.

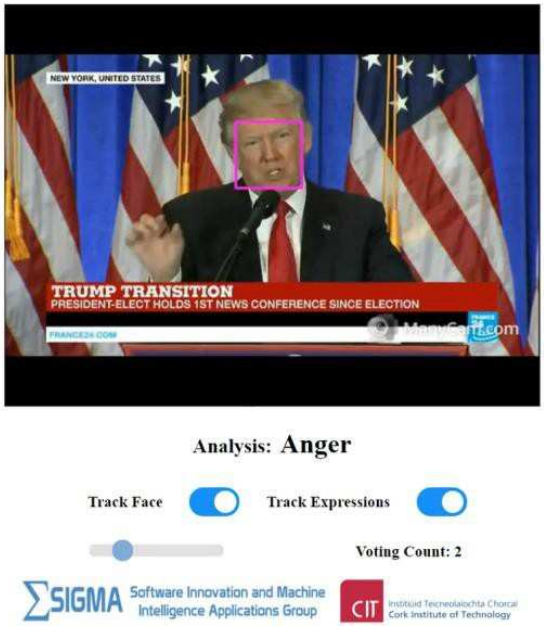

Fig. 2. Detecting emotional states in facial expressions [32, 33]

Table 1. SenseCare timestamped emotion analysis.

Positive			*Negative*		
Happiness	*Interested*	*Enthusiasm*	*Bored*	*Angry*	*Frustrated*
00:50:30	00:21:00	02:00:40	00:35:12	01:10:15	01:48:20
01:32:00	00:40:30		00:41:10		
01:35:55	01:00:35		01:20:41		
	01:05:20		01:25:15		
	01:07:15		01:45:30		
			01:51:30		

4.3 Driverless cars

In the car industry the race is on to develop the first driverless car with many computer companies such as Google, car companies such as Volkswagen, Daimler AG, and even Taxi companies such as Uber working on the problem. Google's *Waymo (New Way Forward in Mobility)* is a self-driving technology company with a mission to make it safe and easy for people and things to move around. Waymo has more than 25,000 autonomous miles driven each day, mainly on

complex city streets on top of 2.7 billion simulated miles driven in 2017. Vehicles have sensors and software that are designed to detect pedestrians, cyclists, vehicles, road work and more from up to three football fields away in all 360 degrees. However, there have been some failures with a *Tesla Model S* car driver being killed in May, 2016 when the car (and driver) did not detect the white side of a truck against the brightly lit sky, with no application of the brake, on *US Highway 27a* and in March, 2018 a *Tesla Model X* electric SUV crashed into a *US Highway 101* barrier killing the driver whilst on autopilot. Also, in March, 2018 at Tempe, Arizona, USA an Uber driverless Volvo SUV killed a female pedestrian walking with her bicycle across the road when the driver was not paying attention after the car attempted to hand over control to her.

4.4 Humanoid robots

Industrial robots have already been used in the car and other manufacturing industries for decades. More recently there has been a focus on more humanoid robots detecting and exhibiting emotions with numerous applications such as companions and healthcare assistants. Examples of such robots are *Erica* developed at Osaka University which is a humanoid female robot and *Pepper* developed by *Softbank*, which can detect and react to people's emotional states. Companies such as *Abyss creations* are developing Sexbots such as *RealDoll* sex doll and sex robot *Harmony*, with customisable AI and swappable faces, which are life-like and can move and speak to their users. Customers can have conversations with Harmony.

4.5 Military robots

Military robots for warfare in the field are also being developed by companies such as Boston Dynamics. These robots which can be animal-like have the ability to move fast over difficult terrain and pick themselves up again after slipping on ice. Robotic drones such as the *Reaper*, have also been developed for warfare, which are currently controlled by people, but there are military moves towards having them operate autonomously. Alternatively, there are drones which are used in the service of society such as environmentalism and search and rescue. Such drones have been used to deliver vital medical supplies to the field in remote regions. Drone waiters have even been used to deliver drinks and food at parties!

4.6 Creativity

The mathematician *Lady Ada Lovelace*, daughter of *Lord Byron*, mentioned above in Section 2, is acknowledged as the first computer programmer. She recognised the creative and artistic potential of computers in the 1840s suggesting that computers "might compose elaborate and scientific pieces of music of any degree of complexity" [35]. There has been work in AI on modelling creativity in art, music, poetry, storytelling [36, 37]. In respect of art, AARON has

been developed since 1973 by Harold Cohen [38, 39] and creates original artistic images. Initial versions of AARON created abstract drawings that grew more complex through the 1970s. In the 1980s more representational figures set in interior scenes were added, along with colour. In the early 2000s AARON returned to abstract imagery, this time in colour. Cohen has used machines to enable AARON to produce physical artwork.

AIVA (Artificial Intelligence Virtual Artist) [40], developed by Pierre & Vincent Barreau in 2016 composes music and is the world's first computer program to be recognised by a music society, *SACEM (Société des Auters, Compositeurs et Éditeurs de Musique)*. By reading a large collection of existing works of classical music written by human composers such as *Bach, Beethoven*, and *Mozart*, AIVA can understand concepts of music theory and compose its own. AIVA is based on deep learning and reinforcement learning AI techniques. AIVA is a published composer, with its first studio album, *Genesis*, released in November, 2016 and its second album, *Among the Stars* in 2018.

Google AI, working with Stanford University and University of Massachusetts, developed a program in 2016 that accidentally produces poetry [41], after attempts to digest romance novels, using an AI technique called RNNLM (Recurrent Neural Network Language Model).

Quill developed by *Narrative Science* in 2015 [42] is a natural language generation storytelling program that analyses structured data and automatically generates intelligent narratives. Narrative Science received some early criticism from journalists speculating that it was attempting to eliminate the jobs of writers, particularly in sports and finance.

5 Ethical AI

Isaac Azimov in *I, Robot* in 1942 [43], provided three laws of robotics:

- A robot may not injure a human being or, through inaction, allow a human being to come to harm
- A robot must obey orders given it by human beings except where such orders would conflict with the *First Law*
- A robot must protect its own existence as long as such protection does not conflict with the *First* or *Second Law*.

Later in 2013, Alan Winfield suggested a revised 5 *Principles of Robotics* published by a joint Engineering & Physical Sciences Research Council (EPSRC)/Arts & Humanities Research Council (AHRC) working group in 2010 [44]:

- Robots are multi-use tools. Robots should not be designed solely or primarily to kill or harm humans, except in the interests of national security.
- Humans, not Robots, are responsible agents. Robots should be designed and operated as far as practicable to comply with existing laws, fundamental rights and freedoms, including privacy.

- Robots are products. They should be designed using processes which assure their safety and security.
- Robots are manufactured artefacts. They should not be designed in a deceptive way to exploit vulnerable users; instead their machine nature should be transparent.
- The person with legal responsibility for a robot should be attributed.

In response to people's fears and a need for ethics in design and production of AI we have seen a rise in the formation of institutes addressing ethical matters in AI such as the *Future of Life Institute* [2], founded in 2014 by Max Tegmark, Elon Musk, Stuart Russell, and Stephen Hawking, the OpenAI institute [45] founded in 2015 by Elon Musk, Microsoft, Amazon, Infosys, the *Future of Humanity Institute* [46] at Oxford University founded in 2014 by Nick Bostrum and the *Centre for the study of existential risk* [47] at Cambridge University founded in 2012, by Jaan Tallinn (founder of Skype) and Seán Ó hÉigeartaigh and the *Foundation for Responsible Robotics (FRR)* [48] at The Hauge in The Netherlands founded in 2015 by Aimee van Wynsberghe (President) and Noel Sharkey (Treasurer) with Shannon Vallor as Secretary. The FRR has as its mission:

> to shape a future of responsible robotics and artificial intelligence (AI) design, development, use, regulation and implementation. We see both the definition of *responsible robotics* and the means of achieving it as ongoing tasks that will evolve alongside the technology.

where *responsible robotics* means that it is up humans to be accountable for the ethical developments that necessarily come with the technological innovation. Recently the FRR and professional services network Deloitte have announced they will be launching a quality mark for robotics and AI to promote transparency and trust in AI products which will match a set of standards to receive the quality mark. Criteria will include environmental protection, sustainability, worker treatment, safety and security. The FRR in partnership with Deloitte will give products a rating out of three. The FRR has supported the *Curbing Realistic Exploitative Electronic Pedophilic Robots (CREEPER) Act*, introduced in the USA on December 14th, 2017 by Congressman Dan Donovan with a bipartisan coalition of 12 original cosponsors, to ban importation and distribution of child sex dolls. Similar bans exist in Australia and the UK.

The *International Committee for Robot Arms Control (ICRAC)* is a Non Governmental Organisation (NGO) of experts in robotics technology, AI, robot ethics, international relations, international security, arms control concerned with the dangers that military robots pose to peace and international security and to civilians in war. A key component of ICRAC's mission statement is:

> the prohibition of the development, deployment and use of armed autonomous unmanned systems; machines should not be allowed to make the decision to kill people

where it is on the Steering Committee for the *Campaign to Stop Killer Robots*, launched in London in April, 2013, an international coalition working to preemptively ban fully autonomous weapons. Recently the European Union (EU)

has passed a resolution supporting a ban on the use of weapons that kill autonomously.

Wilks [49] and Lehman-Wilzig [50] discuss responsible computers and how blame and punishment might be applied to computers and how they might be said to take on social obligations. Wilks notes that humans behind machines and programs can be identified to carry the blame, or the companies who have produced them. However, this can be tricky due to the fact that large teams can be involved in developing software which has been edited and updated over many years and some of these people may also have passed away. Wilks points out that a machine can be turned off and smashed, and the software with it, or burned separately making sure that one has all the copies. He notes that *Joan of Arc's* body was punished but not her soul which reminds us of the discussion on Descartes in Section 2 above.

Plug & Pray [51] is a 2010 documentary film about the promise, problems, and ethics of AI & robotics with the main protagonists being MIT professor Joseph Weizenbaum mentioned in relation to ELIZA in Section 4 above, who died during the making of the film, and the futurist Raymond Kurzweil. Kurzweil dreams of strong AI where machines will equal their human creators where man and machine merge as a single unity. However, Weizenbaum questions society's faith in the redemptive powers of new technologies and their ethical relationships to humans.

6 Digital empathy

It is clear that with the recent rise of developments in AI, and particularly by industry, there is a need more for *digital empathy* between machines and people and people and machines. First, if we take machines and people then failsafe mechanisms such as the *Laws of Robotics* discussed in Section 5 will need to be included as a *backstop* (safety net) in robots and AI, in cases where they have not preemptively had their wings already clipped. Such laws will need to be programmed into the robots and AI so that they make rational decisions in respect of for example making split second decisions whilst avoiding an accident, deciding whether to turn off a life-support system for a patient, or leniency in legal decision making. As emotions and beliefs about others are closely related to empathy, robots and AI will need to have better mechanisms for detecting, representing and responding to people's emotions in speech, gestures, and facial expressions and people's goals, plans, beliefs and intentions. Second, people will have to have more empathy with robots and AI, accepting that they will make mistakes from time to time, but also accepting that they will be better than people at performing particular tasks which involve very large amounts of data where fast decisions may need to be made, also keeping in mind that they are not as prone as people to becoming tired.

7 Conclusion

Here, we have discussed people's fears on the rise of robots and AI in relation to employment displacement, loss of control to robots where people become their slaves, and that this really should only be the work of *God*. Otherwise scientists and industry could inadvertently create Dr. Frankenstein's monster. We have covered what may be deemed silicon discrimination where people have been critical of developments, the successes of AI which have given fuel to people's fears, and efforts to define ethical laws for robots and AI so that they do not get out of control. Future work includes developing further more accurate methods enabling robots to better detect, represent and respond to people's emotional states through improved image and speech processing and people's goals, plans, beliefs and intentions whilst also imbuing them further with ethical principles and laws. Frankenstein's monster can be secured with more *digital empathy*, where people and robots place themselves in each other's shoes.

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Measuring the Impact of Privacy Concerns, Perceived Risk and Trust on the Continuance Intention of Facebook Users by means of PLS-SEM

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Abstract. Facebook became one of the most popular ways of online social interaction. Many social networking sites like Facebook focus on their market, in other words, users. That's why, antecedents of continuance intention of Facebook users should be investigated in order to develop more efficient marketing strategies [1]. According to the literature, privacy concerns, perceived risk and trust are the most important antecedents of continuance intention. The aim of this study is to examine the influence of privacy concerns, perceived risk and trust on the continuance intention of Facebook users in Bursa city of Turkey. Data were collected via an online questionnaire. A total of 241 questionnaires were used for the analysis. According to the results, privacy concerns antecedent was found to have a statistically negative significant impact on trust and positive significant impact on perceived risk. Trust antecedent was also found to have a statistically significant positive impact on continuance intention of Facebook users.

Keywords: Privacy concerns, perceived risk, trust, continuance intention, Facebook, Bursa, Turkey.

1 Introduction

In recent years, social networks especially Facebook attracted a great number of people all over the world [2]. Facebook became one of the most popular ways of online social interaction. Many social networking sites like Facebook focus on their users. The users of social networks are so important for the long-term success of them [3]. That's why antecedents of continuance intention of Facebook users should be investigated in order to develop more efficient marketing strategies [1].

In the literature, there are studies that aim to understand the relations among continuance intention and its antecedents for social media platforms. According to Wang et al. (2016), trust and risk were found to have significant effects on individual behavior toward social media platforms but that trust had a stronger effect [4]. Another study com-

pared two social media platforms (Facebook and LinkedIn) to understand factors affecting users' trust on social media platforms. According to the findings of the study, it was found that users' trust on social media platforms was mainly influenced by effort expectancy, social influence and perceived risk. Besides, it was found that trust had a significant impact on continuance intention [2]. In Tan et al. (2012)'s study, it was aimed to understand the impact of users' privacy concerns on their acceptance of social media platforms [5]. There is also another study that proposed a research model to investigate individuals' social media platform usage facilitators and inhibitors from the perspective of privacy concerns [6]. In addition, there are various researches that aim to understand the antecedents of continuance intention in photo-sharing context [7] [8] [9] [10]. According to the literature, privacy concerns, perceived risk and trust are the most important antecedents of continuance intention. Especially, privacy concerns is a very current topic for the social media market. Thus, it is aimed to examine the influence of privacy concerns, perceived risk and trust on the continuance intention of Facebook users in this study.

2 Methodology

2.1 Research Sample and Method

The research was conducted on Facebook users in Bursa city of Turkey. Data were collected via an online questionnaire. Convenience sampling method was used in the research. Data were collected in the months of June, July and August of 2018. 275 questionnaires were collected from respondents. 34 of them were excluded as they were not complete based on the initial screening. A total of 241 questionnaires were used for the analysis. The antecedents of the model such as privacy concerns, perceived risk, trust, effort expectancy, social influence and continuance intention were measured by the items based on the related literature [2] [3] [11]. Smart PLS 3.0 and IBM SPSS 21.0 were used in order to analyze the data. PLS-SEM was used to test the influence of privacy concerns, perceived risk and trust on the continuance intention of Facebook users.

The popularity of structural equation modeling (SEM) has grown out of the need to test complete theories and concepts. Much of SEM's success can be attributed to the method's ability to evaluate the measurement of latent variables, while also testing relationships between latent variables. Although the initial application of this method embraced a covariance-based approach (CB-SEM), researchers also have the option of choosing the variance-based partial least squares technique (PLS-SEM). While CB-SEM is the more popular method, PLS-SEM has recently received considerable attention in a variety of disciplines including marketing, strategic management, management information systems, operations management, and accounting. Much of the increased usage of PLS-SEM can be credited to the method's ability to handle problematic modeling issues that routinely occur in the social sciences such as unusual data characteristics (e.g. nonnormal data) and highly complex models [12].

2.2 Profile of Respondents

Demographic characteristics of the respondents were given in Table 1. As seen, 110 of the respondents were male and 131 of the respondents were female. Most of the respondents (44.4%) were between 21-30 ages, 34.0% of the respondents were between 31-40 ages and 13.7% of the respondents were between 41-50 ages. Most of the respondents had an undergraduate degree or were more educated (92.6%). Single Facebook users were slightly more than married users. Most of the respondents had a Facebook experience for 4 and more years. 56.4% of the respondents spent 60 minutes or less time on Facebook, while 43.6% spent more than 60 minutes time on Facebook per day.

Table 1. Profile of Respondents.

Demographics	Frequency	%	Demographics	Frequency	%
Gender			Education		
Male	110	45,6	Primary school	3	1,2
Female	131	54,4	High school	15	6,2
Age			Undergraduate	106	44,1
<=20	2	0,8	MSc	97	40,2
21-30	107	44,4	PhD	20	8,3
31-40	82	34.0	Marital Status		
41-50	33	13,7	Single	133	55,2
>50	17	7,1	Married	108	44,8
Facebook experience			Time spent on Facebook per day		
<1 year	5	2,1	60 minutes or less	136	56,4
1-2 years	2	0,8	More than 60 minutes	105	43,6
2-3 years	8	3,3			
3-4 years	9	3,7			
4 years and more	217	90,1			

2.3 Research Model and Hypothesis

The research model is shown in Fig. 1. As it can be seen, the research model includes the variables, which are; “effort expectancy”, “social influence”, “privacy concerns”, “perceived risk” “trust” and “continuance intention” and the relationships among them.

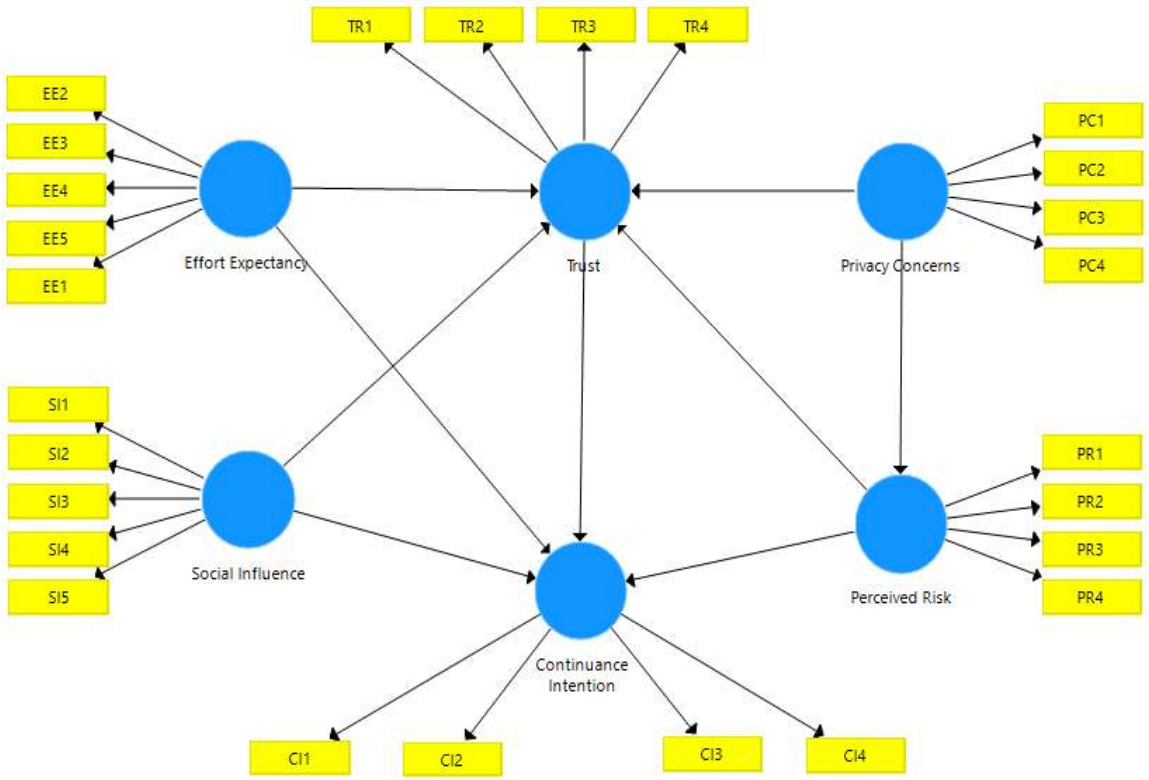

Fig. 1. Research Model

The hypotheses of the research are:

H_1: "Effort expectancy" positively influences "trust".
H_2: "Social influence" positively influences "trust".
H_3: "Effort expectancy" positively influences "continuance intention".
H_4: "Social influence" positively influences "continuance intention".
H_5:"Privacy concerns" negatively influences "trust".
H_6:"Perceived risk" negatively influences "trust".
H_7:"Perceived risk" negatively influences "continuance intention".
H_8:"Privacy concerns" positively influences "perceived risk".
H_9:"Trust" positively influences "continuance intention".

2.4 Construct Reliability and Validity

Table 2 shows the results of construct reliability and validity. The AVE (Average Variance Extracted) values of the structure must be 0,50 or more for the validity of latent structures [13]. Results show that the AVE values for effort expectancy, social influence, trust, continuance intention, privacy concerns and perceived risk are 0.60, 0.55, 0.63, 0.74, 0.76 and 0.56, respectively. As the result of the analysis carried out with Smart PLS and PLS estimation method, the composite reliability value is given. Composite Reliability value should be 0.70 or above [14].

Table 2. Construct Reliability and Validity

Construct	Cronbach's Alpha	Rho'A	CR	AVE
Effort Expectancy	0.84	0.89	0.88	0.60
Social Influence	0.80	0.91	0.85	0.55
Trust	0.80	0.85	0.87	0.63
Continuance Intention	0.88	0.89	0.91	0.74
Privacy Concerns	0.89	0.90	0.92	0.76
Perceived Risk	0.77	0.94	0.83	0.56

2.5 Testing the Research Model by Using PLS

Table 3 shows the results of hypothesis tests and structural relationships. The path coefficient of trust on continuance intention is 0.44, the path coefficient of social influence on trust is 0.41 and the path coefficient of privacy concerns on trust is -0.27. On the other hand, the path coefficients of perceived risk on trust and continuance intention are -0.09 and -0.007, respectively.

Table 3. Results of Hypothesis Tests and Structural Relationships

Hypothesis	Path Coefficient	t-statistic[a]	P Values	Result
H_1	0.28	2.97***	0.003	Supported
H_2	0.41	6.02***	0.000	Supported
H_3	0.35	4.05***	0.000	Supported
H_4	0.22	2.67***	0.008	Supported
H_5	-0.27	2.86***	0.004	Supported
H_6	-0.09	0.65	0.51	Not supported
H_7	-0.007	0.08	0.93	Not supported
H_8	0.34	2.17**	0.03	Supported
H_9	0.44	3.88***	0.000	Supported

According to the results of PLS modeling, all of the hypotheses were supported except hypothesis 6 and 7. Privacy concerns antecedent was found to have a statistically negative significant impact on trust and positive significant impact on perceived risk. Trust antecedent was also found to have a statistically significant positive impact on continuance intention of Facebook users. In addition, effort expectancy and social influence antecedents were found to have significant positive impacts on both trust and continuance intention. As seen from Table 3, the highest path coefficient is 0.44 that belongs to the path of trust-continuance intention. This means that if Facebook wants its users to be loyal then it must build trust. The answer of "how to build trust" question is also

seen from the path coefficients. Facebook must focus on the dimensions of social influence, effort expectancy and privacy concerns in order to build trust, respectively.

3 Conclusion

This study helps draw useful implications for the managers of Facebook and social networking services as well. It is important for practitioners to know the impacts of antecedents on continuance intention to develop more efficient strategies. In this research, both effort expectancy and social influence significantly affected trust antecedent. According to the findings, privacy concerns was found to be one of the important antecedents of continuance intention. Privacy concerns negatively influenced trust antecedent. Besides, trust antecedent was found to have a statistically significant impact on continuance intention of Facebook users. On the other hand, perceived risk was not found to have a significant impact on both trust and continuance intention. According to our findings, effort expectancy and social influence also affected continuance intention significantly. These results implicate that user experience in a social networking service (in this case Facebook) is so crucial. Social networking services should focus on designing positive and unique experiences for users and these experiences should be shared by the users voluntarily. In addition, privacy concerns is very important for Facebook users so that managers of Facebook should be more aware of this finding and develop strategies to be more confidential.

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Multi-project sequencing in the retail sector

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Abstract. In the age of digitalization, the importance of automating internal business processes is increasing. A parallel event is the increase number of projects and their complexity.
Mathematical methods from the field of operation research can be used to determine the optimal sequencing in order to minimize the loss of benefit. And consequently, the optimal sequencing of the projects is sought, which maximizes the overall contribution margin.
The sequencing of the projects determines the total contribution to margin after the project is complete. Therefore, sequencing is of great importance for the company. Sequencing is currently performed manually but due to the number and complexity of the projects optimal solutions can no longer be guaranteed using manual sequencing. As a result, the company suffers a loss of benefit. The loss of added value is the difference between the maximum achievable total contribution margin and the actual total contribution margin achieved.

Keywords: Multi-project, Sequencing, Optimization.

1 The planning and problems of sequencing multi-projects A Subsection Sample

1.1. Sequencing requirements

A prerequisite for successful business management is planning. Complex relation-ships are systematically worked through and summarized. This summary contains in-formation about the consequences and effects of a decision. It is important to design this planning holistically. Underlying this should be thought processes and coordination. An important aspect in planning is the database. Good planning requires important information. The quality of the information has an influence on the deviation of the target from the actual state [1]. Only when the data has been collected post project can it be determined whether the problem was solved in the planned manner. The required data may be insufficient.
The planning of projects can be summarized in the form of a business case. The business case is the profitability analysis for the execution of the project [2]. This contains target information, action alternatives and economic consequence [3].
First, the foundations for a project are in detail. These include a project description with an economic goal. The benefit and the expected total costs should be easily calculable. By comparing the key figures, the company can make a decision. In addition to decision-making, a business case is used for investment planning. In a business case, not only financial aspects are considered. The risks and in particular the strategic economic basis of the enterprise is an important factor for decision-making [4].
In multi-project planning, it is decided which projects will be implemented in the specified time. The business cases support the decision making process. Projects are assigned priorities. On this basis, the company processes the projects. Through the implementation of the projects, the company expects a contribution margin as a benefit.
In order to minimize the loss of benefit and to determine the optimal sequencing, mathematical methods from the field of operation research can be used as a basis. Consequently, the optimal sequencing of the projects is sought, which maximizes the overall contribution to margin.

1.2. Definition of a Job

A project is a realization of a goal-oriented and time-limited undertaking. Project teams implement projects. Projects consist of several partial work steps, which can be carried out by several departments. As the result of a realized project, the company expects both economic and other benefits.

There may be projects that cost more money than they bring in. These projects could be triggered externally. An example would be the enactment of new laws by of the state. These projects are unavoidable for the company and must be implemented within the specified period. In addition to external influences, projects can be triggered internally, e.g. by changing system processes or software [5].

1.3. Controlling and adopting the characteristics of projects for sequencing

Planning itself is not enough. In order to ensure that the actual values correspond to the forecast values, activities must be monitored and controlled [6].
In project control, projects are evaluated using their parameters. The evaluation checks whether the project goals can be achieved. Typical evaluations are plan/actual comparisons. The evaluations must be monitored and evaluated at regular intervals. In order to detect deviations at an early stage and to initiate countermeasures, the observation times must be as small as possible. On the other hand, this leads to a greater control effort [7]. The observation times can take the form of milestones and strategic monitoring. Thus, standardization procedures can be implemented within the company [8].
The early detection of these risks enables control measures to be taken. The purpose of the control system is to minimize or eliminate the deviation from the planned project. If the deviation is too large, the countermeasure results in a new planning of the project. A new planning can also have other reasons. For example, it may be due to limited resources. Early recording and analysis of plan deviations shows the deviating development [9].
On this basis, the countermeasures are specified in concrete terms. Deviations cannot be avoided. The plan and the target comparison lead to new experiences. The experience can be used for future planning in the form of better forecasts. It becomes apparent that the business case is often based on very favorable assumptions and estimates. Only the control leads to the objectification of the imaginary profiles. The control goals are determined by the monitoring and review of the results.
Control activities must not be limited to the duration of the project. Checks must also be carried out after the project has been completed for a specific period. Under this prerequisite, the company can recognize concretely how the planned benefit will be achieved.
A plan/actual comparison can be carried out using a report. The variances can be recorded, analyzed and justified. The planned/actual comparison compares the planned values (target) with the actual values (actual). If variances exists, the causes of the variance are investigated. Only by providing information about the cause of the variance can you take corrective action [10].
Deviations are recorded by three variables:

- Planned size: The planned value estimated in the profitability analysis. It is the planning basis for project approval.
- Target size: Calculated by adjusting the planned value based on current facts.
- Actual size: The actual value [11].

Elementary decisions are made in order to achieve the project goals. The decisions are made based on the deviation analysis. If there are deviations in the negative area, the reasons must be clarified. Once the cause has been localized, countermeasures can be taken. This can take the form of countermeasures. If the control recognizes that the project goals are not reached, then the countermeasure can be undertaken for the reaching of the project goals [12].
In summary, controlling can contribute to achieving the project goals and thus also the benefits of the project. For the application of mathematical optimization methods for sequencing, however, it must be assumed that the project goals and thus the calculated contribution margins are achieved.

1.4. The state of the art in research for sequence problems

Multi-project planning also includes determining the optimal sequence in which the projects are to be implemented. In today's literature there are two problems in the field of operation research that deal with sequence problems. All two problems show a certain similarity to the multi-project sequence planning problem. These are the flow shop problem and the job shop problem.
The Flow Shop problem deals with the problem of the sequence of machine utilization. The machine sequence is defined from the beginning. The jobs to be processed are divided into partial processing steps TBi with i = (1, 2, …). Each TB is processed by a specified machine. In the problem definition there can be up to m machines and j jobs [13].

Fig. 1. Simple Flow Shop Problem with m machines [14]

Generally speaking, the flow shop problem is more complicated than illustrated in Figure 1. The jobs can have less than m operations. Thus the jobs do not run through all machines. At the start time t = 0, there are n independent jobs with m operations each. The sequence of the jobs is known and has no preparation times for processing or is included in the processing time of the job. All machines are available at any time and no processes are aborted [15].

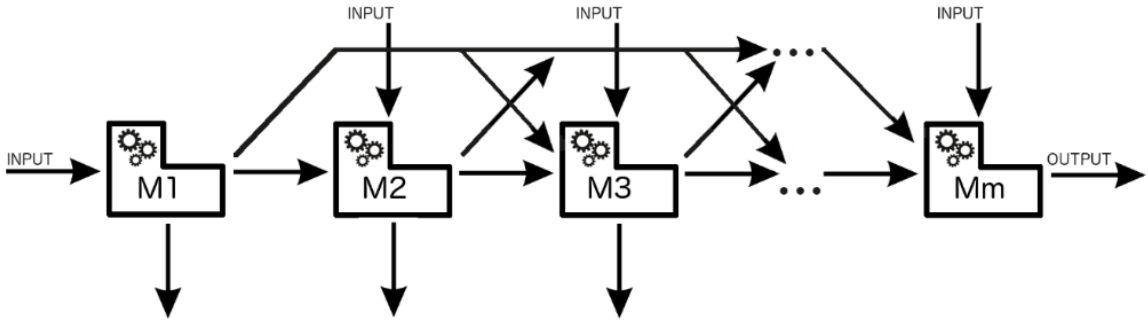

Fig. 2. General Flow Shop Problem with m machines [16]

A job shop problem exists where all work steps for each machine are not necessarily identical. Time-limited resources are allocated to process schedules. Sequences are defined for the individual order instances. This means when and on which production machine a work step takes place. [17].

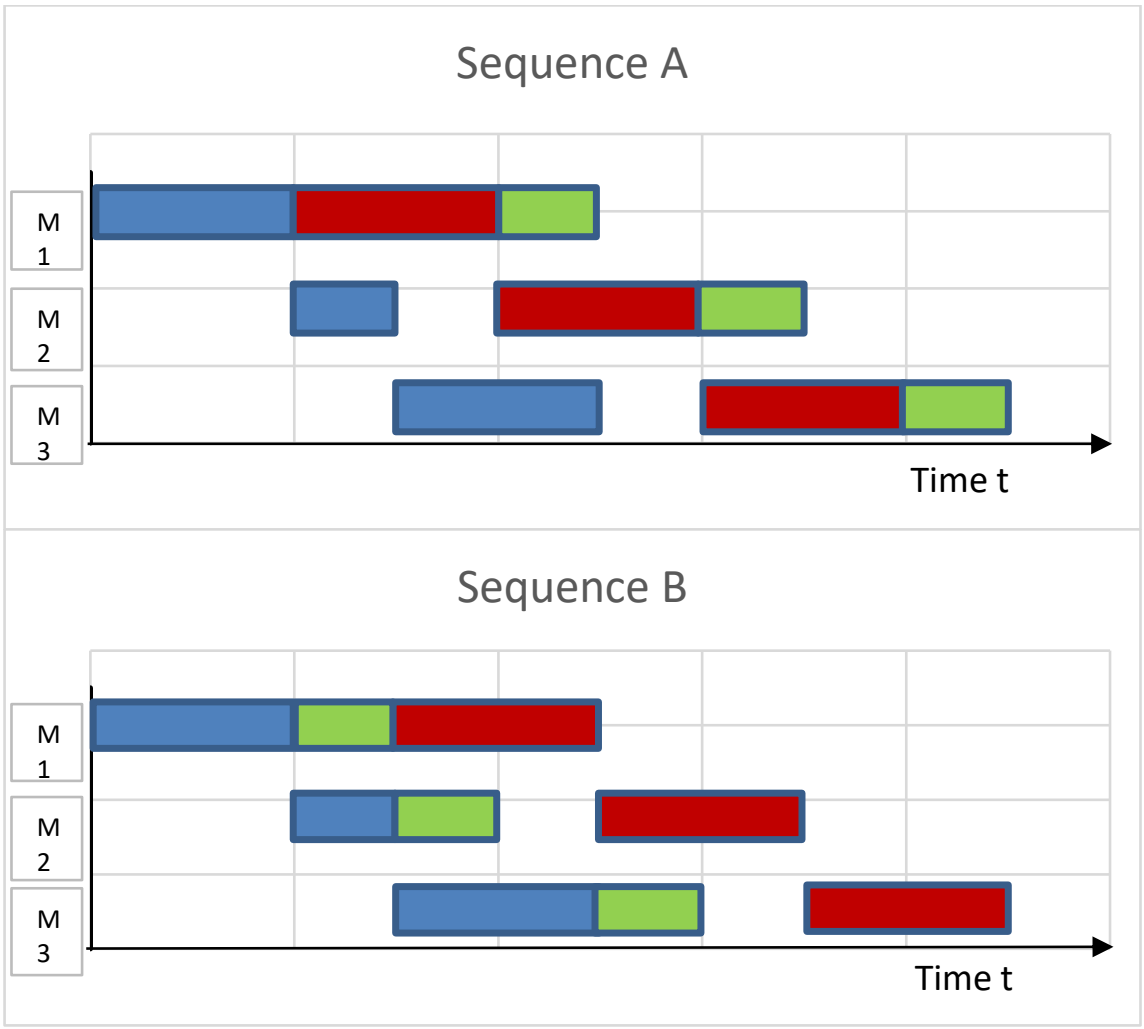

Fig. 3. Example for Sequencing of three projects and three machines

2 Further Research

The multi-project sequencing problem, on the other hand, differs in several respects from the problems presented. A major difference is the question whether existing projects should be implemented. This condition results in a nonlinear constraint. Thus, the multi-project sequence planning problem is a non-linear optimization problem (NLP for short). The constraints are linearized by the use of auxiliary variables. Thus the NLP becomes a linear problem (short LP). There are p projects in the problem definition. Only n projects can be implemented in the given time T, $(n \leq p)$. Thus a prioritization of the projects takes place. The difference of the multi-project sequence planning problem leads to the fact that no research in this direction can be found. The problem is initially defined and solved as an LP problem. Algebraic modeling languages (software like GAMS) are used for the solution. Furthermore, the solvers SIMPLEX and GUROBI have to be compared. Further contents will be clarified during the research. The research leads to the first solution for the existing problem.

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Dealing with Service Failure Smarter: The Critical Role of Customer Voice Management in Service Recovery Process

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Abstract. This research builds upon a service recovery framework, establishing new perspectives of customer voice in service recovery context. Specifically, two studies were conducted to identify how to turn customer voice to opportunity in recovering from service failure. The first study employs venting interaction as a post-failure emotion regulation strategy and tests how it affects customer evaluation of service recovery. Drawing on the role of initiation in the service recovery process, the second study explores how inviting customers to voice dissatisfaction enhances service recovery evaluations. Two separate scenario-based experiments were carried out in a bank service setting. Partial least squares structural equation modeling was conducted to test research hypotheses in study 1. Study 2 uses Multivariate analysis of covariance as a statistical technique. As hypothesized, this research demonstrates that venting interaction and voice initiation can yield favorable recovery outcomes. These findings suggest that service managers encourage customer to voice before providing service recovery to enhance positive service recovery outcomes.

Keywords: Service Recovery, Customer Voice, Satisfaction.

1 Introduction

A major issue in service business is service failure, commonly accepted as an inevitable event in the service encounter context which initially results in customer dissatisfaction [1, 2] and subsequently causes negative customer behavioral outcomes, e.g., negative word-of-mouth or switching service provider [3-5]. In any case, a proper service recovery [6] will not only address a service problem, but also restore customer satisfaction and lead to positive behavioral outcomes [e.g., 7, 8].

A considerable body of service recovery research has recognized customer voice [9] as crucial input for a service provider in coping with service failure. However, the extant literature leaves several important questions regarding the role of customer voice in service recovery unanswered; hence the present research advances service literature across two studies.

Generally, service failure triggers negative customer emotions, and the triggered emotions have negative bias on service recovery evaluation. For this reason, study of

customer emotions has mainly focused on the damaging effects of negative emotions. In the first study, we advance the literature by exploring how regulating negative emotions by using venting interaction to respond to customer voice influences customer evaluation of service recovery, i.e., perceived justice, post-recovery emotions, and customer satisfaction.

From the first study, it was found that venting interaction is an effective emotion regulation strategy in response to customer direct voice. However, it is reported that up to 95% of dissatisfied customers do not voice to the service provider [2]. While previous recovery studies only explored service recovery based on customer voice and service recovery based on no customer voice (the firm was aware of service failure and provided service recovery), no study has explored how customers would respond to service recovery if they were invited to voice or whether that voice leads to service recovery. Drawing on the role of initiation in the service recovery literature, we propose that a customer receiving service recovery based on firm-initiated voice perceives service recovery efforts differently than voice- or no-voice customers in those two service recovery situations. The second study thus explores the role of customer voice initiation on perceived justice, satisfaction, and negative word-of-mouth intention. The overall contribution of this research is shown in figure 1.

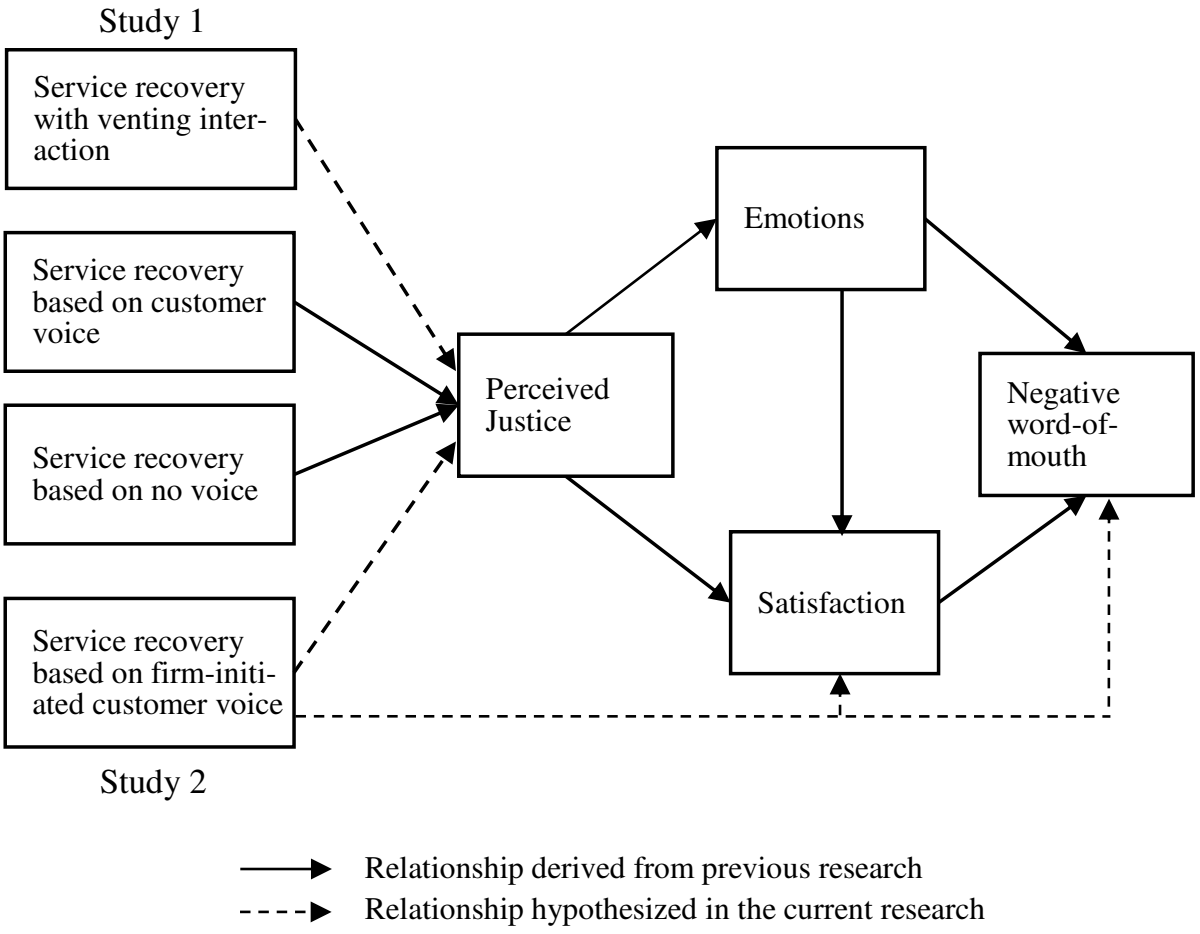

Fig. 1. Research contributions and conceptual model.

2 Methodology

In both studies, scenario-based experiments were conducted to elicit customer responses in a bank service setting. The first study followed a between subject design (service recovery with venting interaction vs. service recovery without venting interaction). The scenario entailed a customer who went to the bank and encountered service failure that triggered negative emotions. In the venting interaction condition, the customer vented to the frontline staff who then tried to regulate the negative customer's emotions by listening and showing sympathy before providing service recovery. In the no-venting interaction condition, the customer vent to the frontline staff who provided service recovery without the venting interaction.

Bank customers in Thailand were recruited to participate in the experiment and were randomly assigned to one of the two experimental conditions. They then were asked to read and imagine that they were the customer in the scenario to respond to a series of questions regarding manipulation check, response to the scenario, and personal information. 205 out of 238 questionnaires were usable. In terms of sample characteristics, 48.3% of the respondents were male, with 20.5% of respondents aged 20-29; 29.3% aged 30-39; 28.8% aged 40-49; and 21.4% aged over 50. In terms of education, 32.7% had a high school degree or lower; 53.7% held an undergraduate degree; and 13.6% had earned a graduate degree or higher. Manipulation check results indicated that the manipulation worked as intended.

The second study conducted a between-subject experiment with three types of voice (customer-initiated voice; firm-initiated voice; or no voice). The scenario described a service failure that was caused by an unintentional error made by the frontline staff. After the customer noticed service failure, the bank addressed the mistake based on three different voice scenarios. In the customer-initiated voice scenario, the customer complained to the staff. In the firm-initiated voice scenario, the customer complained when the staff checked customer satisfaction following the service delivery and encouraged the customer to complain if not satisfied. Lastly, in the no-voice scenario, service provider pre-emptively addressed the mistake without customer complaint.

A total of 202 undergraduate students, from two universities in Thailand, participated in this experiment, of which 39.6% of the respondents were male, and all respondents were aged 20-29. Following the same data collection process as the first study, the respondents were randomly assigned to the scenario and asked to answer to the questions. Manipulation check results showed that the manipulation of the scenario was successful.

3 Analysis and Results

In the first study, partial least squares structural equation modeling (PLS-SEM) analysis was conducted to test the research hypotheses. In terms of measurement model assessment, the results confirmed item reliability with the loadings of all items on the corresponding constructs at above 0.7. The scale reliability was established as Cronbach's Alpha, and composite reliability values were above 0.7. Average variance extracted

(AVE) of all constructs were higher than 0.5, reflecting convergent validity. Finally, discriminant validity was confirmed with the AVE of each construct exceeding squared correlation with any other constructs. The test of the structural model indicated that the proposed model showed high predictive accuracy (R^2 for all endogenous variables, namely, perceived justice, post-recovery emotions, and satisfaction ranged between 0.49 – 0.69). The model's predictive relevance (Q^2) for all endogenous variables was between 0.38-0.55.

The second study carried out Multivariate Analysis of Covariance (MANCOVA) to test research hypotheses. The measurement model assessment was satisfactory as factor loadings exceed 0.7, AVEs were higher than 0.5, and the AVE of each construct was above the shared variance between it and the other constructs. MANCOVA results showed the significant effects of voice initiation on set of dependent variables, namely, perceived justice, satisfaction, and negative word-of-mouth (Wilks's λ=0.59, F=14.26, p<0.0001). In addition, voice initiation individually affects each dependent variable (the p-values were all less than 0.001).

4 Findings

The first study demonstrates that venting interaction plays an important role in regulating negative emotions and reducing negative bias of negative post-failure emotions on service recovery evaluations. Specifically, it shows that perceived justice, post-recovery emotions, and satisfaction varied in the different venting interaction conditions.

These findings provide support for emotion literature indicating that when individuals vent to the offender, they expect listening and empathy [10] a response which positively affects perceived interactional justice [11]. In addition, the findings supported service recovery literature indicating that a firm's interaction, such as one demonstrating empathetic listening [12, 13], concern, and empathy, heightened customer perception of interactional justice [2, 11, 14, 15]. Eventually, perceived interactional justice mediates the effects of service recovery with venting interaction on post-recovery emotions [16, 17] and satisfaction [18].

The second study found that service recovery evaluations are different across voice initiation situations. Specifically, customers reported higher perceived justice and satisfaction and lower negative word-of-mouth intention when receiving service recovery based on voice invited by the staff.

The above findings are consistent with previous research of the role of initiation in the service recovery context. Research on co-creation initiation suggested that when the company initiates co-creation recovery, customers perceive greater procedural justice and satisfaction than when co-creation is initiated by customer [19]. Similarly, study on service recovery initiation has documented firm-initiated recovery has positive effects on customer perception of a service provider's efforts [20-22].

5 Theoretical and Managerial Implications

This research investigated the under-researched issues involving customer voice management in the service recovery context, i.e., post-failure negative emotion management and voice initiation. From an emotional management perspective, the first study established the role of venting interaction as an emotion regulation strategy in the service recovery encounter. By introducing a new perspective of customer voice, the second study extends customer voice literature by demonstrating that voice initiators affect customer evaluation of service recovery.

These findings provide a number of practical implications for service managers in several service industries, e.g., banking industry, hotel industry, and restaurant industry. First, managers should be aware that when customers vent, they need to engage in appropriate interactions, e.g., listening, understanding, and showing sympathy, together with addressing the service problem. Second, as service failure may be unintentionally caused by the service provider, managers can easily assure customer satisfaction by posing standard follow-up questions. Finally, inviting customers to speak about their perceived service problem is an effective service recovery strategy because their service recovery satisfaction is higher under that condition than when the service recovery stems from a normal complaint.

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The Influence of Internet Celebrities (Wanghongs) on Social Media Users in China

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Abstract. This study aims to decipher how internet celebrities in China, or Wanghongs, accumulate their credibility and how they gratify the follower in China. By conducting qualitative research based on in-depth interviews in Guangzhou, China, this study fills a research gap in understanding the internet celebrity culture in the digital China. The analysis shows that Chinese followers were attracted by Wanghongs because of Wanghongs' positive personality traits, e.g. being humorous. They followed Wanghongs mainly because they gained useful information and advice from Wanghongs and at the same time got entertained. The benefits from following Wanghongs are mainly the fulfillment of information and emotional needs. This information was then shared to boost the follower's self-image and to strengthen the follower's connection with his or her social circle, i.e., to fulfill other needs as being categorized by Katz, et al (1973). However, interviewees were not satisfied with their parasocial interaction with Wanghongs.

Keywords: Internet Celebrity, Wanghong, Chinese Social Media.

1 Introduction

1.1 China's Social Media Phenomena

Although the popular social media might have their inception in the US and those most popular services such as Facebook, Twitter and Instagram are blocked in China [1], Chinese internet users have not been immune from the social media fever. Chinese users' active engagement in social media emerged from the intense use of instant messaging service such as QQ in 1999 [2]. Since then, QQ has generated a sizeable amount of active users who later became the customer base of the other social media platform, WeChat, in 2011. WeChat allows users to use smartphones to connect with friends on a personal level; users can communicate with family and friends and share files and news on the move. Meantime, Weibo, a Twitter-like service developed by Sina in 2009, is the most widely used microblogging service in China [3] and allows users to follow other users, celebrities, business organizations and government agencies on a public

level [4]. The noticeable difference between Weibo, WeChat, and QQ are privacy and anonymity of users. While Weibo allows users to reach openly accessible information from grassroots sources and focuses on sharing of information and opinions, WeChat and QQ are more for social interaction on a personal level [5].

Besides the above mentioned social media platforms, several other services similar to the social media in West can be found in China, e.g., Toudou Youku (vs. Youtube), Meipai (vs. Instagram) and Momo (vs. Tinder) [1]. These services have been developed into a 'social media ecosystem' containing the core services, such as WeChat, QQ and Weibo, for social interactions and the derivative services mainly letting users acquire information [6]. The latter is the main breeding ground for China's internet celebrities, or Wanghongs. In the following discussion, we will therefore use internet celebrities and Wanghongs interchangeably.

1.2 Internet celebrities: West vs East

The advent of internet celebrities might be traced back to the appearance of Lonelygirl15 in 2006 [7]. Since then, attracting and accumulating fans and followers through posting contents in various social media platforms such as Youtube, Facebook, Twitter, and Instagram has become a phenomena. For instance, Ryan Higa reached his stardom by 'strategically' posting, e.g., funny videos, to gain noticeability; he is named a 'digital star' and owns the most followed comedy Youtube channel (Forbes.com, not dated).

Internet celebrities manage their fan base using varieties of affiliating methods and gain popularity by creating a sense of closeness between themselves and their followers; they share common languages with their supporters and use alike cultural references to create relationships with and attachment of their fans and followers in various online communities. They often become opinion leaders for fashions, books, restaurants, movies and travels and interact with fans and followers as if the followers were friends.

Wanghongs, Chinese interpretation of internet celebrities, are ordinary people who attract millions of fans and followers by creating original digital contents on social media platforms and demonstrating the characteristics of opinion leaders [8][9]. Wanghongs might generate original contents through live-streaming, blogging and microblogging to provide rich information for their fans and followers, or to provide shopping advice as 'fashionistas' [10].

1.3 Research Aims

Extant studies, e.g., [11][12], often focus on internet celebrities' or social media's credibility in delivering brand messages, but few has focused on why and how an internet celebrity as a brand influences followers' and fans' attitudes and behavior. By conducting qualitative research based on in-depth interviews in China's third most populated city, Guangzhou, this study fills a research gap in understanding the internet celebrity culture in the digital China. This study aims to decipher how Wanghongs accumulate their credibility of being reliable sources of information in social media and how they gratify the follower in China.

2 Literature Review

2.1 Source Credibility Theory

Source credibility theory posits that 'individuals or receivers are more likely to be persuaded when the source presents itself as credible' [13]. When social media users perceive that an internet celebrity has higher credibility, it is more likely they will build connection with the internet celebrity [14][15].

Past studies have found that 'trustworthiness', 'expertise' and 'attractiveness' are dimensions, which highly influence source credibility [15-19]. Trustworthiness is the honesty and believability of a source [14]. When an internet celebrity is trustworthy, social media users might be more likely to take actions, such as following the celebrity and sharing personal information with the followed celebrity [18]. Expertise is the extent to which an information source is considered to be able to make correct assertions [15]. Attractiveness encompasses not only physical attractiveness, but also psychological traits, such as intellectual skills and personalities [13]. In advertising studies, attractiveness of an endorser is found to be more important than expertise and trustworthiness [15].

2.2 Uses and Gratifications Theory

Uses and gratifications theory [20] posits that an individual actively seeks out and uses particular media to satisfy specific needs. Katz, et al. [21] classify needs that users seek to fulfil through the use of media into 5 groups: needs for information, knowledge and understanding; needs for aesthetic, pleasurable and emotional experience, needs for credibility, confidence, stability and status, needs for contacts and needs for tension-release. Traditional media were an agent for information and exerted great influence on individuals, but the user played a passive role in media consumption. In contrast, social media users have become also media content creators who can share multimedia contents, such as texts, photos and videos. Sharing contents and information with other users on social media enables individuals with common interests to interact in a shared platform and creates parasocial interactions [22]. Therefore, social media provide an individual with the opportunity for fulfilling their social needs of belonging. At the same time, social media could help the user fulfil psychological needs, such as feeling competent and knowledgeable.

Although the function of social media seems multifaceted, it can be said that the essential objective for social media users is to gratifying users' needs [23]. Hence, uses and gratifications classification [20] could provide a framework for understanding social media users' various needs.

3 Methodology

The data were collected through in-depth interviews by one of the authors with 12 undergraduate students from Guangdong, China; all 12 students, 6 male and 6 female, are

single and aged between 21 and 23. All interviewees were online at least 3 hours per day and almost all (11) had over 10 years (included) of using the internet at the time of the interview. The interviewees' profile is consistent with the profile of Wanghong followers reported by [24]. The top three social media used by the interviewees were WeChat, Weibo and QQ. The main purpose of using social media was communication, followed by information search and checking news. All interviewees mentioned that they followed Wanghongs every day; the number of Wanghongs followed by interviewees ranged from 1 (3 interviewees) to more than 5 (2 interviewees).

The interview questions (available upon request) were designed in order to understand why the interviewees follow Wanghongs (based on source credibility theory) and what benefits the followers could get from Wanghongs (based on uses and gratifications theory). The interviewees were briefed with research ethics policy before the interview. Collected data were coded and categorized by one of the authors and the results were discussed between the authors.

4 Discussion and Conclusions

4.1 Basic conditions for building a fan base

Regarding the social media used by interviewees for following Wanghongs, the most frequently used was Weibo (58.33%), followed by WeChat (33.33%) and YY (8.33%). YY is a live-streaming platform; such type of social media is currently very popular in China. The use of live-streaming platforms could indicate that fans are seeking prompter responses from Wanghongs [25].

Each interviewee provided multiple answers for which characteristics a Wanghong should have. 29 positive characteristics (e.g., cheerful, daring and pragmatic) were coded and categorized; among them, being funny and humorous (24.14%) is the most important characteristics. Majority of interviewees (75%) also expected that Wanghongs could post funny videos.

To keep interested, interviewees expected that Wanghongs are present online (75%). Further, 9 interviewees explained what they hope Wanghongs could do on social media; 4 expected that Wanghong could interact with fans (41.67%) and 5 hoped that Wanghongs could provide useful information (33.33%). The information is not only from Wanghongs' postings, but also Wanghong's interactions with fans. And fans not only took information shared by Wanghongs as advice for themselves, but also shared this information with family and friends.

4.2 Why Do Fans Follow Wanghongs? – The Source Credibility Perspective

Data for source credibility were coded, based on three themes: trustworthiness, expertise and attractiveness. Interviewees (50%) considered a Wanghong credible when s/he shows responsibility for what s/he says or does. Interviewees were more likely to trust a Wanghong they had known for quite a while (33.33%) and they trusted Wanghongs who had gained public acceptance (66.67%).

Although academic achievements may add credibility to a Wanghong (25%), interviewees considered that Wanghongs' expertise should be judged by their life experience (41.67%); Wanghongs' expertise should be from knowledge and experience gained from trial and error in real life and could be used for solving particular problems fans encounter (83.33%).

66.67% of interviewees considered Wanghongs' attractiveness is important for judging their credibility, but attractiveness should be based on 'inner beauty' (66.67%), rather than appearance (8.33%). Inner beauty could mean a Wanghong's connotation, humor (both combined: 40%) and other personality traits, such as out-of-the-box thinking, being humble, affable, credible and being unique.

The above analysis indicates that although public acceptance is important for gaining initial trust, a Wanghong's credibility is mainly built upon the long-term observation of fans or followers. To understand the 'inner beauty' and experience of a Wanghong and then to know whether a Wanghong is responsible for his or her behavior could not happen overnight. Besides, the analysis shows that 'inner beauty' is the interviewees' definition for 'attractiveness'; such a result echoes the definition by Shimp (2000; cited from Umeogu, 2012).

4.3 Uses and Gratifications From Following Wanghongs

Regarding the benefits of following Wanghongs, 6 interviewees (50%) mentioned that it is for knowledge and useful information, while the other 6 (50%) mentioned for entertainment. In order to interact with followed Wanghongs, 10 interviews (83.33%) would ask questions or share what they know with Wanghongs. However, not all the questions and sharing were responded by Wanghongs and only 4 interviewees mentioned that they felt gratified by the responses from Wanghongs.

Each interviewee provided multiple answers for the usefulness of information Wanghongs had shared. Among the 30 coded and categorized answers, psychological or emotional benefits (56.67%) were mentioned more frequently than intellectual gains (43.33%). Yet, feeling more knowledgeable (36.67%) is the leading benefit interviewees mentioned; feeling happy (16.67%) and being entertained (13.33%) are the second and the third.

10 interviewees (83.33%) mentioned that they would share the information with family and friends, particularly those with similar interests (66.67%). Sharing Wanghongs' information not only makes the whole social circle more knowledgeable (33.33%), but also brings the interviewees a happy feeling. 10 interviews mentioned that such sharing is positive for self-esteem, mostly because they gain confidence from possessing new and useful information (50%), besides getting noticed by friends.

Regarding the feedback from family and friends after sharing the information, 7 interviewees (58.33%) mentioned that they were praised by friends and family. These 7 interviews also mentioned that friends considered that they are more knowledgeble (42.86%) and counted on them for more information in the future (57.14%).

Based on the above analysis, it appears that following Wanghongs mainly fulfilled interviewees' needs for information and for emotional experience. Meantime, interviewees shared Wanghongs' information with family and friends to fulfill other needs,

such as needs for contacts and needs for confidence and status [21]. The above analysis also indicates that the interviewed followers were gratified not by their parasocial interactions with Wanghongs, but by strengthening their current social circle through sharing Wanghongs' information.

4.4 Limitations

Although this qualitative research produced useful insights, some limitations should be considered. First, the qualitative research design limited the sample size and research location. Future research should consider a large scale survey incorporating multiple locations and a larger sample pool. Second, since the social media ecosystem evolves rapidly, how and why fans follow Wanghongs could also change rapidly. Future research might take a longitudinal approach to study how fans of Wanghongs or internet celebrities change over time. Besides, a cross-cultural comparison between fans in East and West could also help the understanding of cultural differences in the internet-celebrity-fan interaction and even the phenomena of the internet celebrity economy.

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Chapter 7

Nature Science and Engineering

Simultaneous PIV/SO_2-PLIF imaging in multi-regime combustion processes

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Keywords: combined PIV/PLIF imaging, multi-regime combustion, partially premixed combustion, conditional flow field statistics

Introduction

While combustion processes are often classified as purely premixed or purely non-premixed, partial premixing and recirculation may give rise to complex multi-regime combustion scenarios in practical applications. Therefore, a representation of local flame characteristics by pure premixed or non-premixed processes may not be sufficient [1]. In contrast to the conditions in practical applications, the majority of laboratory flames, investigation turbulent combustion, are operated with homogeneous mixtures. Due to the lack of compositional inhomogeneities, these flames do not exhibit multi-regime behavior. A number of experiments have been conducted to overcome these limitations, e.g. by Meares et al. [2,4], Barlow et al. [3] and Mansour et al. [5]. However, a comprehensive database of experimental results for multi-regime combustion processes based on canonical flame configurations with well-defined boundary conditions is required for both the understanding of the underlying processes as well as the validation and development of more generalized numerical models. In order to provide this data, a novel burner configuration to quantitatively investigate multi-regime combustion processes, the multi-regime burner (MRB), was designed.

Burner design

The novel multi-regime burner configuration consists of three inlet streams, which can be operated with different equivalence ratios (see Figure 1). A central stainless steel jet tube with an inner diameter of 3 mm and an outer diameter of 3.3 mm is surrounded by an annular slot (slot 1) with an outer diameter of 7 mm. Slot 2 has an inner diameter of 40 mm and an outer diameter of 60 mm. A recirculation zone between slot 1 and slot 2 is stabilized by a bluff body which is kept at a temperature of 80°C by circulation of heated water to avoid condensation on the burner surface. The burner slots are staged with an angle of 26° to allow for optical access at the exit plane. An additional air co-

flow (1 m/s) around the outer body of the burner (outer diameter of 80 mm) shields the flame and provides well-defined boundary conditions.

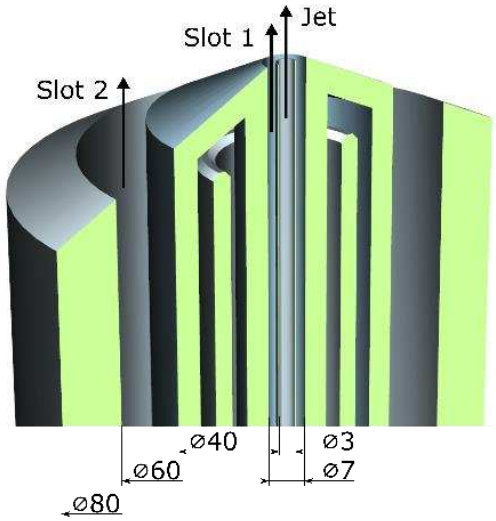

Fig. 1. Illustration of the MRB burner geometry

Operating conditions

Operating conditions including different ranges of methane/air-mixtures extending beyond the rich flammability limit have been studied. The flow from slot 2 was kept at an equivalence ratio of $\varphi = 0.8$ with an exit velocity of 20 m/s while the jet flow was varied from $\varphi = 1.4$ up to $\varphi = 2.6$ with a velocity of 105 m/s, yielding a Reynolds number of about 20000. Flames are named according to the equivalence ratio in the jet flow, where case 14 corresponds to $\varphi = 1.4$ and so forth. Jet and slot 2 are separated by a flow of pure air emanating from slot 1 with velocities of 7.5 m/s ("a"-cases) and 15 m/s ("b"-cases). Figure 2 show flame photographs of selected operating points.

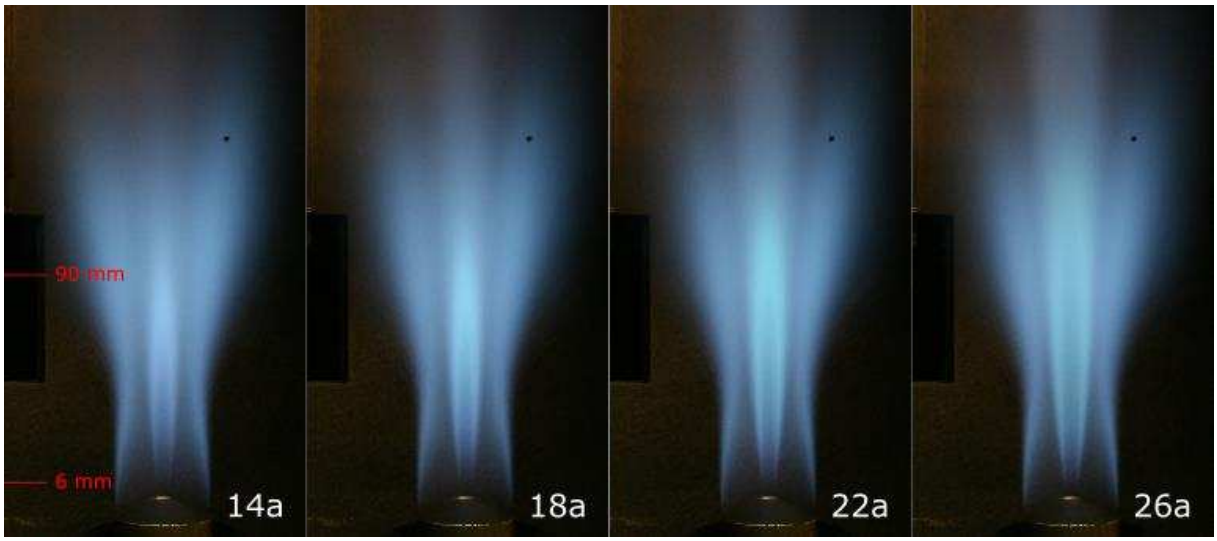

Fig. 2. Flame photographs

Multi-regime combustion

In order to decide if pure premixed or non-premixed flame structures can describe the local flame structure of the multi-regime burner setup, canonical flame characterizations were investigated as a preliminary step. Following, the suitability of the manifolds, based on freely propagating flames (premixed) and 1D counterflow flames (non-premixed) flames and the effect of multi-regime combustion is discussed.

Simultaneous PIV/PLIF

Three dimensional velocity data was acquired using stereo particle image velocimetry (PIV). Experimental results characterize the flow field of both reacting and non-reacting cases and provide valuable data for the validation of numerical simulations. Further, the intensity of planar laser induced fluorescence (PLIF) of Sulphur dioxide is strongly temperature dependent and has been demonstrated as a useful tool for flame front tracking [6]. Therefore, a detailed examination of the interaction of fluid dynamical quantities and the turbulence-chemistry-interaction is enabled by the simultaneous acquisition of the velocity field (PIV) and information on the position and orientation of the flame front (PLIF). Figure 3 shows profiles of axial and radial velocities (mean and standard deviation) at selected axial positions above the burner exit as well as a processed PLIF image with detected flame fronts above the jet and slot 2.

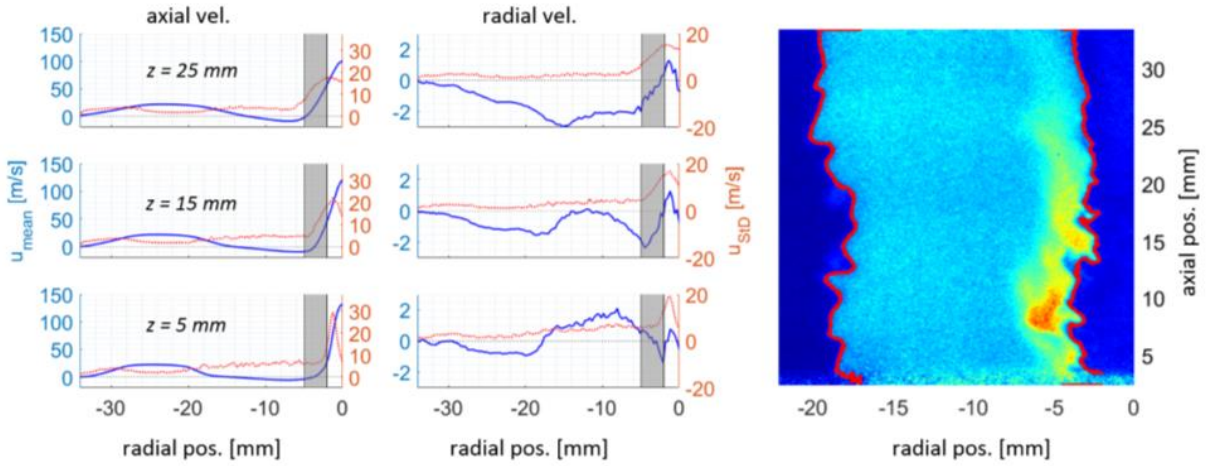

Fig. 3. Mean and standard deviation of velocities at three axial positions z above the burner (mean flame position indicated by grey boxes) and instantaneous PLIF image with detected flame fronts (red)

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A Survey of Fire Loads for Different Room Types found in a Third Level Educational Building

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Abstract: This paper presents the results of fire load surveys undertaken at a third level educational building, the Cork Institute of Technology in Cork, Ireland. The results show that movable fire load densities for canteen areas, classrooms with fixed and movable seating arrangements, exam halls and libraries are less than those previously published in literature while computer rooms, administration offices and lecturer offices are higher than published values. It was found during the fire load calculation process that much of the calorific values of the materials found in these rooms were unknown. Extensive oxygen bomb calorimetry tests were performed on over 170 representative materials ranging from carpets, ceiling tiles, furniture laminates, marmoleum samples, paints, plastics, structural materials, tiles, upholstery foams and fabrics, wall linings and insulations, wallpapers, window blinds, wiring samples, woods and miscellaneous items such as printed circuit boards and paper based building contents. These test results are also presented in this paper.

Keywords: Calorific value, characteristic fire load density, design fire load density, fire load survey, third level educational building

1. Introduction

Fire loads can be seen to be the basis on which the potential severity, size and duration of a fire can be evaluated when used in unison with other data such as building ventilation characteristics. Once known, these values can be used to further determine the smoke and heat produced from a fire whereby the smoke produced will be a key factor in the time available for occupants to egress from the building and the heat will impact on the structure causing unprotected structural members to weaken.

Fire load data is used by a range of professionals which include architects, building control officers, fire modellers, fire investigation bodies, fire risk assessors, fire safety engineers and insurance assessors. These are instrumental for a multitude of reasons such as when evaluating active and passive protection systems required in a building, conducting fire scene investigations, modelling the movement of fire, smoke and gases in buildings and when assessing insurance premiums. They are also useful in establishing building risk profiles when preparing fire safety risk assessments.

2. Objective

In the past, fire load surveys have been conducted on numerous buildings encompassing residential, commercial, institutional and industrial occupancies which are summarised by Yii (2000); however, educational buildings were seen to be the least surveyed occupancy type. In terms of previously published data for educational buildings, fire load data was found to be limited to European, Dutch, Swiss and American data for schools in the CIB W14 report (1983), Canadian elementary and high schools by Hadjisophocleous and Chen (2010) and Australian primary and secondary schools by Barnett (2015). In the search for previously published fire load data for educational buildings, information for third level educational buildings was found to be extremely limited.

To help fill this gap, a fire load study at the Cork Institute of Technology, Cork, Ireland (CIT) was undertaken and assumed to be a typical representation for this occupancy type. A survey was conducted to quantify the types and frequency of all the different types of rooms present in the main campus building. This entailed a walk-about survey using building drawings and recording room numbers, the types of rooms and floor coverings for a sample floor area of 25,000m^2. The results of this survey can be seen in Figure 1. In an effort to better evaluate room types with the largest proportion of floor areas, room types with floor areas less than 3% of the total building floor area were eliminated from the study. Furthermore, workshops and laboratories were also omitted from the study due to difficulties with materials and contents typically found here.

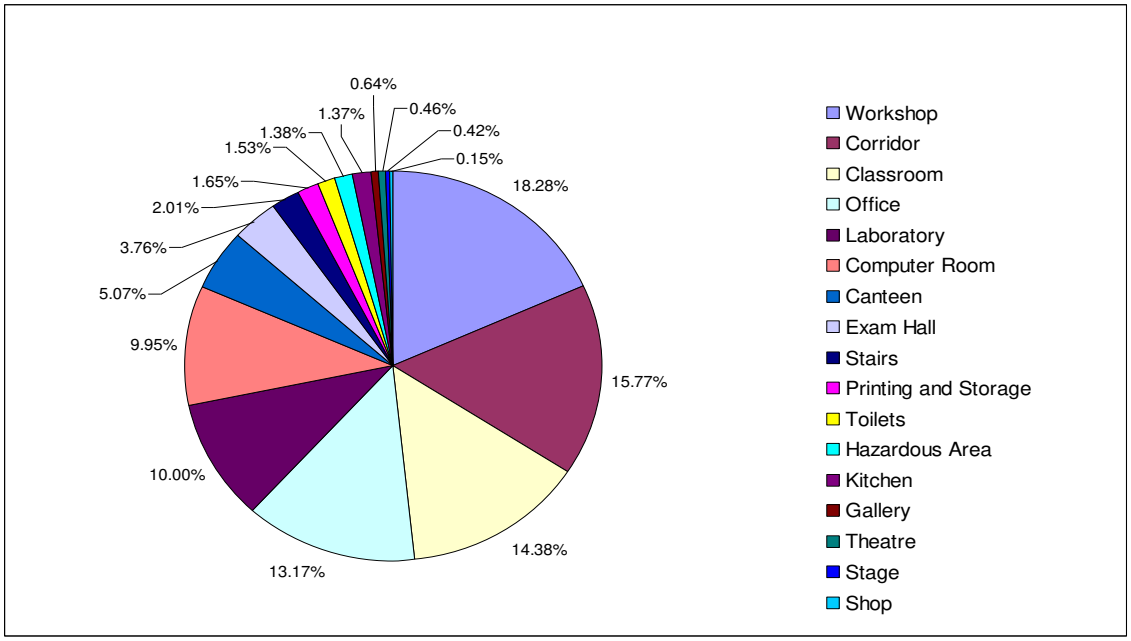

Fig. 1. Room types in the main CIT campus building

Fire load surveys were conducted for each of the remaining room types which were classified under exam halls, canteens, computer rooms, administration offices, lecturer offices, classrooms with fixed seating, classrooms with movable seating and corridors. Subsequently, as libraries are a significant space in educational buildings, this room type was also surveyed. A total of five surveys for each of the aforementioned room types were performed as recommended by BS PD 7974-1 (2003), encompassing a total surveyed floor area of 2,984m^2. In an effort to be as accurate as possible, a number of building materials typically found here was also tested in order to obtain their true fire loading contributions. This paper describes the calculation of fire loads and the determination of characteristic and design fire load densities for these room types in addition to their comparison with previously published values for similar room types.

3. Fire Load Calculation and Methodology

The fire load of a compartment, in its basic form, is the total heat or energy content released stemming from the complete combustion of all the combustible materials located there and can be either permanent or movable. Permanent fire loads are loads from combustible materials which are unlikely to vary over the life of the compartment and include fire loads from structural materials, built-in furniture and permanently installed equipment such as air-conditioning units. Movable fire loads are loads from combustible materials which do vary over the life of the compartment and include fire loads from free-standing furniture, soft furnishings and electrical equipment such as computers.

The determination of fire loads is generally completed by either conducting fire load surveys or using previously published generic fire load data. These are typically discussed in terms of fire load densities which is simply the total fire load in the compartment divided by the area of the compartment. In older fire load surveys and calculations, fire loads were characterised in terms of inner compartmental surface areas whereas modern fire load densities are outputted in terms of compartmental floor areas. Characteristic fire load densities can be evaluated using equation (1) from BS PD 7974-1 (2003).

$$q_k = \sum \frac{m_c H_c}{A_f} \tag{1}$$

Where:

q_k = characteristic fire load density (MJ/m^2),
m_c = total mass of each combustible item (kg),
H_c = effective or net calorific value of each combustible item (MJ/kg) and
A_f = total internal floor area (m^2).

Nowadays, fire loads used in modern fire design principles are called design fire loads. These are effectively characteristic fire loads but modified to take various factors into account such as the room size, space usage and active firefighting measures present. This paper will present the determination of characteristic and design fire load densities for the different room types examined in CIT which were found using the most modern procedures descirbed in the Eurocodes and associated Irish National Annex, NFPA 557 and the SFPE Handbook of Fire Protection Engineering.

3.1 Mass of Combustible Items

In terms of recording the mass of combustible items in the rooms surveyed, three survey techniques were employed; the inventory method, direct weighing method and combination method. The inventory method involves the measurement of material dimensions and extracting associated densities from property tables to obtain material volumes and densities. The product of these values outputs combustible item weights. The direct weighing method requires the use of weighing equipment to find the weights of combustible items while the combination method allows for the use of the two aforementioned techniques in conjunction with one another to obtain combustible item weights.

3.2 Calorific Values of Combustible Items

Calorific values are a measurement of the energy released as heat which is produced by the complete combustion of a specified amount of a compound with oxygen and is commonly measured in units of Megajoules per kilogram (MJ/kg). In general, the greater the calorific value of a compound, the higher the energy content in the compound. This principle is what makes gasoline (46.7 MJ/kg) ideal for vehicle fuel as it has a much higher calorific value in comparison with that of ethanol (29.67 MJ/kg), with values provided in the NFPA Fire Protection Handbook (2008).

Calorific values are classified into two categories; gross and net. The gross calorific value of a material or substance is essentially its total energy content and may be found using bomb calorimetry. Following its combustion, the resultant water is in the form of steam and as it cools and condenses to liquid water, it releases heat energy. Thus, gross calorific values include this second energy source in its measurement of energy contents. In comparison with the determination of gross calorific values whereby energy released from the condensing of steam to liquid water is added to the energy of the substance, net calorific values do not include this second energy source in its measurement.

Recent research by Doyle (2011) has concluded that there is a significant lack of available calorific data for building materials, internal finishes and contents which are most certainly required when completing fire load calculations. It was seen that available data previously published is quite limited and to overcome this issue the testing of numerous building materials for their calorific values was completed.

Determination of Gross Calorific Values

Oxygen bomb calorimetry is the most commonly used scientific technique for determining the gross calorific values of solid and liquid compounds. In contrast, those of gaseous elements are found using gas chromatography. For the testing of building materials, a PARR 6200 isoperibol oxygen bomb calorimeter was employed. This instrument, which can be seen in Figure 2, has a precision class of between 0.05% and 0.1%.

Fig. 2. PARR 6200 Oxygen Bomb Calorimeter

In this, a sample with a typical weight of 1g is burned in an oxygen-filled bomb within an accurately weighed water bath surrounded by an insulating jacket and the temperature of the water is plotted throughout this process. By knowing the heat capacities of the bomb calorimeter materials, components and the water, the heat of combustion of the sample can be determined. The gross calorific value of the sample can then be calculated by dividing this heat of combustion by the initial mass of the sample. Three tests on each sample were conducted in accordance with BS EN ISO 1716 (2010) and the test results were validated using code criteria also found in this document. In total, more than 900 individual bomb calorimetry tests were performed on over 170 building materials in order to evaluate their gross calorific values.

Determination of Net Calorific Values

It can be seen from equation (1) that the formula for determining characteristic fire loads requires the input of net calorific data. This is because the implementation of gross calorific data would result in unrealistic fire loads. Unlike the determination of gross calorific values, there are no direct experimental techniques available for assessing the net calorific values of substances and materials. To overcome this, approximation methods were implemented to transpose the gross to net calorific values of tested materials which involved researching the hydrogen content of previously published material data. Table 1 presents the net calorific values of materials tested.

Table 1. Net Calorific Values of Assorted Materials Tested

Material	Net Calorific Value (MJ/kg)	Material	Net Calorific Value (MJ/kg)
Carpet Underlay	20.29	Upholstery Foams	
Carpets		Polyurethane	23.86 – 24.15
Polypropylene pile fibres with bitumen backing	33.45 – 36.83	Recycled	25.43
Nylon pile fibres with hessian/jute backing	12.06 – 23.02	Window blinds	
Nylon pile fibres with polyethersulfone backing	12.71 – 15.93	75% PVC & 25% Fiberglass	13.68 – 14.19
Ceiling Tiles	1.88 – 2.76	100% Polyester	13.74 – 18.91
Furniture Laminates	17.15 – 18.12	50% Cotton & 50% Polyester	21.85
Marmoleum	15.74 – 17.66	Wiring	
Acrylic	29.27 – 29.32	Blue Conductor Cable	6.83
Canteen Tray	18.88	Red/Brown Cable	6.10
Printed Circuit Board	7.28	Green/Yellow Cable	5.72
Paper Based Building Contents	11.11 – 17.26	White Four Conductor Cable	11.00
Oil Based Paints		Wall Insulation	
Cream	7.87	Phenolic Insulation	26.33
Grey	11.53	Wallpapers	
Purple	13.38	Pasted	12.20 – 14.81
White	5.69	Unpasted	13.03 – 15.37
Red	16.57		
Yellow	11.19	Woods	
Gloss Paints		Beech	16.39
Black	26.46	Iroko Teak	16.58
		MDF	16.91
Plastics		Plywood	16.46
Black Bag	41.39	Red Deal	17.39
Seating Plastics	34.25 – 42.21	Red Oak	16.42
Electronic Casing	30.88	Sapele Mahogany	16.27
Projector Screen	7.34	Southern Yellow Pine	17.24
Polystyrene	39.23	White Ash	16.81
PVCu Wire Casing	19.26	White Deal	16.52
Red Safety Flooring	18.64	Walnut	16.60
		White Oak	16.61
Upholstery Fabrics			
Wool, Polypropylene and Viscose	16.38 – 34.07		
Vinyl	19.84 – 21.15		

Materials which were found to be non-combustible include ceramic and porcelain tiles, concrete, glass, stone and gypsum products. Over the course of the fire load surveying process, these values were used in the determination of fire loads. For the small proportion of materials present in rooms which could not be tested, calorific data was taken from the NFPA Fire Protection Handbook (2008) as this contained the most extensive list of published material calorific data.

3.3 Total Internal Floor Areas

The total internal floor areas were obtained using measuring tapes and by reading room dimensions from building drawings in AutoCAD. Both techniques were combined together during the fire load surveying process to effectively evaluate floor areas for the rooms examined.

4. Fire Load Classifications

The different room types surveyed were categorised into low, moderate and high risk areas depending upon their total fire load densities which is based upon previous studies summarised in the NFPA Fire Protection Handbook (2008). Here, low risk areas are described as having an average total fire load not greater than 1,134 MJ/m^2; however, this can be increased to 2,268 MJ/m^2 if the storage of combustible materials are protected. Subsequently, these can be described as moderate risk areas if their average total fire load lies between 1,134 – 2,268 MJ/m^2 which can be increased to 4,540 MJ/m^2 provided that the storage of combustible materials here are protected. Lastly, high risk areas are those whose average total fire load densities exceed 2,268 MJ/m^2 but are less than 4,450 MJ/m^2 and this can be increased to 9,080 MJ/m^2 if the storage of combustible materials are once again protected.

5. Fire Load Survey Results

5.1 Characteristic Fire Load Densities

A total of five sections of the West Atrium canteen at CIT were surveyed, each with a floor area of 53.51m^2. Four of these sections had similar furniture while the other section was furnished differently. Here, the average total fire load density was found to be 148.24 MJ/m^2. Results indicated that the fire load from movable furniture could be reduced by 47.38% depending upon the furniture materials used. Interestingly, the additional fire load due to the presence of food within these areas was estimated between 16.43 – 20.79 MJ/m^2. Canteens were found to be low risk areas.

Five classrooms with fixed seating arrangements were also investigated. These are classrooms which bolt or permanently fasten seating units to the floor making different seating arrangements problematic to achieve. The average total fire load density here was found to be 272.86 MJ/m^2. Furthermore, an additional fire load density of 44.50 – 59.33 MJ/m^2 could be included to account for student belongings which assumes a class attendance of between 75 – 100% and a backpack, two books and two refill pads per student. This room type falls under the classification of a low risk area.

In comparison, five surveys of classrooms with movable seating arrangements concluded an average total fire load density of 271.52 MJ/m^2, which is almost identical to that of classrooms with fixed seating and categorizes this room type as a low risk area too. Once again, assuming class attendances of between 75 – 100% and a backpack, two books and two refill pads per student, the additional fire load from student belongings was found to be in the region of 21.33 – 28.44 MJ/m^2. Although this is much lower in comparison to classrooms with fixed seating arrangements, this can be attributed to the lower capacities of classrooms with movable seating arrangements to accommodate students.

Five computer rooms were also surveyed and results yielded and average total fire load density for this room type of 625.07 MJ/m^2. This can be seen to be quite high in comparison with aforementioned densities; however, this can be attributed to the use of carpets, fixed computer benches and electrical cabling present in these rooms. Computer rooms were deemed to be low risk areas.

In terms of corridors, the average total fire load density from five surveys was determined to be 119.68 MJ/m^2, making these low risk areas also. This is quite small compared with previously discussed room types; however, this can be attributed to the almost non-existent presence of furniture and contents located which amounted to an almost negligible 3.41 MJ/m^2.

The average total fire load for exam halls and library sections investigated were found to be 228.30 MJ/m^2 and 518.73 MJ/m^2 respectively following five surveys of each. As anticipated, library fire load density values were expected to be large due to the high presence of combustible materials such as books, shelving units and study benches typically found here. Surprisingly, both of these can be seen to be low risk areas.

Five administration and five lecturer offices were also examined and found to have average total fire loads of 1,897.12 MJ/m^2 and 1,474.21 MJ/m^2 in that order. In comparison with other room types, the fire loads here are exceptionally large and this can be mainly attributed to the presence of combustible materials found in these rooms such as books, folders and papers. Finally, in comparison with other room types which were all seen to be low risk areas, offices ranged between low, moderate and high risk areas.

Table 2 summarizes the movable and total (including permanent) characteristic fire load densities found for the different room types surveyed in CIT using equation (1). In comparison, Table 3 illustrates the average total characteristic fire load densities for the surveyed room types using guidance provided in IS EN 1991-1-2 (2002), NA to IS EN 1991-1-2 (2002), NFPA 557 (2012) and the SFPE Handbook of Fire Protection Engineering (2002).

Table 2. Movable and Total Characteristic Fire Load Densities at CIT based on Equation (1)

Room Type	Movable Fire Load Density (MJ/m^2)				Total Fire Load Density (MJ/m^2)			
	Min.	Max.	Average	S.D.*	Min.	Max.	Average	S.D.*
Canteens	85.79	182.92	147.86	39.62	86.17	183.30	148.24	39.62
Classrooms with Fixed Seating	41.88	69.02	58.50	10.05	240.21	311.58	272.86	26.20
Class with Movable Seating	133.34	275.68	186.88	55.13	193.60	381.70	271.52	71.14
Computer Rooms	189.08	385.01	298.34	75.23	430.21	718.80	625.07	122.85
Corridors	1.84	4.88	3.41	1.32	73.43	158.95	119.68	33.16
Exam Halls	170.80	220.18	198.73	17.80	171.14	349.96	228.30	70.25
Libraries	241.21	382.79	307.25	64.14	409.19	640.90	518.73	105.07
Administration Offices	687.54	2550.09	1752.90	683.83	873.46	2678.34	1897.12	660.69
Lecturer Offices	603.31	2257.56	1358.60	849.92	859.63	2445.29	1474.21	860.85

* Standard Deviation

Table 3. Total Characteristic Fire Load Densities at CIT using formula from different design guidelines

Room Type	IS EN 1991-1-2 Characteristic Fire Load Density (MJ/m^2)	Irish National Annex Characteristic Fire Load Density (MJ/m^2)	NFPA 557 Characteristic Fire Load Density (MJ/m^2)	SFPE Handbook Characteristic Fire Load Density (MJ/m^2)
Canteens	148.24	148.24	118.59	148.24
Classrooms with Fixed Seating	272.86	272.86	218.29	272.86
Class with Movable Seating	271.52	271.52	217.21	271.52
Computer Rooms	625.07	625.07	500.06	625.07
Corridors	119.68	119.68	95.75	119.68
Exam Halls	228.29	228.29	182.64	228.29
Libraries	518.73	518.73	414.98	518.73
Administration Offices	1,897.13	1,897.13	1,517.70	1,897.13
Lecturer Offices	1,474.21	1,474.21	1,179.37	1,474.21

5.2 Design Fire Load Densities

Design fire load densities were calculated for the room types surveyed in accordance with procedures outlined in IS EN 1991-1-2 (2002), NA to IS EN 1991-1-2 (2002), NFPA 557 (2012) and the SFPE Handbook of Fire Protection Engineering (2002).

It can be seen that IS EN 1991-1-2 (2002) seems to output the most reasonable results for design purposes as it takes into account various factors such as the size and types of compartments in addition to active firefighting measures present making design fire loads less than characteristic fire loads. The Irish National Annex does not take these factors into account which results in equal characteristic and design fire loads. The NFPA 557 (2012) procedure for determining fire loads outputs impractical high fire load results, particularly for compartments which were found to have large standard deviation values such as offices. Finally, although the methodology provided in the SFPE Handbook OF Fire Protection Engineering (2002) considers the type of compartment construction, design fire load densities are more conservative in comparison with IS EN 1991-1-2 (2002) design fire load values.

Table 4. Total Design Fire Load Densities at CIT using formula from different design guidelines

Room Type	IS EN 1991-1-2 Design Fire Load Density (MJ/m^2)	Irish National Annex Design Fire Load Density (MJ/m^2)	NFPA 557 Design Fire Load Density (MJ/m^2)	SFPE Handbook Design Fire Load Density (MJ/m^2)
Canteens	99.64	148.24	314.11	126.00
Classrooms with Fixed Seating	215.12	272.86	332.45	231.93
Class with Movable Seating	208.36	271.52	532.26	230.79
Computer Rooms	493.54	625.07	988.33	531.31
Corridors	80.94	119.68	255.49	101.73
Exam Halls	154.52	228.29	516.75	194.05
Libraries	452.89	518.73	790.55	440.92
Administration Offices	1,218.72	1,897.13	4,897.03	1,612.56
Lecturer Offices	947.03	1,474.21	5,374.75	1,253.08

5.3 Fractile Fire Load Densities

Generally, published fire load data is commonly provided in terms of movable fire load densities and lists the average, standard deviation, 80%, 90% and 95% fractile fire load values. For the purpose of the study which had an ultimate goal of producing generic fire load data to be used in future fire design principles for the room types surveyed and for substantially similar room types, this information was developed and can be seen Table 5. The average and standard deviation values were relatively easy to obtain and the statistical distribution software, Easyfit, was employed to determine 80%, 90% and 95% fractile values using a Gumbel distribution as recommended by IS EN 1991-1-2 (2002) and the NFPA 557 (2012).

When using generic fire load data for design purposes, BS PD 7974-1 (2003), IS EN 1991-1-2 (2002) and the NFPA 557 (2012) recommends the use of the 80% fractile movable fire load density value (i.e. the value not exceeded in 80% of rooms examined) as this accounts for local concentrations of fire load. Also to note, the values published in this table are movable fire load densities only and must be summed with permanent fire load densities in order to obtain total fire load densities. This is important as similar rooms may have different permanent fire loads but comparable movable loads. For example, the permanent fire load in a small reinforced concrete office building would be less than that of a similarly sized timber framed building due to structural material combustibility properties.

Table 5. Movable Fire Load Densities at CIT

Room Type	Average (MJ/m^2)	Fractile (MJ/m^2)			Standard Deviation (MJ/m^2)
		80%	90%	95%	
Canteens	147.86	176.37	199.55	221.79	39.62
Classrooms with Fixed Seating	58.50	65.73	71.61	77.25	10.05
Class with Movable Seating	186.88	226.54	258.80	289.74	55.13
Computer Rooms	298.34	352.46	396.48	438.71	75.23
Corridors	3.41	4.36	5.13	5.87	1.32
Exam Halls	198.73	211.53	221.95	231.94	17.80
Libraries	307.25	353.39	390.92	426.92	64.14
Administration Offices	1,752.90	2,244.80	2,645.00	3,028.70	683.83
Lecturer Offices	1,358.60	1,970.00	2,467.30	2,944.30	849.92

5.4 Comparison with Published Data

In addition to the determination of characteristic and design fire loads for the different room types surveyed at CIT, observed results were also compared with those of similar room types which have been previously published. Table 6 presents the comparison of observed movable fire load densities for the room types surveyed with minimum and maximum previously published values for the same or substantially similar room types.

Table 6. Comparison of Observed and Previously Published Movable Fire Load Densities

Room Type	Observed Average Movable (MJ/m^2)	Published Average Movable (MJ/m^2)	
		Minimum	Maximum
Canteens	147.86	300.00	500.00
Classrooms with Fixed Seating	58.50	80.00	303.90
Class with Movable Seating	186.88	80.00	303.90
Computer Rooms	298.34	201.00	211.4
Corridors	3.41	0.00	63.00
Exam Halls	198.73	190.00	285.00
Libraries	307.25	537.80	2,129.00
Administration Offices	1,752.90	224.00	750.00
Lecturer Offices	1,358.60	224.00	600.00

The average movable fire load density for canteen areas can be seen to be up to three and a half times less than higher published values found in Thomas (1986), National Building Code of India (2009) and the New Zealand Building Code (2010). One reason for this could be the exclusion of food preparation, kitchen and servery areas from the observed fire load density result; however, it is unknown if published values included these fire load densities as original data sheets and further information on these values were unattainable. Classrooms with fixed seating arrangements can be seen to be 12 – 74% less than previously published values in the CIB W14 report (1983), Thomas (1986), IS EN 1991-1-2 (2002), National Building Code of India (2009), New Zealand Building Code (2010), Hadjisophocleous and Chen (2010) and Barnett (2015). In comparison, classrooms with movable seating arrangements were found to be consistent with lower previously published movable fire load data for classrooms also published in the aforementioned sources.

Subsequently, the average movable fire load density for computer rooms was found to be one and a half times greater than recently published values found by Hadjisophocleous and Chen (2010) and Barnett (2015). In terms of corridors, the average movable fire load density was determined to be almost nineteen times less than the previously published value in BS PD 7974-1 (2003). Although, no previous fire load data was found for exam halls, these room types were compared with general school areas and found to be almost one and a half times less than higher and almost equal to lower previously published values in BS PD 7974-1 (2003). The average movable fire load for portions of the CIT library was found to be between one and a half and six times less than previously published values taken from Thomas (1986), IS EN 1991-1-2 (2002), BS PD 7974-1 (2003) and Claret and Andrade (2007); however, observed results are reasonably consistent with recent findings by Hadjisophocleous and Chen (2010) and Barnett (2015).

For administration offices, analysis of the fire load survey results yielded an average movable fire load density which is up to eight times greater than previously published values found in the CIB W14 report (1983), Barnett (1984), Thomas (1986), Mabin (1994), Narayanan (1995), IS EN 1991-1-2 (2002), Claret and Andrade (2007), National Building Code of India (2009), New Zealand Building Code (2010) and NFPA 557 (2012), In comparison, lecturer offices were found to have an average movable fire load density which is over six times larger than published values found in the aforementioned sources. These fire loads are quite high in comparison with other room types and this was seen to be attributed to the amount of paper present in the offices surveyed. It is quite possible that this fire load may not be present in other similar room types as storage rooms are generally provided in office buildings.

6. Conclusions and Recommendations

Research conducted over the course of the study showed that generic fire load data, which is used in modern design principles, was generally determined in the 1960's. Much of this information has since evolved significantly with modern building life and this has not been reflected in current fire design guidelines. In addition, there is no fire load data for third level educational buildings as it was not found to have been previously surveyed. To add to this, calorific data for materials found in buildings is extremely limited and over thirty years old. This study aimed to combat this by obtaining the calorific values of modern building materials through testing and to use this data in conjunction with fire load

surveys to accurately evaluate the fire load densities for different room types found in a typical third level educational building.

Overall findings have found that the average moveable fire load densities of canteens, classrooms with fixed and movable seating arrangements, corridors, exam halls and libraries were all less than previously published values. This implies that fire loads in modern design guidelines are perhaps conservative here. In contrast, the average movable fire load densities of computer rooms, administration offices and lecturer offices were all found to be much larger than those previously published. This indicates an under-estimation of fire loads in these room types if published values are used in their design. Fire load densities determined here should be suitable for all third level educational buildings but the similarity of these values to other buildings should be verified. In addition, new calorific data can now be implemented in future fire load calculations for all types of buildings.

Given our knowledge to date, we would recommend the replacement of furniture and soft furnishings in older buildings during renovations with those possessing low fire loads, increasing the application of metals and fair-faced masonry into building finishes and choosing building materials extremely carefully at the start of a project. These ultimately play a huge role in the risk profile and fire load in a building.

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The effect of microwave irradiation on hard rock as pre-treatment to increase the efficiency of underground mining

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Abstract. Due to the euphoria of people to make the impossible possible, increasingly complex construction projects are being planned and implemented. As a rule, projects are currently carried out under high cost and time pressure. This results in the need to optimize known processes in order to save additional time and costs and to continue to do justice to dwindling resources and the growing world population in the future. In the course of population growth and the shortage of space, the urbanized areas of the cities must be connected or expanded underground. Depending on the type of soil, solid rock in the mountains can pose a challenge due to its high strength. This increases the demand for pre-treatment of solid rock. A possible solution is the use of microwaves.

Keywords: Microwave radiation, mining, rock mechanics

1 Idea and description of the research work

1.1 Electronic waves and microwaves

Around 1864, the Scottish physicist James Clerk provided the first mathematical description of electromagnetic waves, which had been partly carried out by the physicist Ernst Lecher some years earlier through experiments (Pehl 2012). The experiments proved that electromagnetic waves consist of oscillating magnetic and electric fields that propagate at the speed of light. These waves are divided into different categories according to their wavelength. All electromagnetic waves are summarized as electromagnetic spectrum as shown in Figure 1.

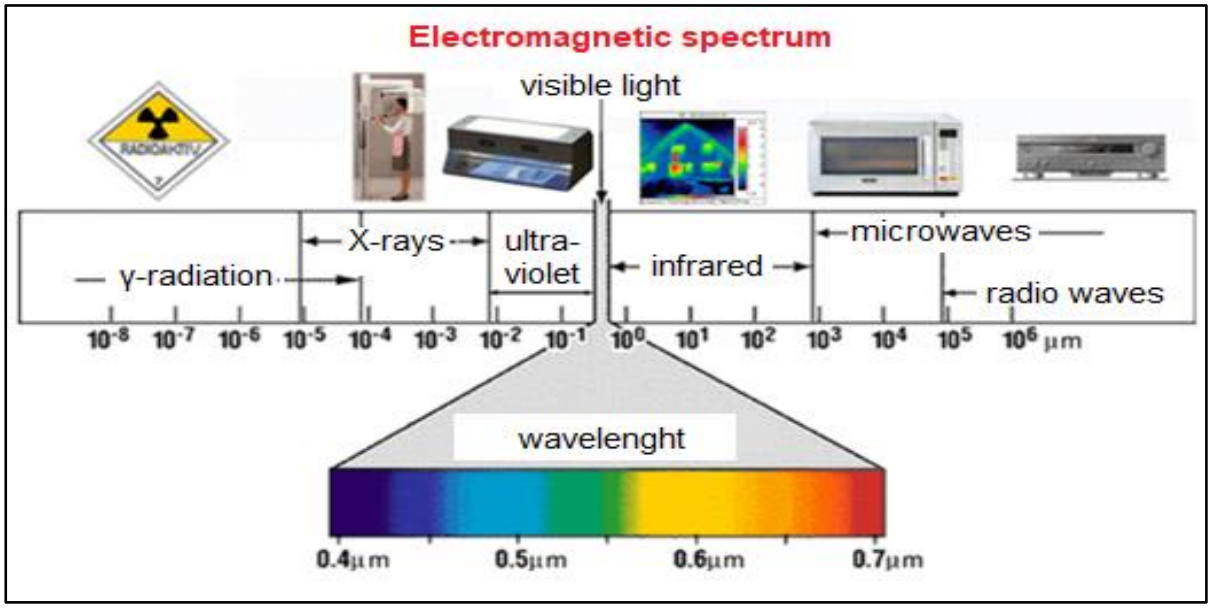

Fig. 1 Wavelength spectrum from teaching material "Experiments with microwaves" FU Berlin (2016)

Electromagnetic waves oscillate perpendicular to their direction of propagation. During these oscillations an electric and a magnetic field meet. The order of magnitude of the wavelengths is between 1 m and 1 mm and the frequency range is 300 MHz to 300 GHz (Pehl 2012).

Percy Spencer developed the first microwave oven in 1950 (Spencer 1950). It worked with a magnetic field tube that converts electrical energy into electromagnetic waves and emits them. The mode of action of microwave energy is determined only by the dielectric properties of the food inside the microwave oven. Each substance or state is characterized by its relative dielectric coefficient. Water has a pronounced dipole character and high dielectric coefficients due to its angled molecular structure and its binding polarity, whereby microwaves are particularly well absorbed. In general, there is a high water content in food. Due to the high frequencies during the irradiation with microwaves, the molecules cannot follow the field changes fast enough due to their rotational movements, a phase delay occurs compared to the electromagnetic field. As a result, field energy is transferred to the molecules, i.e. electrical energy is converted into kinetic or thermal energy (Bloomfield 2015). This conversion results in an almost uniform heating of e.g. food.

1.2 Application of microwaves

But microwaves can also do more than just heat food: They enrich our everyday lives with wireless communication systems such as mobile radio, Bluetooth, WLAN or radar technology (Pehl 2012). In particle accelerators, electric waves accelerate charged particles to the speed of light. Electromagnetic sensors are expected to detect cancer early in the future (Serway et al. 2004). However, what makes life easier can also have the opposite effect and destroy life or existing structures, since electromag-

netic weapons are relatively easy to produce and can pose a threat to many states (German Federal Ministry of the Interior 2001).

For microwave irradiation of solid rock, first theoretical simulations exist to simplify known drilling, blasting and digging techniques. Challenges such as high wear due to abrasiveness, high material consumption, cost-intensive and time-consuming processes or high dust emissions can be positively influenced or controlled. Therefore, pretreatment with microwave radiation is an efficient component, since the microwaves cause stresses in the rock compound and thus exceeds the critical load limit (Hartlieb et al. 2011). When the load limit is reached, cracks appear in the rock, which reduce the strength of the rock and thus facilitate mining.

1.3 Formation of rock and rock mechanics

The distinction of the rocks is made according to the type of formation. The hardest naturally occurring rocks are e.g. granites or basalts, which are called solidification rocks or magmatites (Figure 2, right). These rocks are formed by solidified magma on the earth's surface (effusive rock) or inside the earth (deep rock). Sandstones and sand-lime bricks, on the other hand, are called sedimentary or sedimentary rocks (Figure 2, left), which were deposited in the earth's crust by weathering and transport and subsequently solidified by pressure from superimposed masses. If existing solidification and sedimentary rocks are further influenced by forces such as foliation, uneven pressures, compression or rolling, the coarse structure can change and a granite, for example, becomes gneiss. These are called transformation rocks or metamorphites.

Fig. 2 Sandstone in Killesbergpark, Stuttgart (left), former granite quarry Schleifmühle near Metten (right)

For irradiation with microwaves, the properties of a coherent rock, especially discontinuities and the influence of water, have to be considered. In order to be able to represent an entire rock mass, it must be examined for intact rock, i.e. rock that does not have any continuous interfaces, and for the actually existing interfaces using laboratory and field techniques. Only then can a statement be made on the overall behaviour of the rock through the interaction between rock, parting surfaces and mountain water. An illustration of this can be found in Figure 3.

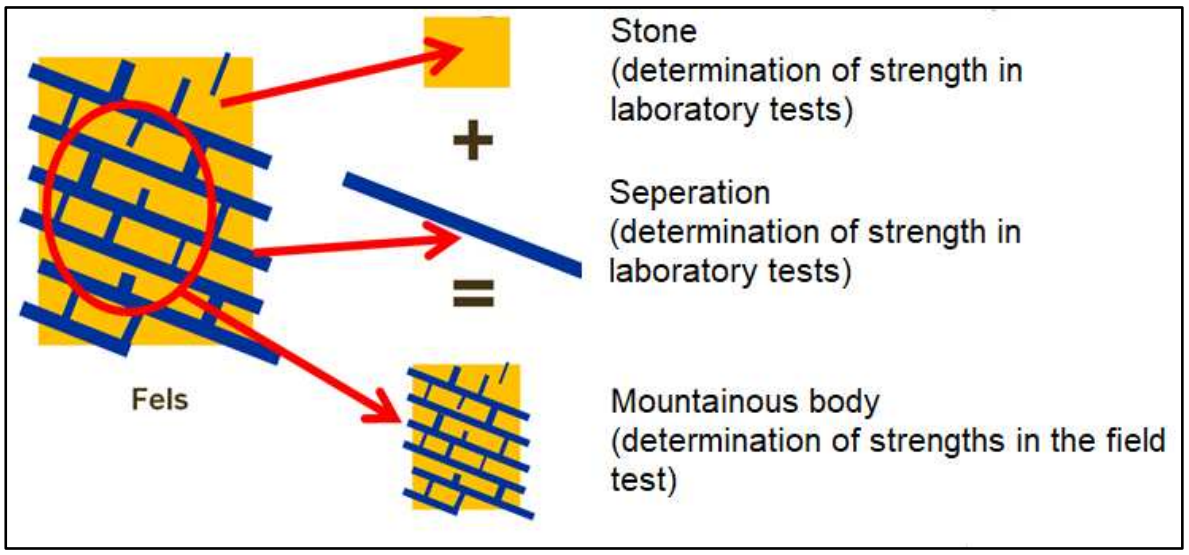

Fig. 3 Behaviour of the mountains as a function of rock and interfaces according to Schmitt (2015)

Based on these findings, it becomes clear that the strength of the rock is influenced by the rock-mechanical interaction between the compact rock and the rock faces. However, the separating surfaces can have different properties depending on their type. Here the degree of separation (possibly existing material bridges and the thickness of the parting surface), parting surface distances and spatial orientation of the parting surface distance and the parting surface covering play a decisive role.

Sandstone is an example of a rock with a high degree of separation and a small separation surface distance. In sandstone, the strength properties of the interface result in lower strengths compared to a rock with a low degree of separation and larger interface spacings, e.g. granite. For the example of granite, higher rock strengths can be assumed, since the rock mechanical influence of the parting surfaces is smaller.

A factor not to be neglected which has not yet been mentioned in Figure 3 is the influence of water. With compact rock in the mountains it can be assumed that no water can penetrate. However, separation surfaces with a high degree of separation and a small separation surface distance offer sufficient space to be able to collect water. Existing water plays a decisive role in the irradiation of microwaves and this has to be investigated by the boundary conditions of the interfaces.

2 The state of the art in research and technology

The technique of "pretreating" the solid rock was used until the 16th century for "setting fire". The rock was heated by fire in order to loosen the dressing due to the different thermal expansion of different types of rock (Agricola 1556). With the first blasting techniques of Giovanni Battista Martinengo (Wild 1992) the preparation of the rock by heat input before the actual mining was forgotten.

Microwaves have been used to heat food since 1960. The water molecules in food are set in motion or a torque is caused, whereby the atoms start to rotate from their resting state and kinetic energy is released, thus increasing the temperature of the environment (Kumar et al. 2014).

At the beginning of the 21st century, microwaves were used to measure moisture in buildings. Here the relative humidity content between water and building material is measured without affecting the condition of existing buildings. The electromagnetic alternating field applied to the component from the outside causes the molecules of the component to rotate. Which molecules are set in motion can be controlled by power and frequency (Wilfried et al. 1997).

The research of Hartlieb et al. (2017) investigated the forces that occur when cutting microwave irradiated and untreated granite. The treated area of the granite showed that pronounced crack networks run through the rock. Irradiation with microwaves at 2,450 MHz with 24 kW significantly reduced the measured peak and average forces of the treated granite (Hartlieb et al. 2017). When cutting the granite through treated and untreated areas, cutting forces of varying magnitude are shown. Figure 4 shows the linear cutting of the granite, the X and Y axes indicate the surface of the granite and the Z axis the cutting direction. It was found that the forces in the treated area are 10% lower than in the untreated area of the granite.

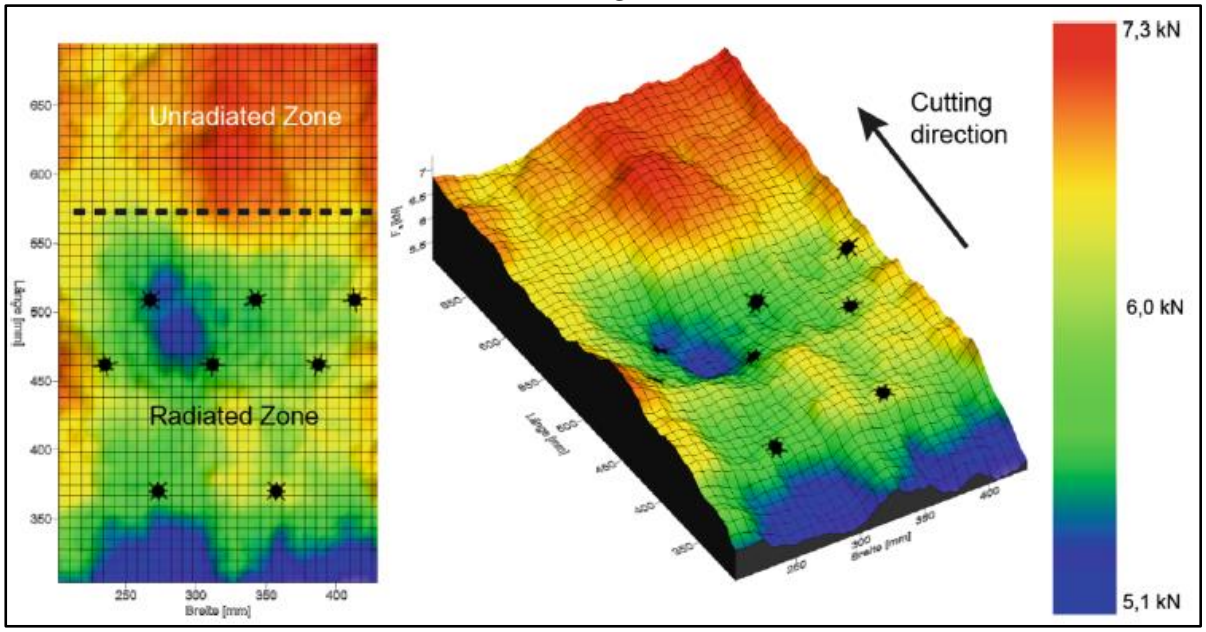

Fig. 4 Cutting wheel forces in granite differentiated according to untreated and treated area by microwave irradiation according to Hartlieb et al. (2017)

Following on from these research results, there are further open questions, e.g. how granite and other solid rocks behave at different frequencies and powers and whether the expansion of solid rocks in the large structure can have a positive effect on crack formation when heated.

Some investigations were limited to crack formation by irradiation of microwaves on Austral Black Gabbro, which has similar properties to granite and basalt. The rock warmed up and the compressive strength was reduced as a function of time and intensity. Using basalt as an example, four cylinders with a height of 40 mm and a diameter of 38.1 mm were exposed to a power of 750 W and a frequency of 2,450 MHz. The temperatures after irradiation were between 14 °C and 115 °C (Satish et al. 2006). Figure 5 shows the crack formation after 360 seconds on the left, which is already clearly visible to the naked eye, and the change in compressive strength over time on the right.

Similar studies in Australia show that higher power and shorter irradiation times can heat up the rock more quickly or cause it to partially melt (Zheng et al. 2017). The Austral Black Gabbro was tested here with a power of 2 kW and a frequency of 2.45 GHz.

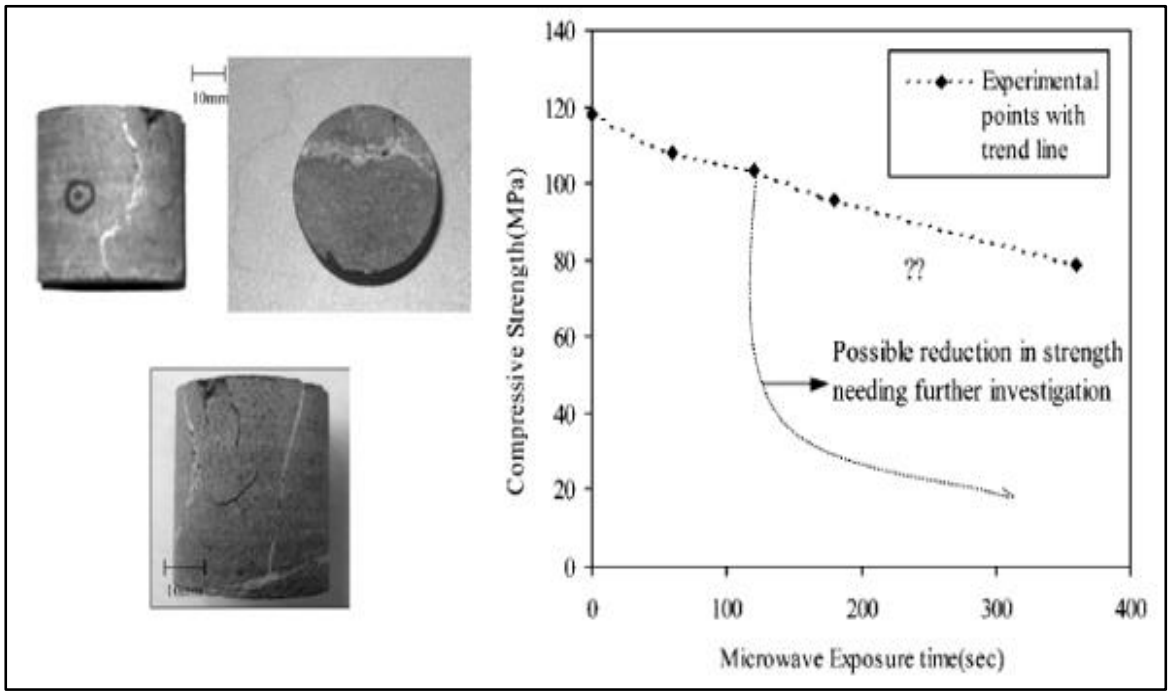

Fig. 5 Cracking after 360 seconds (left). Decrease of compressive strength over time (right) according to Satish et al. (2006)

In the investigations by Zheng et al. (2017) it was found that a basalt sample at a power of 3.2 kW can be heated up to 330° C after only 60 seconds. The same can be said for granite. In the available research by Zheng et al. (2017), Hartlieb et al. (2017) or Kumar et al. (2014), the samples generally consisted of only one type of rock under laboratory conditions. This is not the case in situ, anisotropic conditions are present here.

3 Aim and contribution of the research work

In previous research work, only magmatic and metamorphic rocks have been investigated, which as a rule have only a very low degree of separation and in which the interfaces play only a minor role. The influence of microwave irradiation on sedimentary rocks, for example, where the interfaces are the decisive factor, has not yet been investigated. The irradiation itself and the resulting thermal expansion is carried out similarly to Hartlieb et al. (2011).

The aim of the dissertation is to analyse and evaluate the effects of microwave irradiation on solid rock or rock that is difficult to dissolve in accordance with Class 7 of DIN EN ISO 14688-1, both qualitatively and quantitatively. The interaction of irradiation duration and intensity and the differentiated investigation of material and composition of the solid rock are the key points of this dissertation. Furthermore, further findings on the properties of heated solid rock with the effect on the bond and the influence of interfaces occurring in the rock can be investigated. The result of this work in a scientific sense is the knowledge regarding altered rock mechanical properties of solid rock. Based on this, a recommendation for a more effective mining method can be developed.

The assessment of the changed rock mechanical properties, in particular in connection with interfaces of solid rock, is in the foreground here. Since in tunnelling and mining the compressive strength is particularly relevant for the mining and loosening of rock material, special attention is paid to the reduction of compressive strength by microwave irradiation. The dimensioning of tunnel boring machines or conventional excavation methods is determined to a large extent by the compressive strength of the rock, whereby better results can be achieved in the execution phase in terms of cost savings and environmental compatibility.

4 Research methodology

4.1 Structure

The work includes a theoretical and an experimental focus. The theoretical part contains the basics of electromagnetic waves and how they can be applied in building practice and how they can be refined in the future. Separated from this, an introduction to rock mechanics is given, whereby rock and rock properties, existing interfaces, stresses in the rock and the influence of water are dealt with in more detail. In the experimental section own model experiments are carried out and solid rocks in their input and output state are analytically investigated, i.e. before, during and after irradiation with consideration of heat development, change of strength and stress development.

4.2 Literature research and evaluation

The first step is to prepare the state of the art and research. The basis for this are publications on the basics of microwave technology and the definition and differentiation of solid rocks within their soil class. In particular, the problems of foundation engineering and tunnel construction will be dealt with. A further focus will be the representation of natural interfaces in solid rock. Furthermore the consideration follows, to what extent laboratory tests with microwaves were accomplished by third parties and these play a role for own methods. The publications are compiled, evaluated and general questions concerning the mining of hard and solid rock are clarified.

4.3 Laboratory tests

At the beginning of the laboratory experiments an analytical recording of different rock types and the differentiation or problem of the laboratory conditions in comparison to the natural occurrence is carried out. The central task here is to what extent the experiments can be investigated or reproduced as realistically as possible. In order to limit the deviations, a large number of specimens and tests are required. In order to distinguish themselves from works such as Satish et al. (2006) and Hartlieb et al. (2011), sedimentary rocks and metamorphites are increasingly used as rocks.

First, the specimens are obtained in standardised sizes from regional quarries, adapted to the irradiation equipment and the subsequent laboratory tests. A microwave with up to 3.2 kW power is used as the irradiation device. The selection of solid rocks with uniform and different microstructures is determined in advance. The samples are analysed according to their grain and large structure in order to record the characteristic values and fluctuation ranges within the rock groups. Since the electric field in the microwave will react particularly to water components in the rock structure, the water content must be determined in advance. Some selected samples are subjected to a rock analysis by thin section or X-ray diffraction. This allows the qualitative and quantitative evaluation of the mineral content to be verified.

In the case of solid rocks with pronounced interface structures, e.g. sedimentary rocks, standardized specimens, such as those required for uniaxial compression tests, can only be obtained to a limited extent. More often only specimens with non-standardized dimensions are available. Therefore, in the next step, non-standardized samples of different geometries are collected and evaluated accordingly. It can be assumed that the heat propagation will be distributed unevenly. Here the question is clarified to what extent the geometry and composition of e.g. sedimentary rocks with high discontinuity behave in contrast to magmatic or metamorphic rocks with a low degree of separation.

In order to measure the heat development on the surface and in the core of the sample, the specimen is cut along the core, reassembled for irradiation in the microwave and after irradiation the temperature is measured at various points, in particular the surface

and core temperature. The procedure is analogous to Hartlieb et al. (2011). Infrared cameras are used to measure the temperature. After irradiation, they illuminate the interior and exterior of the rock and thus provide information about the temperature distribution. Since the temperature distribution will behave differently depending on the type of rock, this process must be repeated several times. Therefore, an alternative measuring method is to be developed within the framework of the experiments, so that the temperature measurement can be carried out without affecting the sample beforehand, e.g. by cutting or drilling. Conventional temperature sensors will influence the electric field in the microwave, which is why, for example, fiber-optic temperature measurement can be used. Optical sensors can be used to measure intensity, spectral distribution of the wavelength, time dependence due to frequency, pulse duration and decay and, if modified accordingly, strain changes. These can be analytically investigated in the following process.

After irradiation, the specimens are examined in the laboratory. Special attention is paid to a possible decrease of the compressive strength. The tests are carried out according to Mutschler (2004) in order to implement the requirements of the test equipment, test specimens, procedure for the execution and evaluation of uniaxial compression tests in standardized procedures. Less interesting for the construction industry, but relevant for the general scientific consideration of changes in the rock mechanical properties of solid rock, is the point load test according to Thuro (2010) and the splitting tensile test according to Lepique (2008).

Subsequently, the results are evaluated and the tests carried out with different input values are compiled. It can be assumed that the different variants of the temperature measurement and the choice of geometries will influence the output values accordingly.

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Air flow and heat exchange simulation of a rotary heat exchanger of polyethylene terephthalate (PET) as a sustainable alternative for aluminum

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Abstract. This paper deals with the simulation of rotary heat exchangers made of polyethylene terephthalates using CFD software. First steps for the simulation of simplified flow processes within a heat exchanger are presented. The aim of the project is the substitution of commercially available materials such as aluminum to plastic. The use of plastic as a storage mass material will create new possibilities which will make the heat exchangers even more efficient than their predecessors made of aluminum. For this purpose, the two materials are compared with each other using simulation models with ANSYS Fluent© and the resulting temperature curve is examined. The results show that PET offers a more suitable temperature profile than aluminum for heat exchanger.

1 Introduction and Objectives of the project

The PET rotary heat exchanger research project is being carried out in cooperation between the Gesellschaft zur Förderung technischen Nachwuchses GFTN e.V., Darmstadt, and Klingenburg GmbH, Gladbeck. The main focus of the research project is the substitution of the aluminum by PET for the production of the storage mass. The PET shall use the advantages of plastic and increase the efficiency of the rotary heat exchanger up to 90% by a geometrically optimized shaft structure. The design options for aluminum are limited by the yield strength. This leads to a maximum efficiency of 85%. A further advantage is the recyclability of the PET. The reuse of the material leads to a sustainable and future-oriented alternative to the existing heat exchangers. The aim of the project is to develop the complete production cycle in a process chain. The process chain is to include extrusion, embossing and deep-drawing as well as the joining of the films with subsequent winding. Once the life of the heat exchanger has been reached, it will be taken back and recycled by Klingenburg GmbH.

2 Operating principle of a rotary heat exchanger

Rotary heat exchangers are used with permitted circulating air. The main task is the supply and removal of heat energy in computer centers, office buildings, factory halls

and cruise ships. Due to the large surface area and the associated large air volume, rotary heat exchangers are considered to be the most effective heat exchangers. During operation, two air streams flow through the storage mass, the supply air stream from the outside and the exhaust air stream from the inside. Each of these two flows transfers its heat energy to the storage mass. The energy absorbed is released again and the heat is transferred by the rotation in the respective other stream. [1] The functional principle of the rotary heat exchanger is shown in Figure 1. In the further course of this abstract, the function of a rotary heat exchanger made of aluminum is compared with one made of PET on the basis of simulation results.

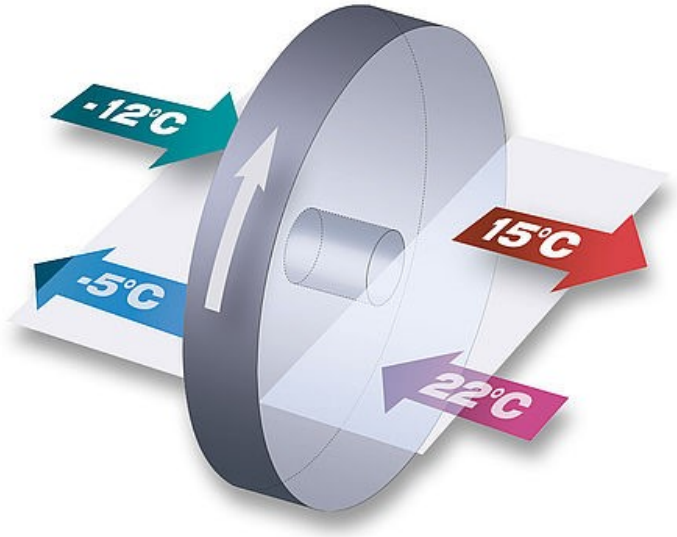

Fig. 1. Functional principle of the rotary heat exchanger

3 Thermal basics of the model

In counterflow heat exchangers, the air flows are guided through a series of parallel plates. Figure 2 shows the simplified principle of the heat exchanger as a volume body in CATIA V5R20®. The arrows indicate the direction of flow of the two air streams. The warm air flow directs the energy through the plate into the cold air flow, resulting in heat exchange. The shown model was calculated under the theoretical basis of single-layer walls.

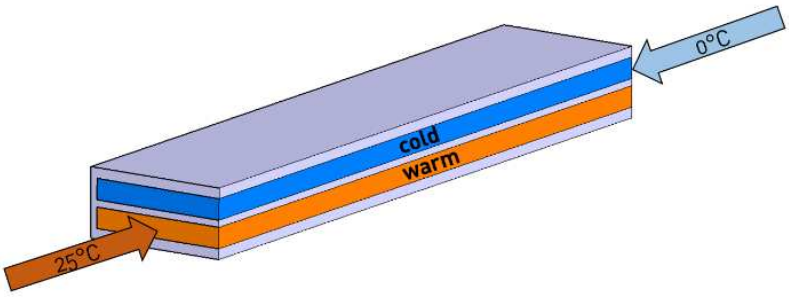

Fig. 2. Used simulation model in half section with displayed flow directions

The proportion of the heat flow absorbed depends on the design of the heat exchanger, the size of the effective heat transfer surface and the material of the transfer surface. The cooperation company Klingenburg GmbH has already carried out the first practical tests in this field, in which the material of the heat exchanger mass was changed from aluminum to PET. It has been shown that PET leads to a better efficiency as soon as the layer thickness becomes very thin.

If the stationary heat conduction is considered in a single-layer wall, the following relationship applies to the heat flow for a plate [2]:

$$\dot{Q} = \frac{(T_{warm} - T_{cold})}{R_\lambda \cdot t} \tag{1}$$

R_λ	=	thermal resistance
$T_{warm/cold}$	=	temperature warm/cold
t	=	time

with the thermal resistance:

$$R_\lambda = \frac{s}{\lambda \cdot A} \tag{2}$$

s	=	wall thickness
λ	=	thermal conductivity
A	=	trea flowed through

If the layer thickness in equation 2 is continuously smaller with the same denominator, the thermal resistance also becomes arbitrarily low. This means that the significantly higher thermal conductivity of aluminum (approx. factor 1000 better than PET) continuously has a considerable influence.

4 Simulation of a counterflow heat exchanger with ANSYS Fluent©

The first simulations were created with ANSYS 18.2 Fluent© CFD software. The geometry used for this was 2.1 mm wide, 0.5 mm high and 5 mm long. Two channels were provided with a height of 0.15 mm and a width of 2 mm over the entire length of this geometry. The dividing wall between them had a continuous thickness of 0.05 mm (50 µm).

In Fluent©, a stationary state was simulated with an air velocity of 1 m/s flowing through both channels. The temperature of the supply air flow duct is 0°C and the temperature of the exhaust air flow is 25°C. The thermal boundary conditions on the outer walls were defined as adiabatic and the material properties varied between aluminum and PET.

Looking at the results in Figure 3, it can be seen that PET has a more favourable temperature profile for heat exchangers. In the case of aluminum, a constant temperature has been set over the entire cross-section, while the PET volume body has a higher temperature difference in the air flow channels.

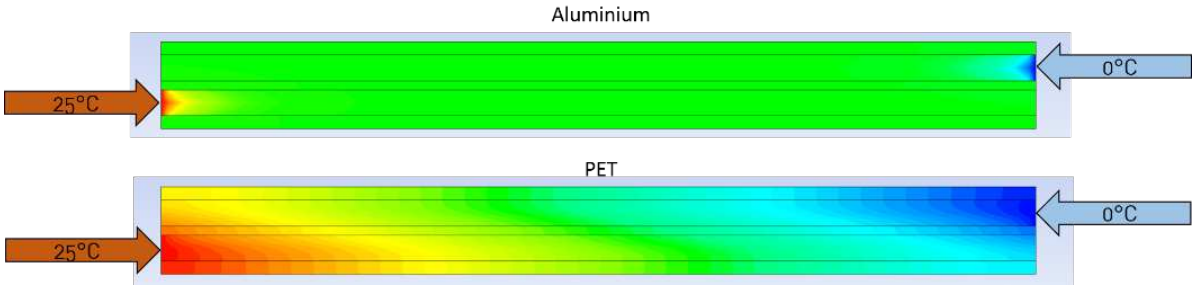

Fig. 3. Temperature curve in the middle of the body for aluminum (top) and PET (bottom)

5 Inference

This simulation is a first comparison of the two materials, aluminum and PET, with a simplified model. The results obtained are similar to the practical tests carried out by Klingenburg GmbH. In order to verify the simulation results, the model will be simulated in practice in the next phase of the project.

6 Acknowledgement

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7 Bibliography

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