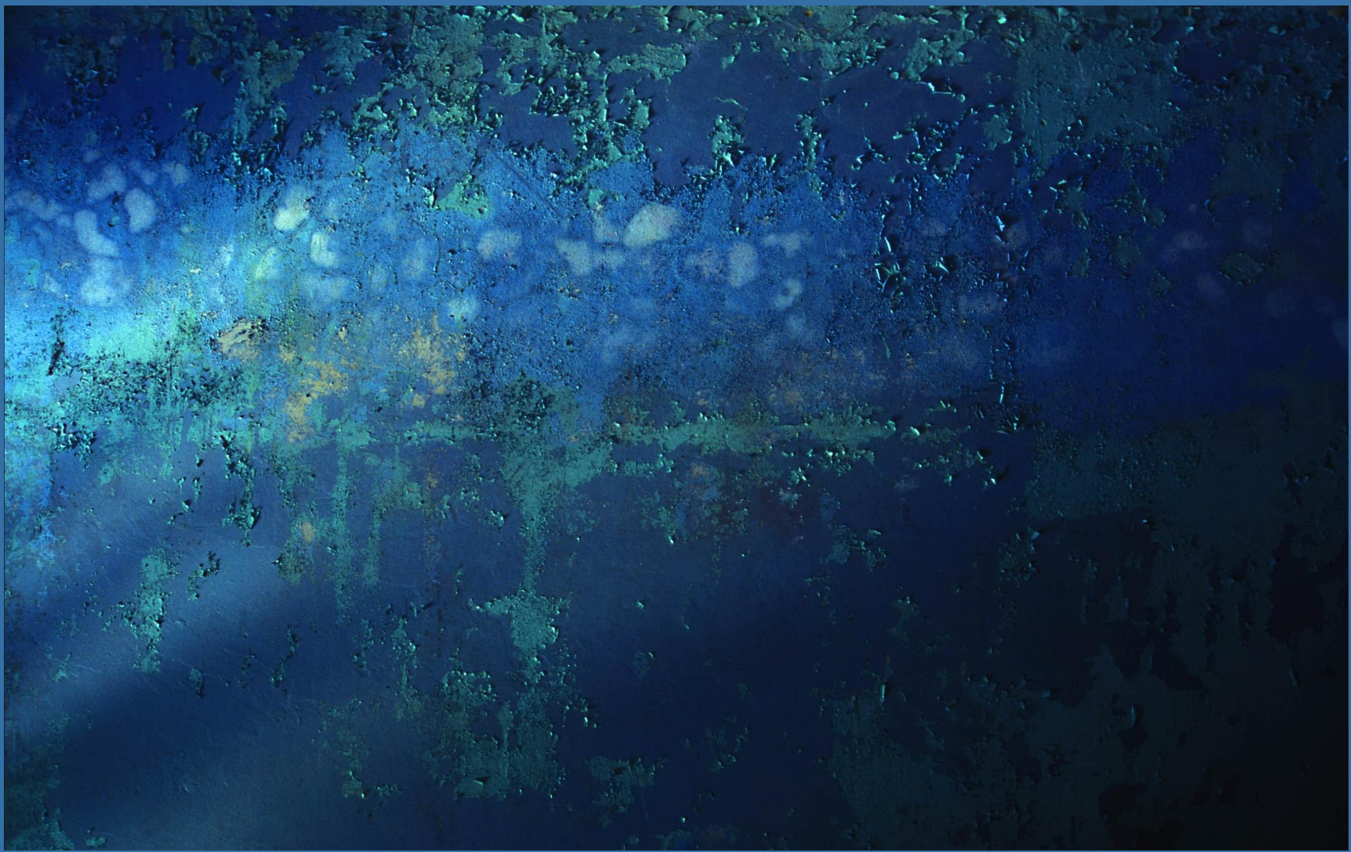
Annals of Computer Science and Information Systems
Volume 22

Position Papers of the 2020 Federated Conference on Computer Science and Information Systems

September 6–9, 2020. Sofia, Bulgaria



Maria Ganzha, Leszek Maciaszek, Marcin Paprzycki (eds.)

PTI

Annals of Computer Science and Information Systems, Volume 22

Position Papers of the 2020 Federated Conference on Computer Science and Information Systems

Maria Ganzha, Leszek Maciaszek, Marcin Paprzycki
(eds.)

POLSKIE TOWARZYSTWO INFORMATYCZNE
POLISH INFORMATION PROCESSING SOCIETY

2020, Warszawa, Polskie
Towarzystwo Informatyczne

Annals of Computer Science and Information Systems, Volume 22

Position Papers of the 2019 Federated Conference on Computer Science and Information Systems

USB: ISBN 978-83-959183-1-5
WEB: ISBN 978-83-959183-0-8

ISSN 2300-5963
DOI 10.15439/978-83-959183-0-8

Ul. Solec 38/103
00-394 Warsaw
Poland

Contact: secretariat@fedcsis.org
http://annals-csis.org/

Cover photo:
Iwona Burdecka,
Elbląg, Poland

Also in this series:

Volume 23: Communication Papers of the 2020 Federated Conference on Computer Science and Information Systems, **ISBN WEB: 978-83-959183-2-2, ISBN USB: 978-83-959183-3-9**
Volume 21: Proceedings of the 2020 Federated Conference on Computer Science and Information Systems, **ISBN Web 978-83-955416-7-4, ISBN USB 978-83-955416-8-1, ISBN ART 978-83-955416-9-8**
Volume 20: Communication Papers of the 2019 Federated Conference on Computer Science and Information Systems, **ISBN WEB: 978-83-955416-3-6, ISBN USB: 978-83-955416-4-3**
Volume 19: Position Papers of the 2019 Federated Conference on Computer Science and Information Systems, **ISBN WEB: 978-83-955416-1-2, ISBN USB: 978-83-955416-2-9**
Volume 18: Proceedings of the 2019 Federated Conference on Computer Science and Information Systems, **ISBN Web 978-83-952357-8-8, ISBN USB 978-83-952357-9-5, ISBN ART 978-83-955416-0-5**
Volume 17: Communication Papers of the 2018 Federated Conference on Computer Science and Information Systems, **ISBN WEB: 978-83-952357-0-2, ISBN USB: 978-83-952357-1-9**
Volume 16: Position Papers of the 2018 Federated Conference on Computer Science and Information Systems, **ISBN WEB: 978-83-949419-8-7, ISBN USB: 978-83-949419-9-4**
Volume 15: Proceedings of the 2018 Federated Conference on Computer Science and Information Systems, **ISBN Web 978-83-949419-5-6, ISBN USB 978-83-949419-6-3, ISBN ART 978-83-949419-7-0**
Volume 14: Proceedings of the First International Conference on Information Technology and Knowledge Management, **ISBN WEB: 978-83-949419-2-5, ISBN USB: 978-83-949419-1-8, ISBN ART: 978-83-949419-0-1**
Volume 13: Communication Papers of the 2017 Federated Conference on Computer Science and Information Systems, **ISBN WEB: 978-83-922646-2-0, ISBN USB: 978-83-922646-3-7**
Volume 12: Position Papers of the 2017 Federated Conference on Computer Science and Information Systems, **ISBN WEB: 978-83-922646-0-6, ISBN USB: 978-83-922646-1-3**

DEAR Reader, it is our pleasure to present to you Position Papers of the 15th Conference on Computer Science and Information Systems (FedCSIS'2020), which took place fully remotely, on September 7-9, 2020. Conference was originally planned to take place in Sofia, Bulgaria, but the global COVID-19 pandemics forced us to adapt and organize the conference online.

Position papers comprise two categories of contributions: challenge papers and emerging research papers. *Challenge papers* propose and describe research challenges in theory or practice of computer science and information systems. Papers in this category are based on deep understanding of existing research, or industrial problems. Based on such understanding and experience, they define new exciting research directions and show why these directions are crucial to the society at large. *Emerging research papers* present preliminary research results from work-in-progress, based on sound scientific approach but presenting work not completely validated as yet. They describe precisely the research problem and its rationale. They also define the intended future work including the expected benefits from solution to the tackled problem. Subsequently, they may be more conceptual than experimental.

FedCSIS 2020 was Chaired by prof. Stefka Fidanova, while dr. Nina Dobrinkova acted as the Chair of the Organizing Committee. This year, FedCSIS was organized by the Polish Information Processing Society (Mazovia Chapter), IEEE Poland Section Computer Society Chapter, Systems Research Institute Polish Academy of Sciences, Warsaw University of Technology, Wrocław University of Economics and Business, and Institute of Information and Communication Technologies, Bulgarian Academy of Sciences.

FedCSIS 2020 was technically co-sponsored by: IEEE Poland Section, IEEE Czechoslovakia Section Computer Society Chapter, IEEE Poland Section Systems, Man, and Cybernetics Society Chapter, IEEE Poland Section Computational Intelligence Society Chapter, IEEE Poland Section Control System Society Chapter, Committee of Computer Science of the Polish Academy of Sciences, Mazovia Cluster ICT Poland, Eastern Cluster ICT Poland and Bulgarian Section of SIAM.

During FedCSIS 2020, the keynote lectures were delivered by:

- Christian Blum Artificial Intelligence Research Institute (IIIA-CSIC), Barcelona, Spain, "*Are you a Hybrid? Yes, of course, everyone is a Hybrid nowadays!"*
- George Boustras, European University Cyprus "*Critical Infrastructure Protection – on the interface of safety and security"*
- Hans-Georg Fill, University of Fribourg, Switzerland, *„From Digital Transformation to Digital Ubiquity: The Role of Enterprise Modeling"*

FedCSIS 2020 consisted of five Tracks. Within each Track, topical Technical Sessions have been organized. Some of these Technical Sessions have been associated with the FedCSIS conference series for many years, while some of them are relatively new. Their role is to focus and enrich discussions on selected areas pertinent to the general scope of each Track.

- **Track 1: Artificial Intelligence**
  - *Topical technical sessions:*
    - 15th International Symposium on Advanced Artificial Intelligence in Applications (AAIA'20)
    - 13th International Workshop on Computational Optimization (WCO'20)
    - 5th International Workshop on Language Technologies and Applications (LTA'20)
- **Track 2: Computer Science & Systems**
  - *Topical technical sessions:*
    - Advances in Computer Science and Systems (ACS&S'20)
    - 13th Workshop on Computer Aspects of Numerical Algorithms (CANA'20)
    - 11th Workshop on Scalable Computing (WSC'20)
- **Track 3: Network Systems and Applications**
  - *Topical technical sessions:*
    - Advances in Network Systems and Applications (ANSA'20)
    - 4th Workshop on Internet of Things – Enablers, Challenges and Applications (IoT-ECAW'20)
    - International Forum of Cyber Security, Privacy, and Trust (NEMESIS'20)
- **Track 4: Information Systems and Technology**
  - *Topical technical sessions:*
    - Advances in Information Systems and Technologies (AIST)
    - 2nd Special Session on Data Science in Health, Ecology and Commerce (DSH'20)
    - 15th Conference on Information Systems Management (ISM'20)
    - 26th Conference on Knowledge Acquisition and Management (KAM'20)
- **Track 5: Software and System Engineering**
  - *Topical technical sessions:*
    - Advances in Software and System Engineering (ASSE'20)
    - 4th International Conference on Lean and Agile Software Development (LASD'20)
    - 6th Workshop on Model Driven Approaches in System Development (MDASD'20)
    - Joint 40th IEEE Software Engineering Workshop (SEW-40) and 7th International Workshop on Cyber-Physical Systems (IWCPS-7)

Each paper, found in this volume, was refereed by at least two referees.

The program of FedCSIS required a dedicated effort of many people. We would like to express our warmest gratitude to all Committee members, of each Track and each Technical Session, for their hard work in attracting and later refereeing 206 submissions (regular and data mining).

We thank the authors of papers for their great contribution into theory and practice of computing and software systems. We are grateful to the invited speakers for sharing their knowledge and wisdom with the participants.

Last, but not least, we thank prof. Fidanova and dr. Dobrinkova. It should be stressed that they made all the preparations to organize the conference in Bulgaria. They also worked with us diligently when we were forced to move the conference online. Stefka and Nina, we are very grateful for all your efforts! As a matter of fact, we hope to organize FedCSIS in Bulgaria as soon as the World returns to normal (even if it will be the "new normal").

We hope that you had an inspiring conference. We also hope to meet you again for the 16th Conference on Computer Science and Intelligence Systems (FedCSIS 2021). Please note an upcoming change in the conference name, from Information Systems to Intelligence Systems. The change is warranted, first, by the changes in the world around us. As can be easily observed, broadly understood, intelligence is permeating all aspects of our reality. Second, this change is already reflected by the kinds of paper submissions that are being received by all FedCSIS Tracks, and our intent to attract even more submissions related to all sorts of Intelligence Systems (including of course Artificial Intelligence, but also Business Intelligence, Management Intelligence, Human Intelligence, Financial Intelligence, Embedded Intelligence, Computational Intelligence, Collective Intelligence, Biomedical Intelligence, Military Intelligence, Network Intelligence…).

Taking into account the level of uncertainty related to COVID-19, we are seriously considering organizing the next edition of the conference online, again. However, the final decision has not been reached, yet.

Co-Chairs of the FedCSIS Conference Series

Maria Ganzha, *Warsaw University of Technology, Poland and Systems Research Institute Polish Academy of Sciences, Warsaw, Poland*
Leszek Maciaszek, *Wrocław University of Economics, Wrocław, Poland and Macquarie University, Sydney, Australia*
Marcin Paprzycki, *Systems Research Institute Polish Academy of Sciences, Warsaw Poland and Management Academy, Warsaw, Poland*

Position Papers of the 2020 Federated Conference on Computer Science and Information Systems (FedCSIS)

September 6–9, 2020. Sofia, Bulgaria

TABLE OF CONTENTS

26TH CONFERENCE ON KNOWLEDGE ACQUISITION AND MANAGEMENT

SOFTWARE AND SYSTEM ENGINEERING

JOINT 40TH IEEE SOFTWARE ENGINEERING WORKSHOP AND 7TH INTERNATIONAL WORKSHOP ON CYBER-PHYSICAL SYSTEMS

4TH INTERNATIONAL CONFERENCE ON LEAN AND AGILE SOFTWARE DEVELOPMENT

5th International Workshop on Language Technologies and Applications

DEVELOPMENT of new technologies and various intelligent systems creates new possibilities for information processing. Natural Language Processing (NLP) addresses problems of automated understanding, processing, evaluation and generation of natural human languages. LTA workshop provides a venue for discussion and presenting innovative research in NLP domain, but not restricted, to: computational and mathematical modeling, analysis and processing of any forms (spoken, handwritten or text) of human language, interactions via Virtual Reality and Augmented Reality, Computational Intelligence models and applications but also other various applications in decision support systems. We welcome papers covering innovative applications and practical usage of theoretical aspects. The LTA workshop will provide an opportunity for researchers and professionals to discuss present and future challenges as well as potential collaboration for future progress in the field.

TOPICS

The submitted papers shall cover research and developments in all NLP aspects, such as (however this list is not exhaustive):

- Computational Intelligence methods applied to language & text processing
- text analysis
- language networks
- text classification
- language networks, resources and corpora
- document clustering
- various forms of text recognition
- machine translation
- intelligent text-to-speech (TTS) and speech-to-text (STT) methods
- authorship identification and verification
- author profiling
- plagiarism detection
- sentiment analysis
- NLP applications in education
- knowledge extraction and retrieval from text and natural language structures
- multi-modal and natural language interfaces
- innovative language-oriented applications and tools
- interactions models and applications via Virtual Reality and Augmented Reality
- NLP for text analysis in forensic linguistics and cybersecurity

TECHNICAL SESSION CHAIRS

- **Damasevicius, Robertas,** Kaunas University of Technology, Lithuania
- **Martinčić – Ipšić, Sanda,** University of Rijeka, Croatia
- **Napoli, Christian,** Department of Mathematics and Informatics, University of Catania, Italy
- **Sanada, Haruko,** Rissho University, Japan

PROGRAM COMMITTEE

- **Artiemjew, Piotr,** University of Warmia and Mazury, Poland
- **Burdescu, Dumitru Dan,** University of Craiova, Romania
- **Harbusch, Karin,** Universität Koblenz-Landau, Germany
- **Kapočiūtė-Dzikienė, Jurgita,** Vytautas Magnus University, Lithuania
- **Kurasova, Olga,** Vilnius University, Institute of Mathematics and Informatics, Lithuania
- **Marszałek, Zbigniew,** Silesian University of Technology, Poland
- **Maskeliūnas, Rytis,** Kaunas University of Technology, Lithuania
- **Matson, Eric T.,** Purdue University, United States
- **Połap, Dawid,** Institute of Mathematics, Silesian University of Technology, Poland
- **Starczewski, Janusz,** Czestochowa University of Technology, Poland
- **Tambouratzis, George,** Institute for Language and Speech Processing, Athena Research Centre, Greece

Position Papers of the Federated Conference on Computer Science and Information Systems pp. 3–8
DOI: 10.15439/2020F212
ISSN 2300-5963 ACSIS, Vol. 22

From Machine Translated NLI Corpus to Universal Sentence Representations in Czech

Martin Víta
NLP Centre
Faculty of Informatics, Masaryk University
Botanická 68a, 602 00 Brno
Czech Republic
Email: info@martinvita.eu

***Abstract*—Natural language inference (NLI) is a sentence-pair classification task w.r.t. the entailment relation. As already shown, certain deep learning architectures for NLI task – INFERSENT in particular – may be exploited for obtaining (supervised) universal sentence embeddings. Although INFERSENT approach to sentence embeddings has been recently outperformed in different tasks by transformer-based architectures (like BERT and its derivatives), it still remains a useful tool in many NLP areas and it also serves as a strong baseline. One of the greatest advantages of this approach is its relative simplicity. Moreover, in contrast to other approaches, the training of INFERSENT models can be performed on a standard GPU within hours. Unfortunately, the majority of research on sentence embeddings in general is done in/for English, whereas other languages are apparently neglected. In order to fill this gab, we propose a methodology for obtaining universal sentence embeddings in another language – arising from training INFERSENT-based sentence encoders on *machine translated* NLI corpus and present a transfer learning use-case on semantic textual similarity in Czech.**

I. INTRODUCTION

NATURAL language inference (NLI) task, i.e., a sentence-pair classification task with respect to the entailment relation – usually into three classes (ENTAILMENT, NEUTRAL and CONTRADICTION) has been intensively studied in the last (approximately) fifteen years – formerly, this task was known as *recognizing textual entailment (RTE)*. The sentences forming the sentence pair to be classified are commonly known as premise and hypothesis.

The rapid development in NLI area was allowed, on one hand by strong progress in deep learning in NLP and, on the other hand, by releasing the first large volume annotated corpus for NLI in 2015 – well known Stanford NLI corpus (abbr. SNLI) [1], later followed by MultiNLI dataset [2] which covered wider range of topics and genres, both in English. Therefore, the majority of NLI research has been focused on NLI in English, other languages are still highly neglected. It is reminiscent of a "chicken-egg problem": research on languages different to English are neglected, since there are no suitable resources (annotated corpora), and, in the opposite direction, not "so strong research effort means lower pressure for development of relevant annotated corpora".

In [3], Conneau et al. shown, that NLI task is suitable for obtaining (supervised) universal sentence embeddings – these embeddings are produced by sentence encoders that form Siamese architecture called INFERSENT (two identical architectures are used for encoding both premises and hypotheses in the same manner). The entire classification architecture for NLI consists of these two encoders, a merging layer that combine these embeddings – the output of the merging layer is subsequently fed into a dense layer, followed by a final sigmoid layer. Sentences at the input are represented as sequences of word embeddings (like GloVe [4], word2vec or fastText. The INFERSENT authors trained this architecture on previously mentioned SNLI corpus, in some variants augmented by MultiNLI corpus. As we can observe, this work is again limited to English.

To fill this "language gab", we introduce a machine translated version of SNLI corpus into Czech. Subsequently, we have trained on this newly proposed dataset one of INFERSENT-based architectures. Alongside with this model for SNLI in Czech, we have obtained also sentence encoder for Czech. To demonstrate the capabilities of these Czech sentence embeddings, we used these sentence encoders for a task of *semantic textual similarity* in Czech.

This proposed process may be shift into a more general level – the process can be performed in the following steps:

1) The NLI corpus (e.g., SNLI) is machine translated to a selected target language (Czech for instance).
2) An INFERSENT is trained on the translated NLI dataset in the target language and sentence encoders are obtained.
3) Sentence encoders are used within models or other semantic oriented tasks in the target languages (transfer learning).

The requirements for this process are implicitly specified in the first two steps: this process relies on the availability of machine translation tools (or TranslationAPI) for a considered source-target language pair. The second requirement is the availability of suitable word embeddings. However, within MUSE project, FASTTEXT embeddings are available for more than one hundred languages.

In the following parts of this position paper we will elaborate on each step of the outlined process.

II. NLI Corpora and DNN Architectures

At first, we are going to summarize the key characteristics of the SNLI corpus and DNN architectures involved.

A. Original SNLI Corpus in English

Nowadays, SNLI (Stanford NLI corpus) is probably the best known corpus for NLI task. The entire corpus contains of 570K labeled sentence pairs split in a TRAIN (550K), DEV (10K) and TEST (10K) sets. These pairs were generated by annotators (crowdworkers) based on image captions mostly of the FLICKR30K dataset [5] and a minor part of the TRAIN set (4K) on captions that were taken from the VisualGenome dataset [6]. The annotators were asked, given a textual caption (without the original photo), to create a three other sentences (i.e., alternative captions) that satisfy the following conditions [1]:

- one is "definitely a true description of the photo",
- one "might be a true description of the photo",
- one is "definitely a false description of the photo."

The original sentence given to annotators was taken as premise, the three sentences produced by annotators were taken as hypotheses. These sentence pairs were labeled according to the conditions as ENTAILMENT, NEUTRAL and CONTRADICTION, respectively. Subsequently, 56,941 samples were validated by four additional judgments showing a high annotation agreement. The details about the corpus development process is provided in the original paper [1].

B. Machine Translated SNLI Czech Version of SNLI Corpus

In order to obtain Czech NLI annotated corpus, we chose a (machine) translation approach. Since the inference is a semantic phenomenon (and hence "invariant to translation", i.e., the entailment relation between a premise and a hypothesis expressed by the label, is the same in both original/source and target language), we can simply use the original labels.

In recent years, the machine translation (MT) approach was utilized for German in a task of *contradiction detection*, see [7]. However, in this case, the authors took only a part of SNLI corpus (110,000 items in particular) and translated it subsequently using DeepL service[1]). No analysis of the German counterpart was performed.

In our case, the Czech MT version of SNLI was created using translation LINDAT Translation API [2] – we have translated the entire SNLI corpus sentence-by-sentence. The TRAIN/DEV/TEST splits remain unchanged. This process relies on the implicit assumption MT system produces translations in a sufficient quality. This assumption is supported by the fact that image captions that form the "premises" part of the corpus are usually short and do not have a complicated dependency structure, thus we may expect reasonable results of machine translation process. However, this quality assumption will be analyzed in the further text.

[1]https://www.deepl.com/translator

[2]https://lindat.mff.cuni.cz/services/translation

TABLE I
EXAMPLE OF ITEMS IN CZECH MT VERSION OF SNLI CORPUS

Premise: *Přes řeku právě projíždí terénní vůz.* (orig.: *A land rover is being driven across a river.*)
Hypothesis: *Vozidlo přejíždí řeku.* (orig.: *A vehicle is crossing a river.*)
Label: ENTAILMENT
Premise: *Muž v černé košili se dívá na kolo v dílně.* (orig.: *A man in a black shirt is looking at a bike in a workshop.*)
Hypothesis: *Muž se rozhoduje, které kolo si koupí.* (orig.: *A man is deciding which bike to buy.*)
Label: NEUTRAL
Premise: *Holky jdou po ulici.* (orig.: *The girls walk down the street.*)
Hypothesis: *Dívky se usadily na ulici.* (orig.: *Girls set down in the street.*)
Label: CONTRADICTION

TABLE II
1- TO 4-GRAMS BLEU SCORES

Type	1-gram	2-gram	3-gram	4-gram
Score	80.35	62.18	50.92	42.38

To provide a better idea about the corpus, we selected three sentence pairs from Czech MT version of SNLI corpus – from the TEST subset in particular (one sentence pair for each label), see Table I. This table also shows the original source sentences, hence it provides also the examples of original sentence pairs of SNLI corpus.

The Czech MT version of SNLI corpus is freely available for download[3].

C. Selected Characteristics of Czech MT version of SNLI Corpus

As we have already mentioned, we are going to present an evidence that justify our the MT approach. At first, we have computed a "traditional" MT evaluation metric: BLEU score [8], [9]. We have prepared a sample of 100 randomly selected hypotheses from the TEST set and translate them manually from English to Czech. This manual translation was done by two independently working Czech native speakers. Then we have computed BLEU score w.r.t. machine translation and this human translated (reference) sentences using Interactive BLEU score evaluator[4]. The results for 1- to 4-grams are summarized in Table II.

In unigram setting, we have obtained a value exceeding 80%. This suggest a sufficient quality of translation. At this point we should notice that our primary aim is not to focus on "translation quality" and its assessment, but on the quality of the NLI corpus being developed. (And, we should take into account that the "wrong" translation does not necessarily lead to incorrect entailment labels. It may be obvious mainly in case of sentence pairs labeled as NEUTRAL: if the sentences forming a pair in NLI corpus are translated incorrectly, then the label is regardless most likely correct.). Nevertheless, we performed an experiment that elucidate the question of quality of labels in the Czech MT version of SNLI corpus.

[3]https://github.com/martinvita/CZinferSent

[4]https://www.letsmt.eu/Bleu.aspx

D. EN-CZ Label Transfer and its Quality

To estimate the quality of the entailment labels in the target language corpus, we assess the entailment labels manually again by two independently working Czech native speakers. The task was stated as follows: given (only) sentence pairs in Czech (machine translated) accompanied with transferred labels, the annotators were asked to check the correctness of the label (in a binary way) without the knowledge of the original sentence pairs (in the source language). This experiment was done on a random sample of 500 sentence pairs from the Czech TEST dataset with the following results:

- 454 items were marked as correct, i.e., the label corresponding to Czech premise-hypothesis sentence pair was correct.
- 46 (i.e., 9.2% of 500) items were revealed as incorrect.

However, in the further (human) analysis it was found that in majority of the incorrect cases, the incorrectness of the labels was contained already in the source SNLI corpus.

E. INFERSENT *Architecture*

Nowadays, we can observe a huge number of deep learning approaches to NLI in general. A comprehensive overview of the architectures involved in SNLI task can be found on the SNLI dashboard[5]. However, for the purposes of this paper, it is not necessary to provide a survey of these approaches, we only divide the deep learning into two major classes:

- Architectures encoding premise and hypothesis separately (usually using Siamese architectures), there is no mutual "interaction" between premise and hypothesis within the "encoding phase". Premise and hypotheses embeddings are subsequently merged and the final decision is made usually using fully connected layers.
- Architectures encoding the problem into a "joint embedding" using based on cross-sentence features constructed by various attention mechanisms between premise and hypothesis.

From our perspective (i.e., development of sentence embeddings) the first class of approaches is a keystone. The general architecture of such approaches / architectures is depicted in Figure II-E. (it is a generalization of a scheme on Figure 1 in [3]): premise and hypothesis embeddings u, v (obtained from GRUs or LSTMs for instance) are merged using a function f, that may be a simple concatenation of u, v, i.e., $f(u, v) = (u, v)$, or enriched representation dealing with pointwise absolute value of difference of u, v, and their pointwise product, i.e., $f(u, v) = (u, v, |u - v|, u * v)$ – this "enriched" approach is the utilized in [3] and also in this work. The final decision is made by a dense layer(s) and a 3-way softmax.

The INFERSENT approach is basically a collection of similar architectures corresponding to scheme in Figure II-E with different encoders, including LSTM [10], GRU [11] and their bidirectional variants, self-attention architecture, hierarchical convolutional networks and others. Their detailed description is provided in [3].

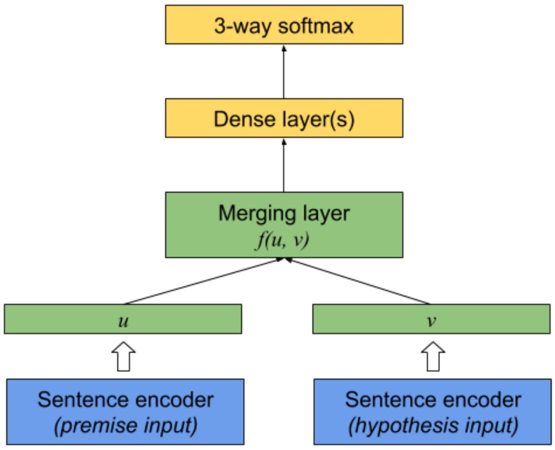


Fig. 1. General architecture of the first class of approaches (no attention between premise and hypothesis)

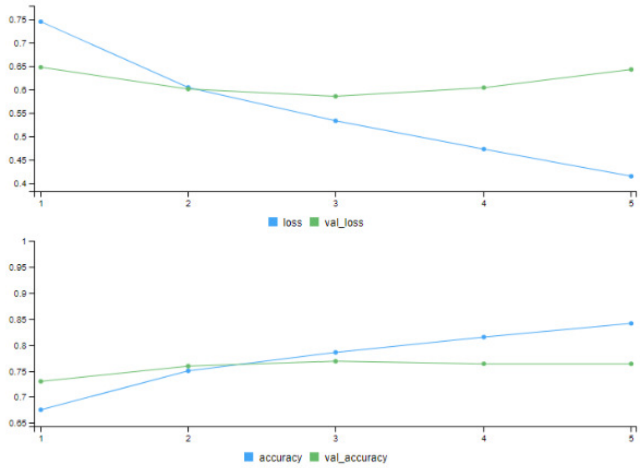


Fig. 2. Training one of the INFERSENT-based model in 5 epochs

For our proof-of-concept, we have chosen an INFERSENT architecture using GRU sentence encoder (i.e. encoders are GRU layers sharing the same parameters in premise and hypothesis part, i.e., Siamese architecture).

Sentences (premises/hypotheses) that are fed into the GRU layers are represented as sequences of word embeddings. Since we deal with Czech, we did not used GLOVE [4] as in the original INFERSENT model, but we exploited precomputed FASTTEXT embeddings from MUSE project[6]

Architecture and training details: the dimension of GRU layer was set to 512 as well as the dimension of the fully connected layer which follows the merging layer. The model was trained in 10 epochs using SGD optimizer, the implementation was written in R+Keras and rewritten in Python+Keras. Illustration of the training process is depicted in Figure II-E.

[5]https://nlp.stanford.edu/projects/snli/

[6]Available for download at https://github.com/facebookresearch/MUSE.

On the Czech TEST set we achieved 78.69 accuracy within the setting described above. This result may serve as a strong baseline for the Czech MT version of SNLI corpus.

III. TRANSFER LEARNING USE CASE – SEMANTIC TEXTUAL SIMILARITY IN CZECH

As an application of supervised sentence embeddings in Czech, i.e., for transfer learning, we chose a well known task of semantic textual similarity (in Czech).

A. Semantic Textual Similarity (STS) - Task Description

Semantic Textual Similarity (STS) can be defined by a metric over a set of documents with the idea is to finding the semantic similarity between them [12]. It was introduced for short texts (sentences) in [13]. Given two text snippets/sentences the task is to assign a numeric value from an interval $[m, n]$ for this pair, where the n value stands for identity, m corresponds with total unrelatedness of sentences considered.

STS is an intensively studied problem for years, the great development in this area was accelerated by SemEval challenges [14], [15] etc. In the framework of these challenges, this task was standardized into the following form: given a sentence pair, the task is to assign them a similarity score between 0 and 5, where 5 corresponds with (total) semantic equivalence and 0 corresponds with complete unrelatedness.

Each integer value refers to the following meanings [15]:

§ 5 – identical,
§ 4 – strongly related,
§ 3 – related,
§ 2 – somewhat related,
§ 1 – unrelated,
§ 0 – completely unrelated,

STS has many downstream applications including question answering systems, computer-aided translation (translation memory systems) etc. [16].

NLI and STS both deal with sentence pairs, however, there are substantial differences between these two tasks. Formally, STS is a regression task (in contrast to NLI, which is considered as a classification task). Another difference in the form is "symetry": entailment relation obviously depends on the "direction", whereas in STS the order of the two sentences does not matter.

As an evaluation metric for STS task, a Pearson correlation coefficient is traditionally used.

B. STS Corpus in Czech

Although STS in English is a well resourced problem, the same does not hold for STS in other languages, including Czech. At the time, there exists *only one* STS annotated dataset for Czech introduced in [17]. It contains 1,425 annotated pairs. It was developed upon the English sentence pairs from SemEval challenges (2013–2015) corpora. The sentence pairs were *manually* translated by four Czech native speakers ensuring the high quality of produced final corpus. The original labels were simply transferred (the assumption is the same as in the case of NLI corpora translation). The Czech STS contains two distinct domains/topics: news headlines and image captions. The corpus is split into two parts: TRAIN (925 instances) and TEST (500 instances) having no DEV subset. The structure of the corpus is summarized in Table III.

TABLE III
STRUCTURE OF THE CZECH STS CORPUS [17]

Dataset	Split	No. of Pairs
SemEval 2014–15 Images CZ	TRAIN	550
SemEval 2013–15 Headlines CZ	TRAIN	375
SemEval 2014–15 Images CZ	TEST	300
SemEval 2013–15 Headlines CZ	TEST	200

TABLE IV
EXAMPLE OF CZECH STS CORPUS ITEMS

Sentence 1: *Dva černí psi si hrají na trávě.* (original: *Two black dogs are playing on the grass.*)
Sentence 2: *Dva černí psi si hrají na travnaté planině.* (original: *Two black dogs are playing in a grassy plain.*)
Label: 4.60
Sentence 1: *Skupina čtyř dětí tancujících na dvorku.* (original: *A group of four children dancing in a backyard.*)
Sentence 2: *Skupina dětí se protahuje na barevných podložkách.* (original: *A group of children do stretches on colored mats.*)
Label: 1.60
Sentence 1: *Žena drží dítě, zatímco muž se kouká na jiného muže držícího dětské hodinky.* (original: *A woman holds a baby while a man looks at it as another man holding a child watches.*)
Sentence 2: *Žena stojí v obchodě s rukama venku, zatímco jiná žena drží kameru.* (original: *A woman stands with her arms out in a store while another woman holds a camera.*)
Label: 0.40
Sentence 1: *Žena držící noviny.* (original: *A woman holding a newspaper.*)
Sentence 2: *Muž na kolečkových bruslích na kovové tyči.* (original: *A man rollerblading on a metal bar.*)
Label: 0.00

The corpus is publicly available for download[7].

Again, in order to provide a better overview of the corpus, we also provide several examples taken from the "Image" part of the corpus, see Table IV.

The authors in [17] proposed several approaches to STS in Czech (over their corpus), based on (strong) text preprocessing (stemming/ lemmatization) and feature engineering (n-grams, TF-IDF scores etc.) as well as bag-of-words (BOW) approaches with FASTTEXT embeddings. The authors achieved a Pearson correlation coefficient $\mathbf{0.7887}$ on the TEST set/Image part, using linear regression over feature vectors.

C. Architecture for STS that Uses INFERSENT Encoders

Analogously to NLI, STS (regression) task has inputs in the form of sentence pairs, hence we can exploit similar architectures as in Figure II-E assuming that sentence encodings are already prepared. The difference is obviously in the last layer, since we do not elaborate on classification, but regression. We squeezed the output interval from $[0, 5]$ to "more natural" $[0, 1]$ (without loss of generality, since Pearson correlation coefficient is invariant to linear transformations). The final output is provided by a *sigmoid layer.*

[7]https://github.com/Svobikl/sts-czech

TABLE V
RESULTS ON THE CZECH STS CORPUS

Merging fnc	Train set	TEST	IMG
f_1	TRAIN-FULL	0.7086	0.8046
f_1	TRAIN-IMG	0.6902	0.8170
f_2	TRAIN-FULL	**0.7488**	0.8412
f_2	TRAIN-IMG	0.7409	**0.8511**
f_3	TRAIN-FULL	0.7123	0.8096
f_3	TRAIN-IMG	0.6906	0.8198
f_4	TRAIN-FULL	0.4879	0.5698
f_4	TRAIN-IMG	0.3690	0.4944
f_5	TRAIN-FULL	0.7447	0.8358
f_5	TRAIN-IMG	0.6857	0.8410

We investigated the following settings regarding merging sentence embeddings (corresponding to architecture from Figure II-E):

» $f_1(u,v) = (u, v, |u-v|, u*v)$
» $f_2(u,v) = (|u-v|, u*v)$
» $f_3(u,v) = (u, v, |u-v|$
» $f_4(u,v) = (u, v, u*v)$
» $f_5(u,v) = (|u-v|)$

We performed experiments with architectures described in the previous subsection. Moreover, we also used different subsets of TRAIN and TEST splits of Czech STS – we elaborated on the following scenarios:

» training on the entire TRAIN split, abbr. TRAIN-FULL,
» training only on the "Image part" of the TRAIN split, abbr. TRAIN-IMG.

D. Results

Table V summarizes our results. Training was done in 24 epochs using Adam optimizer [18]. The fully connected layer following the merging layer had 28 units (set using grid search) using *elu* activation.

The evaluation uses Pearson correlation coefficient of predictions and gold labels.

IV. DISCUSSION

We have achieved results comparable to those obtained by feature-based approaches presented in [17]. In case of "Image part" of Czech STS corpus (for both training and test), we strongly outperformed results presented in [17] (0.8511 vs. 0.7887). The reason most likely arises from the fact that sentence encoders were trained on the same domain.

From the results we have also seen that including the separate sentence embeddings that form an input pair does not lead to improvements. The architecture which yields the best results on Image subset used only "merged representations/embeddings" (concatenated vectors $|u-v|$ and $u*v$, where u, v are corresponding embeddings of sentences of the STS task). We can observe that in case of "Image part" of the TEST set, all architectures omitting separate u, v (i.e., using merging functions f_2 and f_5) and hence using only "fusions" of u, v provide better results than all other architectures (using merging with separate sentence embeddings).

Relatively poor results achieved on "Headlines part" of the TEST set (causing lower results on the whole set compared to the "Image part" only) are probably caused with a large amount of out-of-vocabulary words (the vocabulary used in tokenization was derived from Czech MT version of SNLI, i.e., from "image domain" that perfectly fits to "Image part" of Czech STS corpus, but, in contrast, it is not so suitable for news headlines which often contain proper names – surnames, locations' names etc. not covered by the dictionary). Future experiments and datasets augmentations are needed – mainly in the sense of adding labeled data to Czech MT version of SNLI corpus. One of possible (and feasible) approaches is probably a machine translation of MultiNLI corpus that contains more genre-diverse sentence pairs, however, the "methodology" may stay unchanged.

V. CONCLUSION AND FURTHER WORK

In this paper we have introduced a Czech MT version of SNLI corpus and state an INFERSENT (GRU) baseline of the corpus, together with obtaining sentence encoders in Czech. These encoders were directly used in transfer learning approach to semantic textual similarity task in Czech. We achieved notable results on particular "Image captions" dataset (0.8511 in terms of Pearson correlation coefficient).

This work primarily demonstrates the feasibility of this general approach to sentence embeddings available for all target languages, where suitable English-target language MT system / translation API exists. Thanks to simplicity of this process, it can be easily implemented even in cases when only limited computational resources are available.

Further Work

Our presented results indicate that supervised sentence embeddings obtained from NLI task is a promising way of investigations. There are several research questions arising from this initial work, mainly:

1) How does the INFERSENT particular architecture used affects the result in Czech comparing to English?
2) Are there any statistically significant differences in accuracy achieved with same architectures on different languages?

Another direction of further research is extrinsic evaluation of sentence embeddings obtained on different transfer tasks (including tasks like sentiment analysis, CST relations classification [19] etc.) in different languages.

A related issue to this direction of research is investigating the impact of quality of machine translation on the quality of final sentence embeddings obtained.

Sentence embeddings are generally an emerging topic. In contrast to English, where this topic is intensively and deeply studied, the research for other languages is in the beginning. However, there some attempts including Slavic BERT [20]. A solid comparison of our proposed INFERSENT based approach and BERT approach for Czech is also an open issue.

Remark: This position paper contains several results from the author's PhD thesis – submitted after the the FedCSIS deadline, currently under the review.

REFERENCES

[1] S. R. Bowman, G. Angeli, C. Potts, and C. D. Manning, "A large annotated corpus for learning natural language inference," *arXiv preprint arXiv:1508.05326*, 2015.

[2] A. Williams, N. Nangia, and S. Bowman, "A broad-coverage challenge corpus for sentence understanding through inference," in *Proceedings of the 2018 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies, Volume 1 (Long Papers)*, Jun. 2018, pp. 1112–1122.

[3] A. Conneau, D. Kiela, H. Schwenk, L. Barrault, and A. Bordes, "Supervised learning of universal sentence representations from natural language inference data," *arXiv preprint arXiv:1705.02364*, 2017.

[4] J. Pennington, R. Socher, and C. D. Manning, "Glove: Global vectors for word representation," in *Proceedings of the 2014 conference on empirical methods in natural language processing (EMNLP)*, 2014, pp. 1532–1543.

[5] P. Young, A. Lai, M. Hodosh, and J. Hockenmaier, "From image descriptions to visual denotations: New similarity metrics for semantic inference over event descriptions," *Transactions of the Association for Computational Linguistics*, vol. 2, pp. 67–78, 2014.

[6] R. Krishna, Y. Zhu, O. Groth, J. Johnson, K. Hata, J. Kravitz, S. Chen, Y. Kalantidis, L.-J. Li, D. A. Shamma *et al.*, "Visual genome: Connecting language and vision using crowdsourced dense image annotations," *International Journal of Computer Vision*, vol. 123, no. 1, pp. 32–73, 2017.

[7] R. Sifa, M. Pielka, R. Ramamurthy, A. Ladi, L. Hillebrand, and C. Bauckhage, "Towards contradiction detection in german: a translation-driven approach," in *2019 IEEE Symposium Series on Computational Intelligence (SSCI)*. IEEE, 2019, pp. 2497–2505.

[8] K. Papineni, S. Roukos, T. Ward, and W.-J. Zhu, "Bleu: a method for automatic evaluation of machine translation," in *Proceedings of the 40th annual meeting of the Association for Computational Linguistics*, 2002, pp. 311–318.

[9] C. Callison-Burch, M. Osborne, and P. Koehn, "Re-evaluation the role of bleu in machine translation research," in *11th Conference of the European Chapter of the Association for Computational Linguistics*, 2006.

[10] S. Hochreiter and J. Schmidhuber, "Long short-term memory," *Neural computation*, vol. 9, no. 8, pp. 1735–1780, 1997.

[11] K. Cho, B. Van Merriënboer, D. Bahdanau, and Y. Bengio, "On the properties of neural machine translation: Encoder-decoder approaches," *arXiv preprint arXiv:1409.1259*, 2014.

[12] G. Majumder, P. Pakray, A. Gelbukh, and D. Pinto, "Semantic textual similarity methods, tools, and applications: A survey," *Computación y Sistemas*, vol. 20, no. 4, pp. 647–665, 2016.

[13] Y. Li, D. McLean, Z. A. Bandar, J. D. O'shea, and K. Crockett, "Sentence similarity based on semantic nets and corpus statistics," *IEEE transactions on knowledge and data engineering*, vol. 18, no. 8, pp. 1138–1150, 2006.

[14] E. Agirre, D. Cer, M. Diab, and A. Gonzalez-Agirre, "Semeval-2012 task 6: A pilot on semantic textual similarity," in * *SEM 2012: The First Joint Conference on Lexical and Computational Semantics–Volume 1: Proceedings of the main conference and the shared task, and Volume 2: Proceedings of the Sixth International Workshop on Semantic Evaluation (SemEval 2012)*, 2012, pp. 385–393.

[15] E. Agirre, D. Cer, M. Diab, A. Gonzalez-Agirre, and W. Guo, "* sem 2013 shared task: Semantic textual similarity," in *Second joint conference on lexical and computational semantics (* SEM), volume 1: proceedings of the Main conference and the shared task: semantic textual similarity*, 2013, pp. 32–43.

[16] R. Gupta, H. Bechara, and C. Orasan, "Intelligent translation memory matching and retrieval metric exploiting linguistic technology," *Proc. of Translating and the Computer*, vol. 36, pp. 86–89, 2014.

[17] L. Svoboda and T. Brychcín, "Czech dataset for semantic textual similarity," in *International Conference on Text, Speech, and Dialogue*. Springer, 2018, pp. 213–221.

[18] D. P. Kingma and J. Ba, "Adam: A method for stochastic optimization," *arXiv preprint arXiv:1412.6980*, 2014.

[19] P. Kędzia, M. Piasecki, and A. Janz, "Graph-based approach to recognizing cst relations in polish texts," in *Proceedings of the International Conference Recent Advances in Natural Language Processing, RANLP 2017*, 2017, pp. 363–371.

[20] M. Arkhipov, M. Trofimova, Y. Kuratov, and A. Sorokin, "Tuning multilingual transformers for language-specific named entity recognition," in *Proceedings of the 7th Workshop on Balto-Slavic Natural Language Processing*, 2019, pp. 89–93.

Advances in Network Systems and Applications

THE rapid development of computer networks including wired and wireless networks observed today is very evolving, dynamic, and multidimensional. On the one hand, network technologies are used in virtually several areas that make human life easier and more comfortable. On the other hand, the rapid need for network deployment brings new challenges in network management and network design, which are reflected in hardware, software, services, and security-related problems. Every day, a new solution in the field of technology and applications of computer networks is released. The ANSA technical session is devoted to emphasizing up-to-date topics in networking systems and technologies by covering problems and challenges related to the intensive multidimensional network developments. This session covers not only the technological side but also the societal and social impacts of network developments. The session is inclusive and spans a wide spectrum of networking-related topics.

The ANSA technical session is a great place to exchange ideas, conduct discussions, introduce new ideas and integrate scientists, practitioners, and scientific communities working in networking research themes.

TOPICS

- Networks architecture
- Networks management
- Quality-of-Service enhancement
- Performance modeling and analysis
- Fault-tolerant challenges and solutions
- 5G developments and applications
- Traffic identification and classification
- Switching and routing technologies
- Protocols design and implementation
- Wireless sensor networks
- Future Internet architectures
- Networked operating systems
- Industrial networks deployment
- Software-defined networks
- Self-organizing and self-healing networks
- Mulimedia in Computer Networks
- Communication quality and reliability
- Emerging aspects of networking systems

TECHNICAL SESSION CHAIRS

- **Awad, Ali Ismail,** Luleå University of Technology, Sweden
- **Essai, Mohamed Hassan,** AL-Azhar University, Egypt
- **Furtak, Janusz,** Military University of Technology
- **Hodoň, Michal,** University of Žilina, Slovakia

PROGRAM COMMITTEE

- **Ajlouni, Naim,** Istanbul Aydin University, Turkey
- **Brzoza-Woch, Robert,** AGH University of Science and Technology, Poland
- **Chumachenko, Igor,** Kharkiv National University of Municipal Economy named after Beketov, Ukraine
- **Davidsson, Paul,** Malmö University, Sweden
- **Dotsenko, Sergii,** Ukrainian State University of Railway Transport, Ukraine
- **Długosz, Rafał,** UTP University of Science and Technology, Bydgoszcz, Poland, Poland
- **Elmougy, Samir,** Mansoura University, Egypt
- **Faria, Lincoln,** Department of Computer Science, Fluminense Federal University, Brazil
- **Khairova, Nina,** National Technical University Kharkiv Polytechnic Institute, Ukraine
- **Kochláň, Michal,** University of Žilina, Slovakia
- **Lavrov, Eugeniy,** Sumy State University, Ukraine
- **Salem, Abdel-Badeeh M.,** Ain Shams University, Egypt
- **Smolarz, Andrzej,** Lublin University of Technology, Poland
- **Stamatescu, Grigore,** University "Politehnica" of Bucharest, Romania
- **Tymchuk, Sergiy,** Kharkiv National Technical University of Agriculture. Petro Vasilenko, Ukraine
- **Zieliński, Zbigniew,** Military University of Technology

Position Papers of the Federated Conference on
Computer Science and Information Systems pp. 11–14
DOI: 10.15439/2020F207
ISSN 2300-5963 ACSIS, Vol. 22

Proposed Method for Partial Node Replacement by Software Defined Network

Sawsan Youssef
Brno University of Technology
Faculty of Information Technology
Bozetechova 2, Brno, Czech republic
Email: iyoussef@fit.vutbr.cz

Ondrej Rysavy
Brno University of Technology
Faculty of Information Technology
Bozetechova 2, Brno, Czech republic
Email: rysavy@fit.vutbr.cz

***Abstract*—Since it is impractical to replace the entire traditional network by the SDN network due to some constraints i.e. financial budget, limited skills to SDN, in addition to the need to have the benefits and flexibility of the traditional network, the partial replacement implemented by deploying or replacing some legacy nodes by the SDN switches have emerged. Such replacement requires routing and security addressing coordination issues. In this research, we present our proposed solution for automatic replacement of a segment of the legacy network by SDN nodes, and generation of a set of OpenFlow rules and switches configuration that meets the traditional network behavior requirements. The rules are identified based on the analysis of the network traffic acquired from the legacy segment.**

I. Introduction

THE main concept of the Software-Defined Network is the separation of the control plane from the data plane; such a separation allows the operator to insert new functions in the network, increasing the flexibility and the programmability of the network. In the traditional systems opposed to the SDN, the forwarding devices run control functions such as the forwarding decision and the path discovering algorithms, maintain the network state, etc. The function of individual network devices is reprogrammed, and the devices together run distributed algorithms for routing and security policy enforcement. On the other hand, the SDN concept considers that the network devices have only basic functionality necessary for packet forwarding, and the network functionality is composed of the set of network applications executed mainly by network controllers.

Due to several constraints of the full replacement of the traditional network by the SDN nodes, the incremental deployment of SDN is often considered leading to the hybrid network containing the conventional IP network and SDN network. Such a gradual installation of the SDN nodes, smooth the migration toward the SDN networks, and take benefits from the two kinds of systems. Still, on another side, the partial deployment of SDN switches faces several challenges; one of them is the consistency between the protocols and policies in the whole network. Because of different devices and rules control packet forwarding, the hybrid SDN must be configured to provide consistent routing and security policies for different network segments.

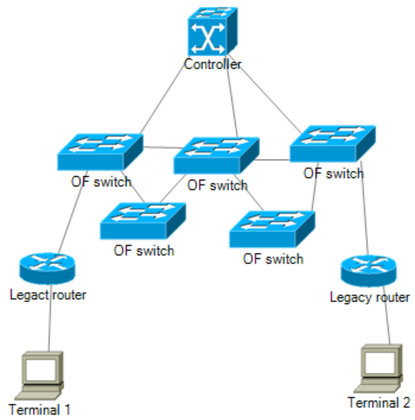


Fig. 1. Hybrid SDN network topology

OpenFlow preinstalled rules play an essential role in mitigating the flooding of the undefined packets and reducing the time needed to make the rule decision about the traffic, in addition to minimize the signaling overhead with the controller. This paper is organized as follows: section II presents the related work followed by proposed framework in section III, then conclusion and future work are presented in section IV.

II. Related Work

The replacement of the IP infrastructure by OpenFlow switches strategy is a different subject on the objective to be achieved, for example; the SDN nodes could be deployed among traditional switches and behave like virtual IP nodes, e.g., Cardigan [1]. Conversely, the grouping of the IP nodes in a VLAN could be achieved to make IP VLAN controlled by the SDN controller, e.g., HybNet [2]. The third type is to create two island solutions, and every island is controlled by its functions, but such a solution requires a translation between the two types of nodes, e.g., B4 [3].

Such a migration toward Hybrid SDN should preserve the original policies of the network like Routing and End-To-End policy. One of the researches targeted the problem of creating SDN rules during migration from IP to HSDN networks is project Exodus [5], where Cisco router configurations are used to produce the corresponding rules for the HSDN network. Another approach for SDN migration is presented in B4 [3], where a logic replacement of the BGP border router by the SDN switches is presented and proxy is added for communication between the two segments .

Such frameworks did not ensure the routing or End-To-End policy of the original IP segment, in addition to the need to properly analyze and parse the configuration of each type of network device possibly from different vendors.

An essential method for ensuring the SDN End-To-End policy is One-Big switch that is presented in [4], such an approach was implemented by using the equivalence classes (set of packets that are manipulated in same manner) of the SDN switched forwarding rules to create non-overlapping rules of One-Big switch, the main limitation is there is no insuring of routing policy inside the SDN segment. The generation of SDN rules by a packet trace example was implemented in NetEgg tool [6]. Still, such an approach is used for creating only forwarding rules in pure SDN networks without a discussion about the filter or rules replacement. All these approaches analyzed the existing SDN forwarding rules by taking a static snapshot of the network rules or data plan.

We found a lack of upgrading strategies toward Hybrid SDN. Previous solutions for migration from IP to SDN, such as Exodus [5] and Telekinesis [7], consider translating the static cisco configuration files into SDN rules involving a lot of complexity because of different vendors and configuration languages, and these approaches do not provide verification of the produced rules concerning the original configuration, and because of the limited capacity of OpenFlow table; it is not practical to translate the configuration without rule minimizing or rules scheduling. In this paper we will address the migration of traditional network to SDN network by analyzing the traffic data acquired from normal training of network.

In the proposed research, the objective is to analyze and assess the transformation toward Hybrid SDN networks (an example in Fig. 1) considering routing and security policy. The main goal is to develop a method for creating a Hybrid SDN configuration based on profiling the network behavior of the traditional network and creating routing and security policy models.

III. PROPOSED FRAMEWORK:

In this section, we present the network model to generate the SDN rules (output) from IP network communication (input); the intermediate traffic analysis model that captures IP network behavior is created first. After that, the model, which is the source of the exploration procedure that makes SDN rules will be presented.

A. Problem Formalization

The entire network is represented as a directed graph: $B\left(N,L\right)$ where $N \subseteq IP$ is a set of the nodes in the network topology represented, and $L \subseteq NXN$ is a set of edges in the network that refer to the connections between nodes.

The specific network segment that will be replaced by SDN nodes is represented as: $G\left(V,E\right)$ where $V \subseteq N$ and $E \subseteq L$. Routers are represented as a non-intersected subset of IP. The router is thus defined by IP addresses assigned to its interfaces.

For all routers R_i and R_j, the following must hold: R_i, R_j $\subseteq IP$ and $R_i \cap R_j$ = $\emptyset$ or R_i = R_j. Let IP represents the set of all Internet addresses, this set thus also contains addresses assigned to router interfaces. (Table I presents the main items of the model.)

TABLE I
FORMAL MODEL SYMBOLS.

Symbol	Description
F	Flows that are traversed in the network
S	Switches in the network
En	The endpoints of the network
C_s	Capacity of the SDN switch
$P_{i,j}$	$s_x, s_y, ..$ path form i to j.
$r_{i,j}$	Single rule.
$m_{i,j}$	Match fields of the rule $r_{i,j}$.
$d_{i,j}$	Decision field of the rule.
$v_{i,j,k}$	Test if the $r_{i,j}$ is placed on the switch s_k .
RI	Router local interfaces
EP	Endpoints of network (Hosts/Networks)
RN	Router immediate neighbors IP addresses
RL	Router links with neighbor interfaces

Forwarding Table FT of the switches in the resulting SDN segment consists of the records describing the observed traffic of the sector before replacement.

For every router R, the observed traffic is represented as: OT_R = $< InIface, SrcIP, DstIP, Proto, OutIface >$ where $InIface, OutIface \in IfaceR$, $Proto \in ProtoType$, $SrcIP$ and $DstIP \in IP$, and $IfaceR$ = if_1, if_2, ...if_n is the set of router interfaces. Each interface has assigned IP address, thus $if_i \in IP$.
The set of the protocols are represented as $ProtoType = Tcp, Icmp, Udp, Igmp.$

B. Proposed solution

The proposed solution is divided into several logical steps:

1) Traffic Collection: In order to collect traffic in the legacy network, all routers were NetFlow enabled (ingress and egress monitoring on all interfaces), we chooses NetFlow because of its feature to present the ingress and egress port of the incoming flow.
2) Feature Extraction: From the collected network traffic, we need to select such features that are substantial for routing and security models. The main features for extracting the paths, topology, filters, and forwarding rules are: source IP, Destination IP, protocol type (in case of taking QoS under consideration), in addition to input interface and output interface. This information will be used to extract the paths and forwarding rules of the flows.
3) Topology Extraction: In this work, the proposed network topology discovery method, depends on the existence of flows of control and routing protocols.

TABLE II
BROADCASTING FLOW EXAMPLE.

SrcIP	DstIP	InIface	OutIface	Proto
192.168.60.1	255.255.255.255	2	0	Udp

Algorithm 1 Broadcast Records Isolation

Input : OT
Output : RN, D_1, RI
For all records from D:
if $DstsIP \in BroadcastIP$ **then**
  Add $SrcIP$ to RN
  Add $InIface$ to RI;
else
  Add $record$ to D_1;
end if
Add RN to V;

For instance, routing protocols such as RIP, EIGRP, and OSPF allow a router to discover other adjacent routers on its local links and networks (see Table II). The vital information used in the detection of neighbor devices is the presence of broadcast or local multicast packets.
To extract routers interfaces IP addresses and directed neighbors; the proposed algorithm is represented:

- Extracting Broadcast/Multicast records as a starting point to determine the immediate neighbor IP addresses (see algorithm 1 and 2) . Connections sourced from the neighbors will be analyzed to derive the Router local interface IP address and Interfaces number and the direct links. If the endpoints do not send periodic packets to prove its presence, then they will not appear in the router discovery topology and step 2 will manipulate with such case.
- The router endpoints will be concluded from records that contain interface numbers that are not discovered by step 1. To extract such connections, we perform the following algorithm (See algorithm 2): The records that contain new values of $InIface$ or $OutIface$ not listed in the existing router local interfaces RI; will be analyzed and new interface number will be added to RI, and the $SrcIP$ or $DstIP$ will identifies the endpoint address.
- The filters to drop specific flows will be explored from the NetFlow traffic records which have the field $OutIface$ is 0, and it is not targeted a local interface of the router.

4) OpenFlow Rules Extraction: In order to replace the IP network area with an equivalent SDN segment, the forwarding rules need to be generated for the SDN switches.
The SDN forwarding table contains OpenFlow rules $r_{i,j}$ represent the rules between the source i and destination j that consist of a match condition $m_{i,j}$ and an action

Algorithm 2 Extract the Neighbor Connections

Input : RN, V, D_1, RI ;
Output: D_2, V, EP, RL, $Router-Interface-Table$, $Router-Link-Table$.
For all $record$ from D_1:
if $OutIface = 0$ and $srcIp \in RN$ **then**
  Add $DstIP$ to V;
  Add <$SrcIP, DstIP$> to RL;
  Add <$DstIP, InIface$> to $Router-Interface-Table$;
  Add <$srcIP$, $InIface$> to $Router-Link-Table$
else
  Add $records$ to D_2 ;
end if
For all the records from D_2:
if $Inface \notin RI$ **then**
  Add $SrcIp$ to EP;
  Add $InIface$ to RI;
  Add <$SrcIP$, $InIface$> to $Router-Link-Table$;
else { IF $record$ where $OutIface \notin RI$}
  Add $DstIp$ to EP;
  Add $OutIface$ to RI;
  Add <$DstIP$, $OutIface$> to $Router-Link-Table$;
end if
Add EP to V;

$D_{i,j}$: forward to output port (if 0 it mean: drop the packet), as depicted on the example in Table III.

TABLE III
OPENFLOW RULE FIELDS.

Router/switch	**Match $m_{i,j}$**	**Action $D_{i,j}$**
R	INPORT=InIface, SourceIP= SrcIP DestinationIP=DstIP	Forward to OutIface

The direct approach for OpenFlow rules generation from NetFlow records is to set the Match expression as: <$SrcIP, DstIP, InIface$>, and the action set to forward to the $OutIface$. Thus, the traffic that matches some existing NetFlow record is forwarded, and the other traffic is dropped. The filters at the edge routers of the SDN block will be determined during the traffic analysis. We assume that the SDN switch has one FlowTable conforming to OpenFlow specification 1.0, the first stage of the rule extraction supposed to be exact match (exact rule for every flow).

5) Rule Optimization: Because of the OpenFlow memory limitation, it is not possible to keep similar number of forwarding rules in each switch as the traditional switch, or even to store all access policy on one edge switch or even One-Big switch, the rules should be optimized and distributed after compression without violation of the policy, and the number of rules in every switch should

be less than the switch capacity:

$$\forall s \in S : \sum_{i,j} v_{i,j,s} \leq c_s \quad (1)$$

Where the $v_{i,j,s}$ is a Boolean test if the $r_{i,j}$ is installed in the switch s, and C_s is the capacity of switch FlowTable.

6) Evaluation: To compare the end-to-end behavior of the original network with the hybrid SDN, the same traffic patterns that are used in the traditional network will be sent again in the hybrid network and will be stored in a matrix, the matrix contains the result of applying function $Reachability(i,j)$ to test the reachability between the source i and destination j, and the difference between the matrix-es before and after replacement will be checked. The network behavior should not be violated in the resulting network. The reachability will be identified as:

$$Reachability(i,j) = \begin{cases} 0 & \text{Flow was dropped} \\ 1 & \text{Flow was delivered} \end{cases} \quad (2)$$

The set of the reachable switches that ingress flow can reach should be the same as before the replacement.

C. Current Status

Several examples in the virtual environment on top of eveng tool were implemented, containing routers and endpoints (Virtual PCs). The traffic was generated by using an Ostinato traffic generator. All routers were NetFlow enabled (ingress and egress monitoring on all interfaces). For collecting the NetFlow traffic, the following components should exist:

- NetFlow collector on dedicated server(s). I used NfDump tools installed on Ubuntu server 16.4 (8 GB RAM, HDD 500 GB).
- NFSEN: NFSEN is a graphical web based front end for the Nfdump NetFlow tools.

So far, the experiments were done for routing protocols RIP and OSPF, and for different kinds of network configurations (with/without ACLs).

In One-Big-Switch [4] the destination packet header is analyzed to extract the equivalence class (to obtain the forwarding graph and the one-big switch forwarding rules). The input port and the protocol type as well are not considered in their solution which could minimize the network provision; our model will use the (input port of the packet) to distinguish the paths and the filters will be detected at the edge switches in addition to create hop-by-hop configurations.

IV. Conclusion and Future work

In this paper, we have discussed the safe migration from traditional IP network to HSDN architecture, it is necessary to ensure that newly introduced SDN blocks will interoperate with the rest of the system. One of the most fundamental interoperability problems is to provide coherent routing and security. Our proposed framework relied on traffic analysis to describe the network behavior (topology and the forwarding rules), such forwarding rules will be used to create the SDN switches rules, this will be the base for checking the violation and illegitimate access to the hybrid SDN. The main future work is to complete demonstration of the model, and propose a method for optimizing the rules (compression and distribution) inside the SDN segment.

Acknowledgment

This work has been supported by project FIT-S-20-6293: Application of AI methods to cyber security and control systems.

References

[1] J. Stringer, D. Pemberton, Q. Fu and C. Lorier , R. Nelson and J. Bailey et al., "Cardigan: SDN distributed routing fabric going live at an Internet exchange", *IEEE Symposium on Computers and Communications (ISCC)*, 2014, pp. 1-7, Available on: https://doi.org/10.1109/ISCC.2014.6912501.

[2] L. Hui and A. Nipun and Z. Hui and L. Cristian and R. Junghwan and J. Guofei, "HybNET: Network Manager for a Hybrid Network Infrastructure", *Proceedings of the Industrial Track of the 13th ACM/IFIP/USENIX International Middleware Conference*, USA, 2013, pp 1-6, Available on: https://doi.org/10.1145/2541596.2541602.

[3] J. Sushant and K. Alok and M. Subhasree and O. Joon and L. Poutievski, "B4: Experience with a Globally-Deployed Software Defined Wan", *Proceedings of the ACM SIGCOMM 2013 Conference on SIGCOMM*, 2013, pp 3-14, Available on: https://doi.org/10.1145/2486001.2486019.

[4] Y. Jiaqi and L. Xin and J. Dong, "Simulation of a Software-Defined Network as One Big Switch", *Proceedings of the 2017 ACM SIGSIM Conference on Principles of Advanced Discrete Simulation*, 2017, pp 149-159, Available on: https://doi.org/10.1145/3064911.3064918.

[5] T. Nelson, A. Ferguson, D. YuU, R.Fonseca , S. Krishnamurthi, "Exodus: toward automatic migration of enterprise network configurations to SDNs", *Proceedings of the 1st ACM SIGCOMM Symposium on Software Defined Networking Research*, 2015, pp. 1-7, Available on: https://doi.org/10.1145/2774993.2774997.

[6] Y. Yuan, D. Lin and S. Anil and H. Verma and A. Chelluri and R. Alur and B. T. Loo,"NetEgg: A Scenario-Based Programming Toolkit for SDN Policies", *IEEE/ACM Transactions on Networking*, vol.26, n.5, 2018, pp 2104-2117, Available on: https://doi.org/10.1109/TNET.2018.2861919.

[7] C. Jin, C. Lumezanu, Q.Xu, Z-L.Zhang, and G.Jiang,"Telekinesis: Controlling legacy switch routing with OpenFlow in hybrid networks", *(Symposium on Software Defined Networking (SDN) Research, SOSR* , 2015, Available on: https://doi.org/doi:10.1145/2774993.2775013.

[8] X. Nguyen, D. Saucez, C. Barakat and T. Turletti, "Rules Placement Problem in OpenFlow Networks: A Survey", *in IEEE Communications Surveys and Tutorials*, Second quarter, vol. 18, no. 2, 2016, pp. 1273-1286, Avaliable on: https://doi.org/10.1109/COMST.2015.2506984.

4th Workshop on Internet of Things—Enablers, Challenges and Applications

THE Internet of Things is a technology which is rapidly emerging the world. IoT applications include: smart city initiatives, wearable devices aimed to real-time health monitoring, smart homes and buildings, smart vehicles, environment monitoring, intelligent border protection, logistics support. The Internet of Things is a paradigm that assumes a pervasive presence in the environment of many smart things, including sensors, actuators, embedded systems and other similar devices. Widespread connectivity, getting cheaper smart devices and a great demand for data, testify to that the IoT will continue to grow by leaps and bounds. The business models of various industries are being redesigned on basis of the IoT paradigm. But the successful deployment of the IoT is conditioned by the progress in solving many problems. These issues are as the following:

The IoT technical session is seeking original, high quality research papers related to such topics. The session will also solicit papers about current implementation efforts, research results, as well as position statements from industry and academia regarding applications of IoT. The focus areas will be, but not limited to, the challenges on networking and information management, security and ensuring privacy, logistics, situation awareness, and medical care.

- The integration of heterogeneous sensors and systems with different technologies taking account environmental constraints, and data confidentiality levels;
- Big challenges on information management for the applications of IoT in different fields (trustworthiness, provenance, privacy);
- Security challenges related to co-existence and interconnection of many IoT networks;
- Challenges related to reliability and dependability, especially when the IoT becomes the mission critical component;
- Zero-configuration or other convenient approaches to simplify the deployment and configuration of IoT and self-healing of IoT networks;
- Knowledge discovery, especially semantic and syntactical discovering of the information from data provided by IoT.

Topics

The IoT session is seeking original, high quality research papers related to following topics:

- Future communication technologies (Future Internet; Wireless Sensor Networks; Web-services, 5G, 4G, LTE, LTE-Advanced; WLAN, WPAN; Small cell Networks…) for IoT,
- Intelligent Internet Communication,
- IoT Standards,
- Networking Technologies for IoT,
- Protocols and Algorithms for IoT,
- Self-Organization and Self-Healing of IoT Networks,
- Object Naming, Security and Privacy in the IoT Environment,
- Security Issues of IoT,
- Integration of Heterogeneous Networks, Sensors and Systems,
- Context Modeling, Reasoning and Context-aware Computing,
- Fault-Tolerant Networking for Content Dissemination,
- IoT Architecture Design, Interoperability and Technologies,
- Data or Power Management for IoT,
- Fog—Cloud Interactions and Enabling Protocols,
- Reliability and Dependability of mission critical IoT,
- Unmanned-Aerial-Vehicles (UAV) Platforms, Swarms and Networking,
- Data Analytics for IoT,
- Artificial Intelligence and IoT,
- Applications of IoT (Healthcare, Military, Logistics, Supply Chains, Agriculture, ...),
- E-commerce and IoT.

The session will also solicit papers about current implementation efforts, research results, as well as position statements from industry and academia regarding applications of IoT. Focus areas will be, but not limited to above mentioned topics.

Technical Session Chairs

- **Cao, Ning,** College of Information Engineering, Qingdao Binhai University
- **Furtak, Janusz,** Military University of Technology, Poland
- **Zieliński, Zbigniew,** Military University of Technology, Poland

Program Committee

- **Al-Anbuky, Adnan,** Auckland University of Technology, New Zealand
- **Antkiewicz, Ryszard,** Military University of Technology, Poland
- **Brida, Peter,** University of Zilina, Slovakia
- **Chudzikiewicz, Jan,** Military University of Technology in Warsaw, Poland

- **Cui, Huanqing,** Shandong University of Science and Technology, China
- **Ding, Jianrui,** Harbin Institute of Technology, China
- **Fouchal, Hacene,** University of Reims Champagne-Ardenne, France
- **Fuchs, Christoph,** Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE, Germany
- **Hodoň, Michal,** University of Žilina, Slovakia
- **Johnsen, Frank T.,** Norwegian Defence Research Establishment (FFI), Norway
- **Karpiš, Ondrej,** University of Žilina, Slovakia
- **Krco, Srdjan,** DunavNET
- **Laqua, Daniel,** Technische Universität Ilmenau, Germany
- **Lenk, Peter,** NATO Communications and Information Agency, Other
- **Li, Guofu,** University of Shanghai for Science and Technology, China
- **Marks, Michał,** NASK - Research and Academic Computer Network, Poland
- **Monov, Vladimir V.,** Bulgarian Academy of Sciences, Bulgaria
- **MURAWSKI, Krzysztof,** Military University of Technology, Poland
- **Niewiadomska-Szynkiewicz, Ewa,** Research and Academic Computer Network (NASK), Institute of Control and Computation Engineering, Warsaw University of Technology
- **Papaj, Jan,** Technical university of Košice, Slovakia
- **Savaglio, Claudio**
- **Ševčík, Peter,** University of Žilina, Slovakia
- **Shaaban, Eman,** Ain-Shams university, Egypt
- **Staub, Thomas,** Data Fusion Research Center (DFRC) AG, Switzerland
- **Suri, Niranjan,** Institute of Human and Machine Cognition
- **Wrona, Konrad,** NATO Communications and Information Agency

Position Papers of the Federated Conference on Computer Science and Information Systems pp. 17–22
DOI: 10.15439/2020F209
ISSN 2300-5963 ACSIS, Vol. 22

Increasing the Reusability of IoT-aware Business Processes

Robert Wehlitz, Florian Jauer, Ingo Rößner
Institute for Applied Informatics (InfAI),
Goerdelerring 9, 04109 Leipzig, Germany
Email: {wehlitz, jauer, roessner}@infai.org

Bogdan Franczyk
Leipzig University, Grimmaische Str. 12,
04109 Leipzig, Germany
Wrocław University of Economics, ul. Komandorska
118-120, 53-345 Wrocław, Poland
Email: franczyk@wifa.uni-leipzig.de

Abstract—**The Internet of Things (IoT) is based on connected devices which are often heterogeneous in terms of supported communication protocols, interfaces and message formats. IoT-aware business processes, which are executed by process engines, are often bound to specific device types. This decreases their reusability when they are ought to be deployed in multiple IoT scenarios where the ability of supporting different device types is an important requirement. In this paper, we introduce a novel approach on how to overcome the heterogeneity of IoT devices, thus increasing the reusability of IoT-aware business processes. The contribution of this work to information systems research is twofold: First, we present a device abstraction model as the basis to define business process tasks across heterogeneous device types without the need of dealing with their technical implementations. Secondly, we propose a system architecture which supports the modeling, deployment, execution and reuse of IoT-aware business processes.**

I. Introduction

THE vision of the Internet of Things (IoT) is based on the ubiquitous utilization of electronic devices which are equipped with sensors or actuators and are connected to the Internet. Market analysts estimate that the number of these IoT devices will increase to around 38.6 billion worldwide by 2025 [1]. All of them are sources of data, which provide businesses and customers with possibilities to gain valuable insights into commercial value creation and the everyday life of people. For instance, in the smart home domain, businesses are enabled to collect and analyze more detailed data about customers and their behavior in order to individualize and improve products and services [2]. Customers, in turn, may benefit from smart home solutions enabling them to analyze and reduce their energy consumption, secure their homes, remote control appliances for more convenience or live a longer self-determined life at home in old age [3].

The integration of heterogeneous IoT devices with services, applications and business processes represents a major challenge in this context. Heterogeneity hereby means that IoT devices often support different communication protocols, interfaces to access device functionality and message formats for providing sensor data and receiving device commands [4]. In our previous work [5], we presented an architectural concept on how to cope with heterogeneity issues related to IoT-aware business processes by leveraging IoT middleware and device management functionality in conjunction with system components for business process automation. However, this approach has its limitations when reusing executable IoT-aware business processes for different IoT device types, which provide similar functionality and should therefore be interchangeable from a user perspective. In this paper, we introduce a device abstraction model which enables to define business process tasks across heterogeneous IoT device types. Furthermore, we adapt the architecture presented in [5] to support the modeling, deployment, execution and reuse of IoT-aware business processes.

The remainder of this paper is structured as follows: First, we outline the background for our research, introduce an application scenario in order to illustrate why the reusability of IoT-aware business processes can be important, and provide an overview of related work (Sect. 2). In Sect. 3, we present our device abstraction model and describe its classes as well as their relationships with each other. We then introduce our system architecture proposal and point out how an increase of the reusability of executable IoT-aware business processes is achieved (Sect. 4). Finally, in Sect. 5, the paper concludes with a short summary of the findings and an outlook on future work.

II. Background

Within the scope of this paper, we define IoT-aware business processes as sequences of tasks, events and decisions which integrate IoT devices as process resources in order to achieve a certain process goal. In this regard, we focus on processes that are described using a machine-readable format, e.g. Business Process Model and Notation (BPMN) 2.0, and can be executed by process engines for automation purposes. Against this background, business process tasks are assignable to IoT devices and can be completed by them using their sensing or actuation capabilities. IoT-aware business processes may also be consumers of events, which are detected based on processing sensor data streams and may

This work is partly funded by the European Regional Development Fund (ERDF) and the Free State of Saxony (Sächsische Aufbaubank – SAB).

have an impact on their control flow. Additionally, decisions, e.g. threshold value analysis, within a running process instance can be made automatically by evaluating sensor values against predefined rule sets.

To illustrate the reusability problem regarding executable IoT-aware business processes and to show how our approach works, we use the example of smart home as a user-centric IoT domain. In this example, smart home services, such as automatic light or heating control, are defined using a process modeling language and are executed by a process engine. IoT-aware business process models, thus, define and represent the internal logic of smart home services.

Let us assume a smart home scenario in which two rooms are equipped with smart lamps. To simplify matters, *room A* has several *smart lamps* of type *A* from *manufacturer A* and *room B* has several *smart lamps* of type *B* from *manufacturer B*. All smart lamps provide the same functionalities, which are: Turning the light on or off, change the light color and dim the light. These functionalities can be remote controlled via a Wi-Fi connection. However, *smart lamps* of type *A* require an additional gateway device which receives commands over the Message Queuing Telemetry Transport (MQTT) communication protocol whereas each *smart lamp* of type *B* provides a REST-API in order to be controllable via HTTP requests. Additionally, the accepted message format of each interface differs strongly between *smart lamps* of type *A* and *B*. For instance, the gateway for *smart lamps* of type *A* expects the value "1" to be published to a specific internal MQTT topic structure for turning on a lamp. The *smart lamps* of type *B*, for obtaining the same effect, expect a JavaScript Object Notation (JSON) payload including the property "light" with the value "on" to be posted to a specific REST endpoint.

In order to hide this complexity from developers of smart home services, we use the method of abstraction. Therefore, we distinguish between three different device abstraction levels.

At level zero, the device instance level, a specific device of a certain user is described and no further abstraction is made, e.g. *smart lamp* of type *A* with ID A132 of *user U*.

At level one, the device type level, device instances of the same type are abstracted to a device type, e.g. *smart lamp* of type *A* from *manufacturer A*.

At level two, the device class level, heterogeneous device types, as described in our example above, are mapped by a device class, e.g. *smart lamps* of type *A* from *manufacturer A* and *smart lamps* of type *B* from *manufacturer B* are elements of the device class *smart lamp*.

When an IoT-aware business process in our smart home scenario is to include smart lamps, for instance, to control the room light automatically, a decision has to be made at which abstraction level the devices should be integrated. This has a strong impact on the reusability of the whole process. Modeling business process tasks for IoT devices at the device instance level requires the same process to be modeled twice: For *room A* and *B*. In addition, the process model has to be adapted and redeployed every time this setting changes even slightly. This is the case if, for instance, a smart lamp is broken at some time and has to be replaced by a new one. To increase the reusability of the defined process, smart lamps should be integrated at least at the device type level. Nonetheless, the process needs to be modeled for each room due to the different types of smart lamps, but a replacement of single device instances would not affect the model scope. However, the highest degree of reusability is achieved by modeling process tasks for IoT devices at the device class level. In this case, the process needs to be modeled only once to be deployable for both, *room A* and *B*. Moreover, an additional integration of *smart lamps* of type *C* from *manufacturer C* at a later time would be covered by the model scope as well, if those lamps also support the defined functionalities of the device class *smart lamp*.

Research in the field of IoT-aware business processes is still at its beginning. A state-of-the-art report carried out by [6] shows that numerous publications which focus on the modeling of IoT services (e.g. [7]) and IoT-aware business processes exist (e.g. [8]). However, technical aspects regarding the utilization of heterogeneous IoT devices within executable business processes have not yet been sufficiently investigated. Although some approaches cover implementation and execution aspects, they are mostly limited to the integration of wireless sensor networks [4], which do not provide actuation capabilities, or are based on translations from BPMN to program code (e.g. [9]). Therefore, the concrete implementation of abstract process models in order to deploy and execute them in IoT scenarios remains a major challenge, which is still open [10]. In our previous work [5], we already tackled this challenge by designing a system architecture, which combines an IoT middleware, device management and components for business process automation. However, this approach, like many other related works, has the limitation that IoT devices can only be integrated as business process resources at the device type level, which has a negative impact on the reusability of IoT-aware business processes (c.f. the example above). For this reason, we have improved our concept and extended it by a device abstraction model, which covers syntactical and semantic aspects of IoT devices. With regard to the latter, we are aware that many semantic middleware solutions and ontologies, e.g. SensorML and Semantic Sensor Network (SSN), for IoT systems exist. But in order to enable IoT device integration in business processes at the device class level, we had to design our own model which is partly based on classes and properties of the oneM2M Base Ontology (www.onem2m.org). This ontology, compared to others, proved to be the most suitable starting point for mapping concrete service implementations with generic device functions.

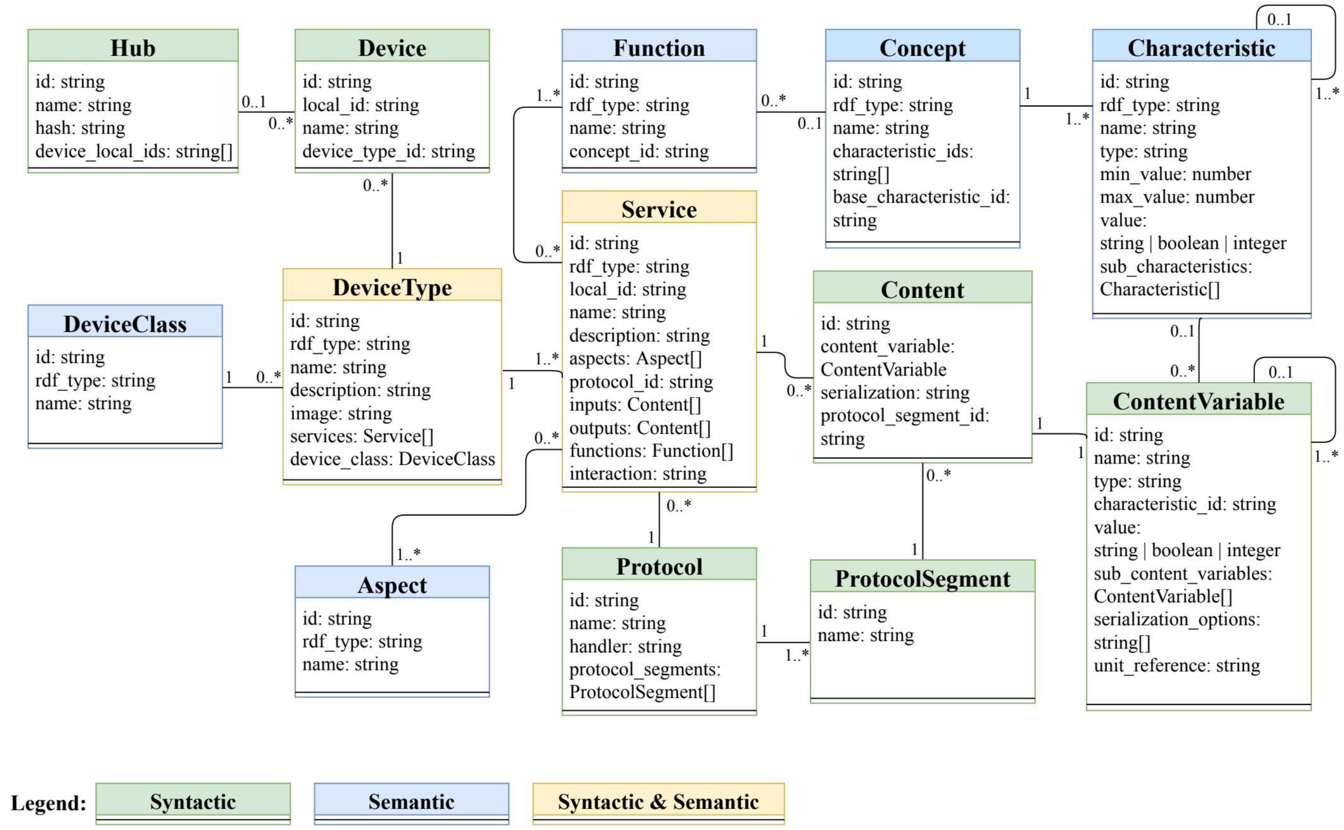


Fig. 1 Class diagram of the device abstraction model

III. Device Abstraction Model

After we outlined the background for our research and gave an overview of related work in the previous section, we present our device abstraction model in Fig. 1.

Our device abstraction model consists of 13 classes which are used to map properties of IoT devices to an internal data structure. In this context, we distinguish between syntactical and semantic aspects of the model. Syntactical aspects address technical details on, for instance, required message formats and are highlighted green in the diagram. Semantic aspects, highlighted in blue, address context information about, for instance, what is measured by a sensor, respectively, what is moved or controlled by an actuator. Classes which are highlighted in yellow cover both, syntactical and semantic aspects.

Diving into the model, a *DeviceClass* (e.g. *smart lamp*) represents a set of *DeviceTypes* (e.g. *smart lamps* of type *A* from *manufacturer A* and *smart lamps* of type *B* from *manufacturer B*) which provide similar functionalities (e.g. change the light color). A *DeviceType*, in turn, represents a set of similar physical *Devices* (e.g. *smart lamps* of type *A* from *manufacturer A* with *local_ids* from A1 to A9999) which may be connected to a *Hub*, also known as gateway, for data transmission. A *DeviceType* has one or more individually implemented *Services* (e.g. *setColorService*) which expose one or more generic *Functions* (e.g. *setColorFunction*) and support event- or/and request-based *interactions*. A *Service* has to be linked to an *Aspect* that is a real-world phenomenon (e.g. room lighting) it relates to. A *Service* also may have several inputs (e.g. color value) and outputs (e.g. response code). Both require a *Content* (i.e. a payload) which is serialized (e.g. using XML or JSON) for data exchange, placed within a *ProtocolSegment* (e.g. header or body) and transmitted over a *Protocol* (e.g. HTTP or MQTT). A *Content* consists of one *ContentVariable* which describes the internal structure of a *Content* (e.g. { “name”: “color”, “type”: “string” }) and can be nested in order to map more complex structures. In the case of an XML serialization, the *serialization_options* field of a *ContentVariable* can be used to define whether it is an XML attribute or the content of an XML tag. *ContentVariables* can be linked to a *Characteristic* which can be nested as well. *Characteristics* (e.g. color definitions, such as RGB, HSB or Hex) define different ways of how a *Concept* (e.g. color), which is a property of an *Aspect* (e.g. room lighting), can be represented. Therefore, it is also possible to declare a base characteristic for each *Concept*. Finally, a *Concept* can be linked to *Functions* in order to indicate which property of an *Aspect* is measured or changed by a *Function* (e.g. *setColorFunction* changes the *Concept* color of *Aspect* room lighting).

The presented device abstraction model enables its users to map the most important syntactical properties of IoT devices and to enrich them with useful context information. Furthermore, the main advantage of the model is that concrete service implementations are abstracted and, thus, decoupled from generic IoT device functionalities, which, in turn, allows defining and using abstract device classes. Hence, heterogeneous IoT devices, which support different communication protocols, interfaces and message formats, can be used in different deployments of the same IoT-aware business process.

IV. System Architecture

In the previous section, we presented our device abstraction model and described its classes as well as their relationships with each other using the example of smart lamps. In the following, we introduce our architectural concept for an IoT-aware Business Process Management (BPM) system (see Fig. 2), which instantiates the device abstraction model to support the modeling, deployment, execution and reuse of IoT-aware business processes. The architecture comprises 13 different components (shown in white) whereby twelve are supposed to run in a cloud environment and one is deployed on IoT devices (shown in grey) in local networks.

The process designer component enables the graphical modeling of executable IoT-aware business processes with a suitable notation and metamodel, such as BPMN 2.0. It generates machine-readable definition files of process models according to drawn process diagrams. To define a business process task for IoT devices, the user selects the task element and assigns a generic *Function* (c.f. Sect. 3) to it. The process designer retrieves *Functions* and other semantic metadata about IoT devices, i.e. *DeviceClass*, *Aspect* and *Concept,* from the semantic repository and enriches the machine-readable definition files with them. This allows composing and reusing business process models at design time independently of the implementation details of device types

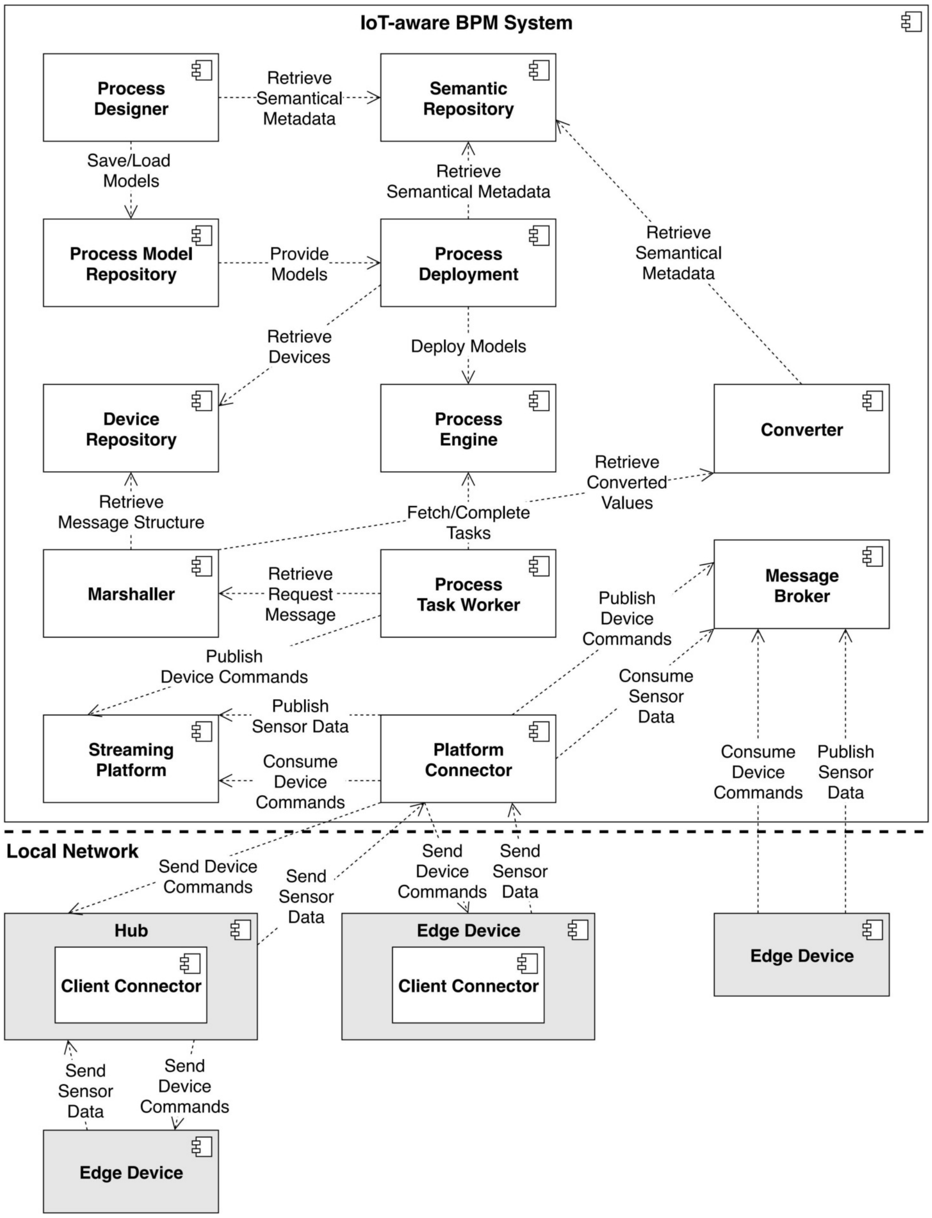


Fig. 2 Component diagram of the IoT-aware BPM system

and instances. Furthermore, it enables to deploy the same business process model multiple times for device instances of different device types.

Created model definitions are stored in the process model repository and provided to the process deployment component for implementation purposes. The process deployment component parses definition files and identifies for each business process task which concrete user devices, that are registered in the device repository, are able to complete the task. In order to achieve this, the semantic repository is queried to match metadata about *DeviceClasses*, *Functions*, *Aspects* and *Concepts* with metadata about *DeviceTypes* and *Services*. The cross-type result set, which contains device instances that are able to execute the task, is presented to the user who then can make the task assignment and define input values for *Services* (e.g. the color for *setColorService*), if required. Thereafter, the business process model is enriched with metadata about device types and instances (i.e. IDs of *Device*, *DeviceType* and *Service*) and deployed to the process engine, which ensures that process instances are executed according to the underlying model.

The business process task execution is done by the process task worker component. It fetches pending execution jobs from the process engine and informs it as soon as a job has been completed allowing the engine to proceed with the next process step. The process task worker also requests device type-specific message formats (i.e. *Content* with *ContentVariables*) from the marshaller component and publishes them together with device instance-related data (i.e. ID of the *Device*) as device commands to the streaming platform. The marshaller component can pass input values required by a *Service* to the converter component, which responds with values that were converted from one *Characteristic* to another (e.g. conversion of RGB values into HSB). This is necessary if the format or unit of input values given by an application is different from those expected by the target device. The streaming platform provides an interface by which the platform connector, that is responsible for handling the communication between the IoT-aware BPM system and edge devices, consumes pending device commands and forward them to client connectors. Client connectors run on edge devices themselves or on hub devices. They are responsible for the registration and discovery of IoT devices and may also pass sensing data from local networks on to the IoT-aware BPM system. Furthermore, they forward device commands to edge devices. The platform connector publishes incoming sensor data to the streaming platform where they can be consumed by other platform services or applications. In the case of IoT devices which use publish/subscribe-based communication protocols, such as MQTT, a suitable message broker can serve as an intermediary component to forward device commands and sensor data between the platform connector and edge devices.

V. Conclusion and Outlook

In this paper, we highlighted the challenge of coping with heterogeneous IoT devices in a business process context. For this, we used the example of smart home as a user-centric IoT domain in which executable IoT-aware business processes define and represent the internal logic of smart home services. We introduced three different levels of device abstraction (device instance, device type and device class) for overcoming heterogeneity issues and discussed how each of them affect the reusability of IoT-aware business processes. We then presented a device abstraction model for mapping the properties of IoT devices to a data structure which covers both, semantic and syntactical aspects. Moreover, it enables the decoupling of generic device functionalities from concrete service implementations which, in turn, increases the reusability of executable IoT-aware business processes. Afterwards, we introduced an architecture for an IoT-aware BPM system, which instantiates the device abstraction model in order to support the modeling, deployment, execution and reuse of IoT-aware business processes.

In the future, we want to evaluate our approach by piloting a software prototype of the IoT-aware BPM system in conjunction with a larger amount of real-world IoT devices. In this context, other application domains than smart home, such as smart manufacturing and Industry 4.0, might be of interest. Against this background, we expect to gain more insights into the applicability, scalability and flexibility of the device abstraction model and the system architecture. Furthermore, we want to extend the architecture in order to achieve interchangeability of IoT devices, not only at the process deployment stage but even at process runtime. This would be beneficial if, for instance, an IoT device has a malfunction and has to be replaced instantly by another suitable one during a running process instance.

References

[1] Strategy Analytics, "Number of internet of things (IoT) connected devices worldwide in 2018, 2025 and 2030 (in billions)", Statista Inc., https://www.statista.com/statistics/802690/worldwide-connected-devices-by-access-technology, last accessed 2020/07/17.

[2] S. Khoshafian, D. Schuerman, "Process of Everything", in *iBPMS – Intelligent BPM Systems – Impact and Opportunity*, L. Fischer, Ed. Future Strategies Inc., Lighthouse Point, 2013, pp. 67–82.

[3] Zion Market Research, https://www.zionmarketresearch.com/news/smart-home-market, last accessed 2020/07/17.

[4] C. Chang, S. N. Srirama, R. Buyya, "Mobile Cloud Business Process Management System for the Internet of Things", *ACM Computing Surveys*, vol. 49, no. 4, pp. 1–42, 2016. doi:10.1145/3012000

[5] R. Wehlitz, I. Rößner, B. Franczyk, "Integrating Smart Devices as Business Process Resources – Concept and Software Prototype", in *Service-Oriented Computing – ICSOC 2017 Workshops*, L. Braubach, J. M. Murillo, N. Kaviani, M. Lama, L. Burgueno, N. Moha, M. Oriol, Eds. Heidelberg: Springer-Verlag, LNCS, vol. 10797, pp. 252–257, 2018. doi:10.1007/978-3-319-91764-1_20

[6] N. Brouns, S. Tata, H. Ludwig, E. S. Asensio, P. Grefen, "Modeling IoT-aware Business Processes – A State of the Art Report", IBM Research Division, San Jose, 2018.

[7] G. Fortino, W. Russo, C. Savaglio, M. Viroli, M. Zhou, "Modeling Opportunistic IoT Services in Open IoT Ecosystems", in *WOA*, pp. 90–95, 2017.

[8] S. Meyer, A. Ruppen, L. Hilty, “The Things of the Internet of Things in BPMN”, in Advanced Information Systems Engineering Workshops, A. Persson, J. Stirna, Eds. Springer International Publishing, pp. 285–297, 2015. doi:10.1007/978-3-319-19243-7_27

[9] F. Martins, D. Domingos, “Modelling IoT behaviour within BPMN Business Processes”, in Procedia Computer Science, Elsevier B.V., pp. 1014–1022, 2017. doi:10.1016/j.procs.2017.11.131

[10] C. Janiesch, A. Koschmider, M. Mecella, B. Weber, A. Burattin, C. Di Ciccio, A. Gal, U. Kannengiesser, F. Mannhardt, J. Mendling, A. Oberweis, M. Reichert, S. Rinderle-Ma, W.-Z. Song, J. Su, V. Torres, M. Weidlich, M. Weske, L. Zhang, “The Internet-of-Things Meets Business Process Management: Mutual Benefits and Challenges”, arXiv eprint, 2017. arXiv:1709.03628

15th Conference on Information Systems Management

THIS event constitutes a forum for the exchange of ideas for practitioners and theorists working in the broad area of information systems management in organizations. The conference invites papers coming from three complimentary directions: management of information systems in an organization, uses of information systems to empower managers, and information ssytems for sutainable development. The conference is interested in all aspects of planning, organizing, resourcing, coordinating, controlling and leading the management function to ensure a smooth operation of information systems in organizations. Moreover, the papers that discuss the uses of information systems and information technology to automate or otherwise facilitate the management function are specifically welcome. Papers about the influence of information systems on sustainability are also expected.

Topics

- Management of Information Systems in an Organization:
  - Modern IT project management methods
  - User-oriented project management methods
  - Business Process Management in project management
  - Managing global systems
  - Influence of Enterprise Architecture on management
  - Effectiveness of information systems
  - Efficiency of information systems
  - Security of information systems
  - Privacy consideration of information systems
  - Mobile digital platforms for information systems management
  - Cloud computing for information systems management
- Uses of Information Systems to Empower Managers
  - Achieving alignment of business and information technology
  - Assessing business value of information systems
  - Risk factors in information systems projects
  - IT governance
  - Sourcing, selecting and delivering information systems
  - Planning and organizing information systems
  - Staffing information systems
  - Coordinating information systems
  - Controlling and monitoring information systems
  - Formation of business policies for information systems
  - Portfolio management,
  - CIO and information systems management roles
- Information Systems for Sustainability
  - Sustainable business models, financial sustainability, sustainable marketing
  - Qualitative and quantitative approaches to digital sustainability
  - Decision support methods for sustainable management

Technical Session Chairs

- **Arogyaswami, Bernard,** Le Moyne University, USA
- **Chmielarz, Witold,** University of Warsaw, Poland
- **Jankowski, Jarosław,** West Pomeranian University of Technology in Szczecin, Poland
- **Karagiannis, Dimitris,** University of Vienna, Austria
- **Kisielnicki, Jerzy,** University of Warsaw, Poland
- **Ziemba, Ewa,** University of Economics in Katowice, Poland

Program Committee

- **Alonazi, Mohammed,** University of Sussex Informatics Department Brighton, UK, United Kingdom
- **Bicevskis, Janis,** University of Latvia, Latvia
- **Bontchev, Boyan,** Sofia University St Kliment Ohridski, Bulgaria
- **Borkowski, Bolesław,** University of Warsaw, Poland
- **Cano, Alberto,** Virginia Commonwealth University, United States
- **Carchiolo, Vincenza,** University of Catania, DIEEI, Italy
- **Czarnacka-Chrobot, Beata,** Warsaw School of Economics, Poland
- **Damasevicius, Robertas,** Kaunas University of Technology, Lithuania
- **Deshwal, Pankaj,** Netaji Subash University of Technology, India
- **Duan, Yanqing,** University of Bedfordshire, United Kingdom
- **Eisenbardt, Monika,** University of Economics in Katowice, Poland, Poland
- **El Emary, Ibrahim,** King Abdulaziz Univetrsity, Saudi Arabia
- **Espinosa, Susana de Juana,** University of Alicante, Spain
- **Fantinato, Marcelo,** University of Sao Paulo, Brazil

- **Gabryelczyk, Renata,** University of Warsaw, Poland
- **Geri, Nitza,** The Open University of Israel, Israel
- **Kania, Krzysztof,** University of Economics in Katowice, Poland
- **Kobyliński, Andrzej,** Warsaw School of Economics, Poland
- **Leyh, Christian,** University of Technology, Dresden, Germany
- **Malgeri, Michele,** University of Catania, DIEEI, Italy
- **Merkt, Oana,** Hohenheim University, Chair of Business Informatics II (530D), Germany
- **Muszyńska, Karolina,** University of Szczecin, Poland
- **Nuninger, Walter,** Polytech'Lille, Université de Lille, France
- **Rizun, Nina,** Faculty of Management and Economics, Gdansk University of Technology, Poland
- **Rozevskis, Uldis,** University of Latvia, Latvia
- **Sobczak, Andrzej,** Warsaw School of Economics, Poland
- **Swacha, Jakub,** University of Szczecin, Poland
- **Symeonidis, Symeon,** Democritus University of Thrace, Greece
- **Szczerbicki, Edward,** University of Newcastle, Australia
- **Szumski, Oskar,** University of Warsaw, Poland
- **Travica, Bob,** University of Manitoba, Canada
- **Wątróbski, Jarosław,** University of Szczecin, Poland
- **Wielki, Janusz,** Opole University of Technology, Poland
- **Zaitsev, Dmitry,** Odessa State Environmental University, Ukraine

Position Papers of the Federated Conference on Computer Science and Information Systems pp. 25–34
DOI: 10.15439/2020F200
ISSN 2300-5963 ACSIS, Vol. 22

A Novel Model of Adoption of M-Commerce in Saudi Arabia

Yahya AlQahtani
dept. of Computer science
King Khalid University
dept. of Informatics
University of Sussex
Brighton, United Kingdom
ya227@sussex.ac.uk

Natalia Beloff
dept. of Informatics
University of Sussex
Brighton, United Kingdom
N.Beloff@sussex.ac.uk

Martin White
dept. of Informatics
University of Sussex
Brighton, United Kingdom
martinwh@sussex.ac.uk

***Abstract*—The market of Saudi Arabia offers considerable potential for the success of mobile commerce (m-commerce) technology. In this context, this study aims to investigate the factors that influence the intentions of Saudi citizens and firms to use m-commerce technology. This study paper advances the literature by proposing a novel model to investigate the motivations behind adopting m-commerce in Saudi Arabia. The model defines factors that influence both customer and provider intentions of adopting m-commerce. The paper also outlines the methodology to be followed to evaluate the proposed model.**

***Index Terms*—acceptance model, adoption of m-commerce, Saudi Arabia**

I. Introduction

MOBILE commerce (m-commerce) is the use of mobile and Internet technologies to conduct transactions for the sake of accessing information, interacting with a service, or purchasing a product [1]. It is a considerable extension to electronic commerce, which appeared in the 1990s and reshaped the business models of many industries. M-commerce provides the benefits of ubiquitous trade anytime and anywhere, thanks to advancements in wireless technologies and the growth of the number of mobile devices.

M-commerce technology has been widely adopted by large-, medium-, and small-scale enterprises. This technology helps enterprises improve their performance and their customer experiences. It allows personalising services based on customer interactions with the Internet in general and m-commerce in particular. Once customers download a m-commerce application on their devices, they become easily reachable by enterprises to send adverts to motivate them to purchase their products and services. The results of this have been demonstrated in increased growth rates and higher profits [2].

Many scholars hold the view that the above advantages of m-commerce motivated the adoption of this technology in developing countries. Those countries provide considerable market for ICT-based services [3, 4]. One case is the country of Saudi Arabia, which is the focus of this paper, where m-commerce is increasingly gaining attention [5]. The country has significant potential for m-commerce providers. First, it has a considerable number of smartphone users. In 2019, 80.7% of the population used a smartphone. This percent is expected to reach 97.1% in 2025 [6]. Second, there is clear governmental interest in advancing the adoption of novel technologies and services in the Saudi market as part of the government 2030 vision, which aims to significantly transform the Saudi economy [7]. This interest is expected to attribute to significant investments that aim to improve mobile technologies. The Saudi private sector is reacting with the government 2030 vision by increasingly investing in the IT sector. This includes utilising new technologies that is not yet popular in Saudi Arabia and promoting existing technologies [8].

On the question of accepting a new technology, several models have been proposed to understand the factors that motivate users to adopt new technology. These include TAM [9], UTAUT [10], and TRA [11], among others. Rondan-Cataluña et al. [12] compare the different versions of popular technology acceptance models. However, briefly we describe the most common models and justify our choice. UTAUT provides a unified framework for understanding both the users' intentions to adopt an innovation and the posterior behaviour. TRA asserts that a person's behaviour is greatly influenced not merely by bias itself but also by personal opinions and expectations. TAM is based on the belief–attitude–intention–behaviour relationship for predicting user intention adopt a new system. We choose to use the TAM (Technology Acceptance Model) because it is a widely used model and it has been validated in many contexts. It identifies two main constructs that fit our work well: perceived usefulness and perceived ease of use, while we add a new third construct, perceived Trust. Perceived usefulness (PU) measures "the degree to which a person believes that using a particular system would enhance his or her job performance," while perceived ease of use (PEoU) as measures "the degree to which a person believes that using a particular system would be free of effort" [9]. We describe Perceived Trust in detail below. The main advantage of TAM is that it helps to understand the users' motivation towards using information system and emerging technologies [13].

In this paper, we aim to understand the factors that motivate the adoption of m-commerce in Saudi Arabia from both a provider and customer perspective. Our focus on the case of

Saudi Arabia is due to the current evidence that shows that "e-commerce is growing in slow adoption pattern" [14]. We propose a novel m-commerce adoption model that extends TAM to suit the case of Saudi Arabia by defining a new construct, Perceived Trust (PT), that, besides PU and PEoU, serve the basis for attitudes towards adopting m-commerce. The model also defines a set of factors that form the independent variables that influence the constructs of PU, PEoU, and PT. The paper also outlines the methodology that is to be followed in order to evaluate the proposed model.

The remainder of this paper is organised as follows. The next section analyses related research work. Section III presents and details the research model adopted in this paper. Section IV outlines the methodology to be followed in our future work to evaluate the proposed model and concludes the paper.

II. Related Work

In alignment with the scope of this paper, this section discusses works that addressed the potential for adopting m-commerce in Saudi Arabia. For this purpose, a number of studies have been identified including [15, 16, 17, 18, 19, 20]. For example, Makki and Chang [16] studied the potential influence of mobile applications usage on e-commerce in Saudi Arabia. Alkhunaizan and Love [17] conducted a study to examine the adoption factors. They focused on Perceived Ease of Use, Perceived Usefulness, Trust, Perceived financial cost, and Individual differences. AlSuwaidan and Mirza [20] studied the Saudi customer preferences behind the interface of the m-commerce mobile application. The study identified basic elements that the user interface should provide in order to encourage Saudi customers to adopt m-commerce. These elements include the ability to save payment information, viewing product images, and browsing ability, among others. Alfahl et al. [15] conducts an exploratory qualitative study which identified factors affecting the adoption of m-commerce in Saudi banks.

These works provide valuable insights on the tendency to accept m-commerce in Saudi Arabia. Their findings confirm the potential of success due to the observed tendency of Saudi customers to use mobile applications and electronic commerce in general. However, these works suffer from two main limitations. First, they lack the investigation of the effect of independent variables that affect intermediate variables and consequently the ultimate objective of adopting m-commerce. For example, PEoU is an intermediate variable that can be affected by a set of dependent variables, including knowledge and culture. The effect of those dependent variables need to be considered to evaluate the effect of PEoU. Second, they focus on one party of the m-commerce actors, the customers, or a specific type of business (*e.g.* banks [18]). Other actors including business firms and governmental influence should also be of interest due to their effects on the adoption of m-commerce. In this paper, we outline a research model that addresses these limitations.

III. The M-commerce Acceptance Framework

This section presents and describes the research model that extends TAM for the case of m-commerce of Saudi Arabia, because the current evidence for effective adoption of e-commerce technologies in general is lacking [14]. The model defines factors (many unique to Saudi Arabia such as culture, social influence and government regulations) that influence the adoption of m-commerce in Saudi Arabia. These factors represent the independent variables of the proposed adoption model. For each factor, a hypothesis is proposed to specify the expected relation to the dependent variable, i.e. 'intention to adopt m-commerce in Saudi Arabia'. Figure 1 summarises the model illustrating its different layers and the factors that are detailed in the following subsections. The figure shows that the dependent variable to evaluate is the 'intention to adopt m-commerce in Saudi Arabia'. This variable represents the goal of the research. This variable is determined by the intermediate variables, which represent the basic constructs of the research model. The basic constructs are in turn influenced by the set of adoption factors that represent the independent variables of the model.

A. Basic Constructs (Intermediate variables)

The basic constructs are factors that influence the behaviour of users with respect to their attitude to adopt a new technology. Three constructs are of interest in this model, namely the Perceived Ease of Use (PEoU), the Perceived Usefulness (PU), and the Perceived Trust (PT), which determine how helpful, convenient, and trusted is the m-commerce technology to use.

1) Perceived Ease of Use: Perceived Ease of Use (PEoU) is defined as "the degree to which a person believes that using a particular system would be free of effort" [9]. Many attributes can contribute to the PEoU in ICT in general and in m-commerce in particulate such as Ease of understanding the system, Ease of finding information, and Ease of performing the required operations (e.g. placing orders, making payments, advertising goods/services etc.) [21]. The easier the user can understand how functionalities provided by the m-commerce system and find any information relevant to those functionalities, including products and services specifications and help and support, the more the user is willing to accept and adopt the system. This hypothesis has been proven in several studies in ICT [22, 23, 24]. Therefore, based on the above, hypothesis (H1) is defined as:

H1: If the ***Perceived Ease of Use*** *of m-commerce technology is increased then this will lead to an increase in citizens* ***intention to adopt m-commerce*** *because citizens will have a better understanding of m-commerce.*

2) Perceived Usefulness (PU): Perceived usefulness is defined as "the degree to which a person believes that use of the system will enhance his or her performance" [25]. This factor is a main construct in the basic TAM model and its extensions. It has been adopted and tested in many ICT studies [26, 27, 28]. It has been found that the extent to which the user finds the system useful plays a significant role in the continuation intention of using that system [29]. The widely

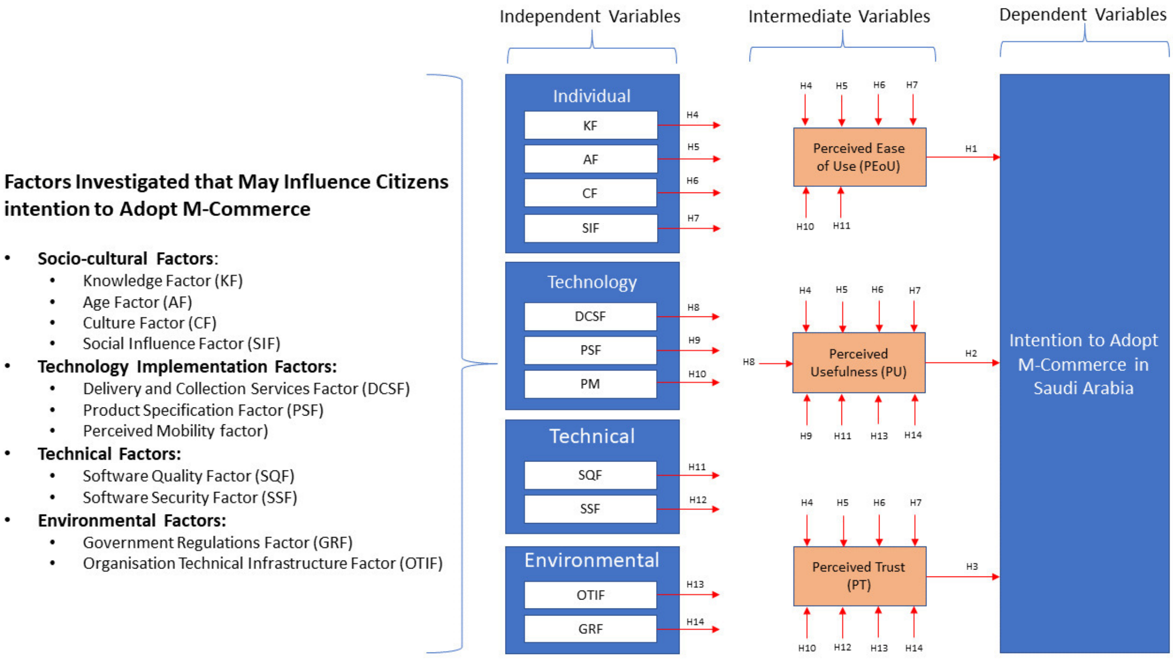


Fig. 1. The m-commerce Acceptance Framework

observed outcome is that PU positively influence the intention of adopting the ICT system. Therefore, based on the above, hypothesis (H2) is defined as:

*H2: If the **Perceived Usefulness** of m-commerce technology is increased then this will lead to an increase in citizens **intention to adopt m-commerce** because citizens will better realise the advantage of m-commerce.*

3) Perceived Trust (PT): One characteristic of m-commerce, and e-commerce in general, is that users will trade goods and services without physical interaction. This includes performing online payments through the electronic medium. Although users use this electronic medium to access internet, purchasing and paying over it is a different issue. It requires users' beliefs about the safety of this medium [30]. Consequently, users' trust of m-commerce is a key factor that influences the adoption of this technology. In the literature, there is no consensus on the definition of PT. Some definitions include Mcknight and Chervany's attempt which defined trust as "the extent to which one believes that the new technology usage will be reliable and credible" [31]. Another definition is "the extent to which an individual believes that using m-commerce is secure and has no privacy threats" [32]. These definitions imply that users' acceptance of m-commerce is not only related to PU and PEoU as a mobile technology, but also related to the customer belief that m-commerce providers are safe to deal with is more important. Therefore, based on the above, hypothesis (H3) is placed.

*H3: If we increase the **Perceived Trust** of m-commerce technology then this will lead to an increase in citizens **intention to adopt m-commerce** because citizens will have reduced uncertainty and fear of using m-commerce.*

B. Adoption factors (Independent variables)

This paper studies the influence of factors on the adoption of m-commence. The conducted research will evaluate this influence on the intermediate variables of the model, which leads to understand the influence on the dependent variable 'intention to adopt m-commerce' in Saudi Arabia. The studied factors are categorised into *Socio-cultural factors*, *Technology implementation factors*, Technical factors, and *Environmental factors* and are described in the following.

1) Socio-cultural factors: Socio-cultural factors relate to residents who are potentially willing to use the new system or who are the target of innovators. Residents can be in different usage of the m-commerce system. Residents can be consumers, traders, innovation staff, and innovation managers, among others.

(a) Knowledge. The knowledge an individual possesses about new technologies in general affect their choice of using those technologies. Furthermore, the level of knowledge a firm's staff have affect the firm's ability to adopt m-commerce. Therefore, the knowledge factor can be viewed from multiple dimensions, including, IT skills, education, and awareness.

- IT skills. The lack of IT skills present in various stakeholders can be a main barrier to adopting m-commerce [33]. Consumers who do not have appropriate knowledge of using mobile applications will prefer in-store shopping to buying goods over using m-commerce applications. Similarly, traders will avoid taking a risk of selling their goods through a mobile application if they do not have enough knowledge of how mobile applications work in an e-commerce solution. In addition, less experienced m-commerce innovation teams (developers and managers) may produce low-quality systems that may influence users to abandon m-commerce. We argue that improving the IT skills of various m-commerce stakeholders motivates them to accept and adopt m-commerce. This can be achieved through training stakeholders through seminars, workshops, and guidance in order to eliminate hesitation and increase confidence of adopting m-commerce [34].

- Education. Both the level and type of education may affect the intention to accept new technologies. Stakeholders who possess knowledge about e-commerce in general tend to accept a new m-commerce technology in Saudi Arabia. Similar attitudes could be expected from stakeholders who are knowledgeable of similar IT systems such as online banking or digital health systems as they are aware of the benefits of such systems.
- Technology awareness. Managers of SMEs in Saudi Arabia are expected to play a pivotal role in promoting m-commerce in the country. Therefore, the more the managers are aware of the advancement of m-commerce and similar technologies worldwide, the more they are eager to motivate the development of m-commerce applications for the Saudi market [35]. Furthermore, awareness of the availability of m-commerce, its functionalities and advantages is a pre-requisite step towards acceptance of it and the intention to use it. Awareness of m-commerce can be defined as the extent to which managers (or generally stakeholders) are aware of m-commerce technology and its advantages and potential. On the contrary, the lack of awareness of the technology will limit its adoption. This is evidenced by relevant research investigating the acceptance of m-banking in Saudi Arabia [36]. Their results revealed that the limited awareness of m-banking among Saudi residents resulted in limited acceptance and use of this service. Therefore, in order to positively influence the intention to use the m-commerce technology SME managers need to promote their awareness of the technology and the users' awareness of the significance of that technology.

Based on the above, hypothesis H4 is defined as:

*H4: If citizens with higher levels of **IT skills, education, and technology awareness** report increased **PEoU, PT and PU** then this will lead to an increase in citizens **intention to adopt m-commerce** because they are more likely to be more accustomed to IT technologies in general.*

(b) Age. The acceptance of a new technology may be strongly influenced by the age of the user. Studies revealed significant influence of age in many cases [37, 38]. Results of some studies revealed negative attitude towards the new technology from consumers in older age brackets, whereas in others age had less significance [39]. Age is thought to have a significant influence on accepting m-commerce in Saudi Arabia as a developing country. Therefore, hypothesis H5 is defined as:

*H5: If **younger** citizens report higher levels of **PEoU, PT and PU** then this will lead to an increase in citizens **intention to adopt m-commerce** because younger citizens better realise the advantage of m-commerce.*

(c) Culture. The culture of any society develops over long periods of time and continually evolves. According to the Cultural Dimensions Theory [40], culture consists several dimensions including Individualism, Collectivism, Power, Masculinity and Femininity, among others. Such evolution and diversity made culture a complex term to define. However, it can be defined as "the values, beliefs, norms and behavioural patterns of a group of people in a society for national culture, staff of an organization for organizational culture, specific professions for professional" [41].

Culture has been considered as a moderator of technology acceptance in many studies from different perspectives [42, 43, 44]. The national level perspective has been widely adopted where the impacts of national values on technology acceptance were examined [45, 46]. Positive and negative correlation between national cultural values and technology acceptance were reported. For instance, Maitland and Bauer [45] found that that technology and acceptance are positively correlated with the impacts of national culture value. On the contrary, some studies revealed that national cultural values fail to anticipate the intention of users to accept the technology as the similarity of cultural values among all users cannot be guaranteed [46]. The above discussion makes the cultural factors at both national level and individual level interesting moderators to test.

The research model presented in this paper considers *Image* as a cultural factor. *Image* refers to the extent to which an individual considers that using new technologies promote their social status and appearance among their peers in the society [47]. This factor was considered in many studies [48, 49, 50]. It has been believed that the tendency towards using new technologies such as e-government, may indicate a higher level of civilisation and modernisation an individual has. Similar context applies to e- and m-commerce where consumers in Saudi Arabia may find it prestigious that they carry out their purchase using their mobile phone. The influence of the Image factor can be more obvious with trading companies that can show off that they adopt m-commerce technologies and can deliver their product to their consumers doorsteps with few phone screen touches. Based on the above, hypothesis H6 is placed.

*H6: If citizens, who engage with m-commerce technology so as to increase their **social image** among their peers, report higher levels of **PEoU, PT and PU** then this will lead to an increase in citizens **intention to adopt m-commerce** because they will be keen to promote their social image.*

(d) Social influence. Social influence refers to the extent to which external social factors impact individual behaviours [51]. People may become involved in various types of behaviour when they are influenced by other individual or group of people [10]. Social influence can be viewed as a result of the interaction between where people sense and realise what is accepted by society. Consequently, the behaviour of a certain group of people may influence others behavioural intention towards the acceptance of new technology. For this reason, Social influence has been widely considered as a main moderator of user behavioural intentions in many studies e.g. [10, 52]. It is also one of essential constructs of the Unified Theory of Acceptance and Use of Technology Model (UTAUT). According to [53], five categories of a new technology adopters are defined, namely, innovators, early adopters, early majority, late majority, and laggards. Social influence can significantly affect each of the three latter categories, which obviously form the majority of the technology adopters. That also may explain the wide adoption of this factor in many innovative technologies including e-commerce [54], e- and m-government [55], fitness applications [56] among others. Based on the above, hypothesis H7 is formulated as:
H7: If citizens, influenced by other individual's or groups' behaviour towards m-commerce technology, report higher levels of ***PEoU, PT and PU*** *then this will lead to an increase in citizens* ***intention to adopt m-commerce*** *because they will be keen to conform to other individual and group behaviour.*

2) Technology implementation factors: Technology Implementation factors refer to a set of processes that are essential to realise the m-commerce technology. Each of them matches and replaces a process that exists in traditional commerce.

(a) Delivery and collection services. When an SME business produces a physical product that to be used by their consumers, at least one of two services are essential for the success of that SME, the delivery service or the click-and-collect service. The delivery service refers to the process of transporting purchased goods to an address specified by the consumer. The click-and-collect service refers to the process of delivering the purchased goods to a destination specified by the seller (sometimes the consumer selects from a set of destinations specified by the seller) along with the process of handing the goods over to the consumer from that destination. Any lack of provisioning for both services means that the m-commerce operation cannot be realised and, effectively, turns the system into an advertising system. In addition, the quality of these services influences the intention to accept m-commerce by the consumers. The more accurate and reliable the service, the more convincing and encouraging the m-commerce to accept [57] Based on the above, hypothesis H8 is formulated as:
H8: If citizens, who experience highly reliable delivery and/or click-and-collect services, report higher levels of ***PU*** *then this will lead to an increase in citizens* ***intention to adopt m-commerce*** *because they will observe the usefulness of m-commerce.*

(b) Product specification Product specification is information displayed to the consumer of the m-commerce system (or e-commerce in general) in order to describe the product features, properties, and recommend operating conditions. The accuracy of the specification is important for the customer satisfaction and the seller reputation. Meeting the customer expectations will encourage the customer to re-buy the product or reusing the service of the seller in addition to recommending it to other users. On the other hand, failing to achieve customer satisfaction will have the opposite effect. Repeatedly failing to meet customer satisfaction may discourage the customer usage of the m-commerce system at all. Therefore, although to maintain high accuracy of product specification is challenging for the sellers, they are still required to do so in order to make their m-commerce system a success [58]. Based on the above, hypothesis H9 is formulated.
H9: If citizens, who observe m-commerce products, technology and services perform as expected, report higher levels of ***PU*** *then this will lead to an increase in citizens* ***intention to adopt m-commerce*** *because they will observe the usefulness of m-commerce.*

(c) Perceived mobility. Perceived mobility refers to the ability users have to access services and information any time while they move [59]. Thanks to the advancement of wireless technology that enabled efficient mobile computing. Benefiting from this technology, m-commence provides a credible extension to e-commerce. Users are no longer restricted to use static computing devices, such as desktop machines, to purchase goods, conduct sales, and access services as mobility allows them to access these functionalities while they move. This allows pervasive e-commerce and provides potential for wider use of technology. Subsequently, perceived mobility has been considered as a crucial factor that motivates users to adopt m-technologies, including m-government [22], m-learning [60], and m-banking [59].
Mobile payment (m-payment) is another aspect of perceived mobility. It is a service that refers to the process of making payments using mobile devices [61]. Practically, one can argue that m-commerce can be realised without m-payment service, e.g. by on-delivery or on- collect payments. However, such service will limit the advantages of m-commerce and its usefulness. Consequently, the acceptance to use this service by the consumers is essential for wide adoption of m-commerce technology. Wu et al. [62] conducted a study to understand the determinants of consumer acceptance of m-payment. Their findings reveal that risk and ease of use are main factors that encourage consumers to use this service. Risk refers to the expected loss associated to making a payment using the m-payment system. As the m-payment can be part of

the m-commerce systems, the associated risk is therefore a factor that affects the adoption of m-commerce. Based on the above view, hypothesis H10 is formulated.

*H10: If citizens, who are able to access m-commerce services from their mobile devices regardless of their location, report increased **PEoU and PT** then this will lead to an increase in citizens **intention to adopt m-commerce** because they will observe the ease of usefulness and better trust m-commerce.*

3) Technical factors:

(a) Software quality. This factor refers to a set of features and properties that software meets in order to satisfy the user requirements. The standard ISO 9126 [63] defines a set of attributes of software quality that concern users and developers. The development of m-commerce software system needs to take into software quality attributes in order to satisfy the users interacting with the system through their mobile devices. The user perception of the system quality may affect the whether he/she will proceed a commercial transaction and consequently may affect the intention to use m-commerce [64]. This study focuses on the following aspects of software quality:

- Presentation. The m-commerce software provides an environment where users utilise technology features. Presentation should take the characteristics of mobile devices into consideration. Such characteristics include limited computational and memory resources, small screen size, limited energy, and cost of data transfer. Presentation on mobile devices highly depends on text and a few number of colours and avoidance of images especially high resolution ones. The presentation should avoid too many colours as that negatively affects readability. Furthermore, as users' mobile devices are heterogeneous (i.e. different in features and capabilities) the m-commerce software may be customised according to the devices capabilities to improve readability and appearance. In short, user-friendly presentation may affect the perceived ease of use of the m-commerce system and consequently may affect the intention to use this technology.
- Reliability. Software reliability refers to the probability that m-commerce software will not exhibit failures for a certain period. This is a critical factor for the success of any system when software is a critical part of it. Software the produces errors, performs slowly, has unresponsive services, or contains broken links is unreliable. Previous studies show a strong correlation between reliability and This may affect the PEoU and PU.
- Navigation. The navigability of a software system refers to the existence of components that eases access to the information and functionalities of the system. These components include navigation bars, site maps and quick links. Each of these components should places in a proper place on the user interface; preferably following the W3C Mobile Web Best Practices 1.0 [65]. For example, the navigation bar should be position at the top of the interfacing page, the main contents appear on the page avoiding any extra scrolling, and any secondary element may be positioned at the bottom. The navigation factor is an important attribute of software quality and mainly affects the PEoU [64]. Based on the above discussion, hypothesis H11 is formulated.

*H11: If citizens, who observe the quality of software based mobile products, report increased **PEoU and PU** then this will lead to an increase in citizens **intention to adopt m-commerce** because they will observe the ease of use and usefulness of m-commerce.*

(b) Software Security. It might be obvious that Software Security affects users' attitudes to adopting m-commerce. A security threat to the system may cause denial of service, disclosure of data, financial losses, and personal abuse, among others [66, 67]. All these threats negatively affect the user intention to adopt m-commerce. Therefore, m-commerce software must implement security protection techniques including authorisation, authentication, data cryptography, and transactions encryption, among others in order to secure the system and reassure the user to adopt it a [68] . Based on that, hypothesis H12 is placed.

*H12: If citizens, who observe that m-commerce products and services are highly secure login and data protection, report increased **PT** then this will lead to an increase in citizens **intention to adopt m-commerce** because they will understand that their data will be less likely to be at risk.*

4) Environmental factors.: The environment in which an m-commerce firm operates and the internal environment of that firm play an important role in the adoption of m-commerce. Therefore, we consider two environmental factors that relate to the state of the firm intending to adopt m-commerce and the government role to support this new technology [15].

(a) Technology Infrastructure. Technology infrastructure is a requirement that firms need to carefully consider when they intend to adopt m-commerce. This involves communication, hardware, inter-organisation network, and staff IT expertise. Wireless networks technology is the key enables of m-commerce. Network coverage and bandwidth are the main features that determine the reliability, speed, and convenience of the communication over the wireless network. Limited network coverage and low bandwidth are indeed barriers to communications and affect comfort with using the m-commerce system. Therefore, firms need to study the national wireless infrastructure in Saudi Arabia and ensure that it is adequate to satisfy their business needs and their customers convenience. In addition, the firms may need to develop mobile application for their m-commerce. This requires hardware resources to build a data centre that hosts the application back-ends and maintains the system data. All the above requires staff expertise to study, build, an maintain the m-commerce system. Based on the above, hypothesis H13 is formulated.

H13: If citizens, who observe that m-commerce products and services implementing secure suitable technological Infrastructure, report increased ***PT and PU*** *then this will lead to an increase in citizens* ***intention to adopt m-commerce*** *because they will be more able to trust and use the m-commerce system.*

(b) Governmental regulations. As discussed above, m-commerce brings many advantages to the consumers. These include comfortable and mobile shopping, search for products, and quick comparison of prices. However, trusting the m-commerce system is a crucial factor for adopting m-commerce. Consumer will purchase items from seller whom the consumers will not physically meet and will purchase items which they do not physically view. Consumers will pay for those items with doubt about the transactions' security. These issues and others necessitate the need for regulations that increase the trust of system. Therefore, a main factor to achieve this trust is to protect consumers through governmental legislation [69]. From a different perspective, producers need also governmental policies that protect their intellectual properties, trademarks, and domain names. They also need governmental polices for supporting technology implementation issues such as securing online payments, setting up exchange rates, and reducing taxes [67]. Based on that, hypothesis H14 is placed.

H14: If citizens, who observe that the Saudi government provides supportive and protective m-commerce technology infrastructure, report increased ***PT and PU*** *then this will lead to an increase in citizens* ***intention to adopt m-commerce*** *because they will feel they are less exposed to dishonest treatment and hence encourage their trust and use of m-commerce products and services.*

IV. Conclusion and Future Research

This paper has developed a new m-commerce acceptance framework for investigating the adoption of m-commerce in Saudi Arabia. The model takes into consideration both customer and businesses perspectives. It defines factors that affect the intention to use m-commerce technology. For the scope of this position paper, we have presented the model and discussed its dependent and independent factors. Our next work is to conduct a thorough study to collect data and analyse the model.

In more details, this position paper will be followed by a thorough study to analyse and evaluate the proposed model. The research methodology is two-fold: quantitative survey, and qualitative interview. The goal of the quantitative analysis is to investigate the customers' perspectives towards adopting m-commerce. This will be undertaken by a survey questionnaire which will be randomly distributed among potential m-commerce users in Saudi Arabia. The survey will be distributed electronically[1] and we aim at a sample size of at least 500 participants. The questions of the survey will look at the extent to which each of the research model factors affects the decision of adopting m-commerce and the extent to which customers find m-commerce easy, useful, and trusted. All of the survey items will be measured using a five-point Likert-type scale with responses from "strongly disagree" to "strongly agree". The reliability of the research instrument will be examined using Cronbach's α, which measures the extent to which a set of items measures a single factor. Resulting quantitative data will be analysed following a statistical method with target significance level of 0.05. On the other hand, the goal of the qualitative analysis is to investigate the businesses perspectives towards adopting m-commerce. This will be undertaken by semi-structured interviews with marketing managers of private companies in Saudi Arabia. We aim at interviewing four to ten company managers. The interview will look at the advantages that m-commerce brings to the company in case the company utilises a m-commerce technology. Otherwise, the interview will investigate the reasons behind abandoning m-commerce and if there are future plans to adopt m-commerce.

[1]In the light of pandemic of Covid'19, only electronic means will be used to distribute the survey in order to comply with the safety and health advises.

References

[1] T.-P. Liang and C.-P. Wei, "Introduction to the special issue: Mobile commerce applications," *International journal of electronic commerce*, vol. 8, no. 3, pp. 7–17, 2004.

[2] T. Natarajan, S. A. Balasubramanian, and D. L. Kasilingam, "Understanding the intention to use mobile shopping applications and its influence on price sensitivity," *Journal of Retailing and Consumer Services*, vol. 37, pp. 8–22, 2017.

[3] A. Y.-L. Chong, F. T. Chan, and K.-B. Ooi, "Predicting consumer decisions to adopt mobile commerce: Cross country empirical examination between china and malaysia," *Decision Support Systems*, vol. 53, no. 1, pp. 34 – 43, 2012. [Online]. Available: https://doi.org/10.1016/j.dss.2011.12.001

[4] L. Puspitasari and K. Ishii, "Digital divides and mobile internet in indonesia: Impact of smartphones," *Telematics and Informatics*, vol. 33, no. 2, pp. 472–483, 2016. [Online]. Available: https://doi.org/10.1016/j.tele.2015.11.001

[5] A. A. Alalwan, A. M. Baabdullah, N. P. Rana, K. Tamilmani, and Y. K. Dwivedi, "Examining adoption of mobile internet in saudi arabia: Extending tam with perceived enjoyment, innovativeness and trust," *Technology in Society*, vol. 55, pp. 100 – 110, 2018. [Online]. Available: https://doi.org/10.1016/j.techsoc.2018.06.007

[6] A. Puri-Mirza, "Smartphone penetration rate as share of the population in saudi arabia from 2017 to 2025," https://www.statista.com/statistics/625436/smartphone-user-penetration-in-saudi-arabia/, publisher=Statista, note=Accessed: 05-08-2020, 2020.

[7] M. Alonazi, N. Beloff, and M. White, "Perceptions towards the adoption and utilization of m-government

services: A study from the citizens' perspective in saudi arabia," in *Information Technology for Management: Current Research and Future Directions*. Springer, 2019, pp. 3–26.

[8] M. Nurunnabi, "Transformation from an oil-based economy to a knowledge-based economy in saudi arabia: the direction of saudi vision 2030," *Journal of the Knowledge Economy*, vol. 8, no. 2, pp. 536–564, 2017. [Online]. Available: https://doi.org/10.1007/s13132-017-0479-8

[9] F. D. Davis, "A technology acceptance model for empirically testing new end-user information systems: Theory and results," Ph.D. dissertation, Massachusetts Institute of Technology, 1985.

[10] V. Venkatesh, M. G. Morris, G. B. Davis, and F. D. Davis, "User acceptance of information technology: Toward a unified view," *MIS quarterly*, pp. 425–478, 2003. [Online]. Available: https://doi.org/10.2307/30036540

[11] M. Fishbein and I. Ajzen, *Belief, attitude, intention, and behavior: An introduction to theory and research*. Reading, Mass.; London: Addison-Wesley, 1975.

[12] F. J. Rondan-Cataluña, J. Arenas-Gaitán, and P. E. Ramírez-Correa, "A comparison of the different versions of popular technology acceptance models," *Kybernetes*, 2015.

[13] G. Lala *et al.*, "The emergence and development of the technology acceptance model (tam)," *Marketing from Information to Decision*, no. 7, pp. 149–160, 2014.

[14] M. AlQulaity and W. Bajaber, *The Growth of E-Commerce in Saudi Arabia and Its Influence on Saudi Women*. GRIN Verlag, 2015.

[15] H. Alfahl, L. Houghton, and L. Sanzogni, "Mobile commerce adoption in saudi organizations: A qualitative study," *Int. J. Enterp. Inf. Syst.*, vol. 13, no. 4, p. 31–57, Oct. 2017. [Online]. Available: https://doi.org/10.4018/IJEIS.2017100103

[16] E. Makki and L.-C. Chang, "Understanding the effects of social media and mobile usage on e-commerce: an exploratory study in saudi arabia," *International management review*, vol. 11, no. 2, p. 98, 2015.

[17] A. Alkhunaizan and S. Love, "Predicting consumer decisions to adopt mobile commerce in saudi arabia." in *Proceedings of the Nineteenth Americas Conference on Information Systems,*, August 2013, pp. 1–9.

[18] W. AlBalawi, I. Hidayat-ur Rehman *et al.*, "The impacts of m-commerce on saudi banks," *Journal of Management and Strategy*, vol. 7, no. 2, p. 1, 2016.

[19] L. Rajabion, "Critical factors for adoption of mobile commerce services," *International Journal of Business and Social Science*, vol. 6, no. 12, pp. 26–35, 2015.

[20] L. AlSuwaidan and A. A. Mirza, "An investigation on user preferences of mobile commerce interface design in saudi arabia," in *Mobile Web Information Systems*, I. Awan, M. Younas, X. Franch, and C. Quer, Eds. Cham: Springer International Publishing, 2014, pp. 275–285.

[21] M. R. Abbasi, M. A. Sarlak, A. Ghorbani, and H. A. Esfanjani, "Csfs of e-commerce admission in small and medium size enterprises (smes)," *African Journal of Business Management*, vol. 4, no. 16, p. 3480, 2010.

[22] E. Abu-Shanab and S. Haider, "Major factors influencing the adoption of m-government in jordan," *Electronic Government, an International Journal*, vol. 11, no. 4, pp. 223–240, 2015.

[23] T. Ramayah and J. Ignatius, "Impact of perceived usefulness, perceived ease of use and perceived enjoyment on intention to shop online," *ICFAI Journal of Systems Management (IJSM)*, vol. 3, no. 3, pp. 36–51, 2005.

[24] A. B. Ozturk, A. Bilgihan, K. Nusair, and F. Okumus, "What keeps the mobile hotel booking users loyal? investigating the roles of self-efficacy, compatibility, perceived ease of use, and perceived convenience," *International Journal of Information Management*, vol. 36, no. 6, pp. 1350–1359, 2016.

[25] F. D. Davis, R. P. Bagozzi, and P. R. Warshaw, "User acceptance of computer technology: a comparison of two theoretical models," *Management science*, vol. 35, no. 8, pp. 982–1003, 1989.

[26] M. Reid and Y. Levy, "Integrating trust and computer self-efficacy with tam: An empirical assessment of customers' acceptance of banking information systems (bis) in jamaica," *The Journal of Internet Banking and Commerce*, vol. 13, no. 3, pp. 1–18, 1970.

[27] A. Molla and P. S. Licker, "E-commerce systems success: An attempt to extend and respecify the delone and maclean model of is success." *J. Electron. Commerce Res.*, vol. 2, no. 4, pp. 131–141, 2001.

[28] A. Sambhanthan and A. Good, "Critical success factors for positive user experience in hotel websites: Applying herzberg's two factor theory for user experience modeling," *International Journal of E-Services and Mobile Applications (IJESMA)*, vol. 5, no. 1, pp. 1–25, 2013.

[29] I. Brown and R. Jayakody, "B2c e-commerce success: A test and validation of a revised conceptual model," *The Electronic Journal Information Systems Evaluation*, vol. 11, no. 3, pp. 167–184, 2008.

[30] D. Gefen, E. Karahanna, and D. W. Straub, "Trust and tam in online shopping: An integrated model," *MIS Q.*, vol. 27, no. 1, p. 51–90, Mar. 2003.

[31] D. H. McKnight and N. L. Chervany, "What trust means in e-commerce customer relationships: An interdisciplinary conceptual typology," *International journal of electronic commerce*, vol. 6, no. 2, pp. 35–59, 2001.

[32] T. T. Wei, G. Marthandan, A. Y.-L. Chong, K.-B. Ooi, and S. Arumugam, "What drives malaysian m-commerce adoption? an empirical analysis," *Industrial management & data systems*, 2009.

[33] A. N. H. Zaied, "Barriers to e-commerce adoption in egyptian smes," *International Journal of Information Engineering and Electronic Business*, vol. 4, no. 3, p. 9, 2012.

[34] R. A. Saif-Ur-Rehman, "A study of barriers to e-

commerce adoption among smes in malaysia," *University of Modern Sciences*, vol. 1, no. 1, pp. 45–58, 2016.

[35] L. V. Huy and P. Filiatrault, "The adoption of e-commerce in smes in vietnam: a study of users and prospectors," *PACIS 2006 Proceedings*, p. 74, 2006.

[36] A. N. Alkhaldi, "Adoption of mobile banking in saudi arabia: An empirical evaluation study," *International Journal of Managing Information Technology*, vol. 8, no. 2, pp. 1–14, 2016.

[37] K. Dickersin, Y.-I. Min, and C. L. Meinert, "Factors influencing publication of research results: follow-up of applications submitted to two institutional review boards," *Jama*, vol. 267, no. 3, pp. 374–378, 1992.

[38] P. Brauner, J. van Heek, and M. Ziefle, "Age, gender, and technology attitude as factors for acceptance of smart interactive textiles in home environments," in *Proceedings of the 3rd International Conference on Information and Communication Technologies for Ageing Well and e-Health, ICT4AgingWell*, 2017.

[39] R. W. Berkowsky, J. Sharit, and S. J. Czaja, "Factors predicting decisions about technology adoption among older adults," *Innovation in aging*, vol. 1, no. 3, p. igy002, 2017.

[40] G. Hofstede, *Culture's consequences: Comparing values, behaviors, institutions and organizations across nations*. Sage publications, 2001.

[41] K. Leung, R. S. Bhagat, N. R. Buchan, M. Erez, and C. B. Gibson, "Culture and international business: Recent advances and their implications for future research," *Journal of international business studies*, vol. 36, no. 4, pp. 357–378, 2005.

[42] S. Sunny, L. Patrick, and L. Rob, "Impact of cultural values on technology acceptance and technology readiness," *International Journal of Hospitality Management*, vol. 77, pp. 89–96, 2019.

[43] M. Ali, V. Weerakkody, and R. El-Haddadeh, "The impact of national culture on e-government implementation: A comparison case study," 2009.

[44] M. Alonazi, "Mgaum: a new framework for the mobile government service adoption in saudi arabia," Ph.D. dissertation, University of Sussex, 2019.

[45] C. F. Maitland and J. M. Bauer, "National level culture and global diffusion: The case of the internet," *Culture, technology, communication: Towards an intercultural global village*, pp. 87–128, 2001.

[46] J. Meng, K. M. Elliott, and M. C. Hall, "Technology readiness index (tri): Assessing cross-cultural validity," *Journal of International Consumer Marketing*, vol. 22, no. 1, pp. 19–31, 2009.

[47] G. C. Moore and I. Benbasat, "Development of an instrument to measure the perceptions of adopting an information technology innovation," *Information systems research*, vol. 2, no. 3, pp. 192–222, 1991.

[48] D. Gilbert, P. Balestrini, and D. Littleboy, "Barriers and benefits in the adoption of e-government," *International Journal of Public Sector Management*, 2004.

[49] C. W. Phang, Y. Li, J. Sutanto, and A. Kankanhalli, "Senior citizens' adoption of e-government: In quest of the antecedents of perceived usefulness," in *Proceedings of the 38th annual Hawaii international conference on system sciences*. IEEE, 2005, pp. 130a–130a.

[50] L. L. Tung and O. Rieck, "Adoption of electronic government services among business organizations in singapore," *The Journal of Strategic Information Systems*, vol. 14, no. 4, pp. 417–440, 2005.

[51] J. Fang, Z. Zhao, C. Wen, and R. Wang, "Design and performance attributes driving mobile travel application engagement," *International Journal of Information Management*, vol. 37, no. 4, pp. 269 – 283, 2017. [Online]. Available: https://doi.org/10.1016/j.ijinfomgt.2017.03.003

[52] Y. Lu, T. Zhou, and B. Wang, "Exploring chinese users' acceptance of instant messaging using the theory of planned behavior, the technology acceptance model, and the flow theory," *Computers in human behavior*, vol. 25, no. 1, pp. 29–39, 2009.

[53] E. M. Rogers, *Diffusion of Innovations: Modifications of a Model for Telecommunications*. Berlin, Heidelberg: Springer Berlin Heidelberg, pp. 25–38. [Online]. Available: https://doi.org/10.1007/978-3-642-79868-9_2

[54] Y. A. Kim and J. Srivastava, "Impact of social influence in e-commerce decision making," in *Proceedings of the ninth international conference on Electronic commerce*, 2007, pp. 293–302.

[55] S. Z. Ahmad and K. Khalid, "The adoption of m-government services from the user's perspectives: Empirical evidence from the united arab emirates," *International Journal of Information Management*, vol. 37, no. 5, pp. 367–379, 2017.

[56] A. D. Beldad and S. M. Hegner, "Expanding the technology acceptance model with the inclusion of trust, social influence, and health valuation to determine the predictors of german users' willingness to continue using a fitness app: A structural equation modeling approach," *International Journal of Human–Computer Interaction*, vol. 34, no. 9, pp. 882–893, 2018.

[57] A. Azam, P. F. Qiang, and M. I. Abdullah, "Consumers' e-commerce acceptance model: Antecedents of trust and satisfaction constructs," in *2012 IEEE Business, Engineering & Industrial Applications Colloquium (BEIAC)*. IEEE, 2012, pp. 371–376.

[58] P. V. Hande, D. Ghosh *et al.*, "A comparative study on factors shaping buying behaviour on b2b and b2c e-commerce platforms in india," *EXCEL International Journal of Multidisciplinary Management Studies*, vol. 5, no. 3, pp. 1–10, 2015.

[59] Y.-S. Yen and F.-S. Wu, "Predicting the adoption of mobile financial services: The impacts of perceived mobility and personal habit," *Computers in Human Behavior*, vol. 65, pp. 31–42, 2016.

[60] A. K. M. Almasri, "The influence on mobile learning based on technology acceptance model (tam), mobile

readiness (mr) and perceived interaction (pi) for higher education students," *International Journal of Technical Research and Applications*, vol. 2, no. 1, pp. 05–11, 2014.

[61] L.-d. Chen, "A model of consumer acceptance of mobile payment," *International Journal of Mobile Communications*, vol. 6, no. 1, pp. 32–52, 2008.

[62] J. Wu, L. Liu, and L. Huang, "Consumer acceptance of mobile payment across time," *Industrial Management & Data Systems*, 2017.

[63] ISO/IEC9126-1:2001, "Software engineering – product quality – part 1: Quality model," International Organization for Standardization, Geneva, CH, Standard, Jun. 2001.

[64] J. D. Garofalakis, A. Stefani, V. Stefanis, and M. N. Xenos, "Quality attributes of consumer-based m-commerce systems." in *ICE-B*, 2007, pp. 130–136.

[65] W. W. W. Consortium *et al.*, "Mobile web best practices 1.0: Basic guidelines," 2008.

[66] S. Alabi, M. White, and N. Beloff, "Contactless palm vein authentication security technique for better adoption of e-commerce in developing countries," in *Science and Information Conference*. Springer, 2020, pp. 380–390.

[67] H. Zhang and S. C. Okoroafo, "An e-commerce key success factors framework for chinese sme exporters," *International Journal of Economics and Finance*, vol. 6, no. 1, pp. 129–137, 2014.

[68] E. P. Hansel and R. A. A. Vianna, "E-commerce based payment system with authentication of electronic invoices," May 19 2016, uS Patent App. 14/789,240.

[69] E. Makki and L.-C. Chang, "E-commerce acceptance and implementation in saudi arabia: previous, current and future factors," *The International Journal of Management Research and Business Strategy*, vol. 4, no. 3, pp. 29–44, 2015.

26th Conference on Knowledge Acquisition and Management

KNOWLEDGE management is a large multidisciplinary field having its roots in Management and Artificial Intelligence. Activity of an extended organization should be supported by an organized and optimized flow of knowledge to effectively help all participants in their work.

We have the pleasure to invite you to contribute to and to participate in the conference "Knowledge Acquisition and Management". The predecessor of the KAM conference has been organized for the first time in 1992, as a venue for scientists and practitioners to address different aspects of usage of advanced information technologies in management, with focus on intelligent techniques and knowledge management. In 2003 the conference changed somewhat its focus and was organized for the first under its current name. Furthermore, the KAM conference became an international event, with participants from around the world. In 2012 we've joined to Federated Conference on Computer Science and Systems becoming one of the oldest event.

The aim of this event is to create possibility of presenting and discussing approaches, techniques and tools in the knowledge acquisition and other knowledge management areas with focus on contribution of artificial intelligence for improvement of human-machine intelligence and face the challenges of this century. We expect that the conference&workshop will enable exchange of information and experiences, and delve into current trends of methodological, technological and implementation aspects of knowledge management processes.

TOPICS

- Knowledge discovery from databases and data warehouses
- Methods and tools for knowledge acquisition
- New emerging technologies for management
- Organizing the knowledge centers and knowledge distribution
- Knowledge creation and validation
- Knowledge dynamics and machine learning
- Distance learning and knowledge sharing
- Knowledge representation models
- Management of enterprise knowledge versus personal knowledge
- Knowledge managers and workers
- Knowledge coaching and diffusion
- Knowledge engineering and software engineering
- Managerial knowledge evolution with focus on managing of best practice and cooperative activities
- Knowledge grid and social networks
- Knowledge management for design, innovation and eco-innovation process
- Business Intelligence environment for supporting knowledge management
- Knowledge management in virtual advisors and training
- Management of the innovation and eco-innovation process
- Human-machine interfaces and knowledge visualization

Position Papers of the Federated Conference on Computer Science and Information Systems pp. 37–44
DOI: 10.15439/2020F138
ISSN 2300-5963 ACSIS, Vol. 22

Learning from Student Browsing Data on E-Learning Platforms: Case Study

Sergen Cansiz
Morpa *R&D Center*
Istanbul, Turkey
sergen.cansiz@morpa.com.tr

Berk Sudan
Morpa R&D Center
Istanbul, Turkey
berk.sudan@morpa.com.tr

Emre Ogretici
Morpa *R&D Center*
Istanbul, Turkey
emre@morpa.com.tr

Mehmet S. Aktas
YTU *Computer Engineering Dept*
Istanbul, Turkey
aktas@yildiz.edu.tr

***Abstract*—Interpretation of the behaviors of students in e-learning platforms with machine learning models has become an emerging need in recent years. Increase in the number of registered students on e-learning platforms is one of the reasons for choosing machine learning models. Tracking, modeling and understanding student activities gets more complex when the number of students is increased. This study is focusing modeling student activities on e-learning platforms with Complex Event Processing (CEP), Association Rule Mining (ARM) and Clustering methods based on distributed software architecture. Within the scope of this study, different modules that work real-time have been developed. An admin panel has been also developed in order to control all modules and track the student actions. Performance results of modules also obtained and evaluated on distributed system architecture.**

***Index Terms*—e-learning, complex event processing, association rule mining, clustering**

I Introduction

E-LEARNING platforms are increasingly preferred and used by students. Students prefer the different learning models provided by e-learning platforms such as self-learning and teacher-assisted learning [1]. However, the integration of advancing technology and artificial intelligence applications into e-learning platforms also adds extra features to e-learning platforms and contributes to students' learning processes [2]. These features also make e-learning platforms more useful and effective on learning. With the artificial intelligence integration, students can be tracked on the basis of e-learning platforms, and various suggestions can be offered to students during training. There are researches made on prediction models by using various machine learning algorithms in order to present these suggestions to users (students) [3].

The purpose of most research and developed applications based on machine learning on e-learning platforms is to ease students' learning processes and to bring the learning performance to the highest level. The data derived from students' actions on the platform directly affects the machine learning models to produce accurate and consistent results. Because of that, it's very important to extract the students' personal behaviors on the platform by considering that the learning style of each student may differ from each other. In addition to predicting student success with machine learning algorithms using behavioral data; students can also be categorized according to the platform usage patterns and learning processes. Thus, system analysts, teachers and parents can evaluate students according to their categories and take actions that will improve the student's performance.

Apart from the e-learning platform, it is a known fact that a teacher pursues students in the class and makes suggestions according to their learning style, corrects their mistakes and guides the student directly. In e-learning platforms, these procedures are expected to be done by experts or teachers. It is almost impossible for experts to provide individual advice to students considering an e-learning platform with thousands of or maybe millions of users. In such cases, In e-learning platforms where teacher membership is available, teachers can follow the students they are responsible for through the system and take the necessary actions. In addition, since there is no physical classroom environment in e-learning platforms, it is impossible for a teacher to monitor and evaluate all students in real time. Therefore, the evaluation process is done by the teacher every other day or weekly after completing the student education. Such situations may also cause delay in actions that should be taken during the student's learning process.

It is possible to monitor whether the behaviors of the users on a system show certain patterns in real-time with the help of the tool developed on Complex Event Processing (CEP). Students' behaviors in an e-learning platform can be interpreted according to certain patterns and action can be taken instantly by using these tools. In this way, when the teachers cannot monitor and evaluate the students' behaviors, our tools can interpret the behaviors of the students instantly according to the directives determined by the experts or teachers.

Each student may have common behaviors as well as different behaviors during the learning process. As an example, a student may need information on “lecture A” while on the exercise of “subject B”. In such cases, it is possible for students to return to the “lecture A” during or after the exercise of “subject B”. In this way students can get the prior knowledge they need. Identifying these and similar actions automatically and showing them to expert analysts or teachers can form the basis for actions to be taken for other students. In addition, these actions can be added on the CEP by experts as a separate pattern (or rule) to automatically send recommendation notifications to students. Plus, students can be divided into clusters according to their behavior data in order to analyze students' situations and interpret their behavior cumulatively. Thus, the learning processes of the students can be examined by generalizing them according to their behaviors over different clusters.

Within the scope of this research, a demo e-learning platform has been developed on the CEP module that detects the students' actions according to certain rules (patterns), performs the predefined notification action according to the detected patterns and extracts the common behaviors (association rules) in the students’ actions. In addition, students were divided into clusters according to various behavioral patterns gathered from an e-learning site. It is aimed to facilitate the learning process by accurately monitoring and interpreting students' behaviors.

In this study, similar studies in the literature are discussed in Section 2. In Section 3, the complex methodology that is followed while developing Complex Event Processing, association rules and developing clustering modules is presented.

II. Literature Review

Complex Event Processing (CEP) is a very effective method for processing real-time streaming data and extracting certain patterns from these streaming data bounded or unbounded [4,5]. Simultaneously, with the help of the distributed system technologies, CEP can work integrated with machine learning models [6]. This method, which is frequently used within the scope of Business Performance Management (BPM), is used in companies with a large number of customers or in e-commerce sites to identify certain patterns based on users' behavior (user behaviors, shopping etc.) and to take necessary actions [7]. The CEP module used in e-commerce sites which are focused on purchasing can be also used in e-learning systems with a focus on student success.

As machine learning techniques have improved, there has been an increase in the amount of applications on student education. Since the early 2000s, students' behaviors have been tried to be modeled by machine learning algorithms in various studies [8,9]. Various model approaches which are used to predict the performance of students were developed on machine learning models [10,11]. One of the most important factors in predicting future success by measuring students' performance and modeling their behavior on e-learning platforms is the data collected from students. In a study, success prediction was made by collecting the student's processing time, idle time, total activities, key-strokes data [12]. The machine learning model developed based on the obtained results makes successful predictions. This situation reveals the importance of the data received from the student. With the help of the CEP tools, students' actions can be stored instantly by a rule-based pre-processing module. These actions can be used on other machine learning models later. Similarly, in a study, CEP and IoT data were collected with predefined rules and these data were used by a machine learning model [13].

Predicting the success of students by using machine learning models and making recommendations out of them is a widely used method in e-learning platforms. However, in some cases it is possible to make recommendations by analyzing student actions with a real-time and rule-based system without the need for a machine learning model. In a study [14], the actions of students in the learning process were tracked based on some rules. In this rule-based system, teachers were given the option of adding and setting rules. Thus, it is aimed to improve the learning processes of the students. The rules are defined based on the order of course lectures to prevent the students from attending one lecture without attending the previous one(s). However, in this study, the rules are not determined by the Complex Event Processing module. In another study, a module makes recommendations to students using association rule mining. In this module, the user actions are read from the server log file and the actions of the users are taken sequentially. Sequential actions have been analyzed and, using data mining methods, a module which sends recommendation notifications to students who exhibit similar behavior has been developed [15]. In a study on language learning, a module which tracks user actions with predefined rules developed using complex event processing methods [16]. This research shows that Complex Event Processing (CEP) can be used on e-learning platforms.

In an e-learning platform where rule-based operations are performed with the complex Event Processing module, rules can be created by experts or by using machine learning methods. By finding common behaviors of students on the platform, significant and successful behaviors can be added as a rule. Rules can be extracted based on common behaviors using Association Rule Mining (ARM) methods, as in [17]. There are studies in which Association Rule Mining is applied in the field of health, finance and e-commerce, as in [18]. However, no research has been found in the field of e-learning.

We observe the use of complex event processing techniques in different domains. This technique is used to detect patterns in different domains such as social media [19-22], internet of things [23-24], cloud computing [25], e-commerce [26] and real time streaming based applications [27]. Our study focuses on detecting predefined patterns within the data collected from the clickstream data generated by user-system interactions. In recent years, in order to keep track of the events in a system, provenance based systems have been utilized [28-32]. In this study, our main focus is to keep track of the traces of user actions on the e-learning platform and detect predefined patterns. We also observe studies in the field of service oriented architecture based systems with a focus on high performance and scalability [33-41]. These systems are designed and implemented based distributed system software architecture. In this study, we also utilize distributed system based open-source software systems such as Apache Flink. However, our main focus is the use of complex event processing for detecting predefined patterns on the user-system interaction data collected from log files.

III. Methodology

In this research, a demo e-learning platform and admin panel with different integrated modules were developed. Demo e-learning platform contains lectures, exercises and exam options in various courses and lectures. The modules where the students' behaviors are tracked, modeled and presented with visualization tools can be controlled by the admin panel. Thus, the actions of students, both private and general, can be tracked.

Two different methods based on instant actions and reporting have been developed in order to increase student success by monitoring the actions of students on the platform. Instant actions are based on recommendations when a student is on the platform. Reporting is intended to be evaluated by the teacher or specialist after students completed courses. Instant action transforms the student actions into recommendation actions based on certain rules. In the reporting section, the actions of all students are evaluated and divided into certain clusters. With these clusters, which are expected to be checked by teachers and specialists, it is possible to determine which cluster the student is included in. Thus, the opportunity to be evaluated with the success-based clustering module is provided to the students. The following modules have been developed to implement the planned system.

- Web server log parser module for tracking user actions on the platform
- Rule engine which rules are managed, and their validity are checked
- Complex Event Processing module to detected using predefined rules
- Association Rule Mining module to get new usage patterns (rules) from students' actions
- Action executer module to take actions over defined rules
- Clustering module which divide students into clusters (segments) according to their usage behavior

The real-time log parser module is allowed to read log files from Web Server. It takes each request on the web server and analyzes page visits or materials activities of the user by separating them according to the session ID and user ID. The student activities obtained by log parser are sent to different modules over the messaging service instead of database. Thus, the transmission of user activities to different modules is done with high speed performance.

The student activities sent by the log parser are taken by the Complex Event Processing (CEP) module to determine if it recognizes any certain pattern rules. The rules that CEP looks for are stored in the database which is controlled by the rule engine. These rules can be created by experts considering factors of affecting students' success. This rule engine also integrated into the admin panel and rules can be updated via an interface. Experts can also deactivate or activate the rules and check their expiry dates.

As mentioned before, the rules used to identify complex actions that affect students' success can be created by experts as well as by analyzing the student's common actions within the system. Therefore, the Association Rule Mining (ARM) module has been developed in order to detect common behaviors of the users based on their actions in the platform. Considering that thousands of students can be enrolled on the platform, distributed system architecture has been used for faster performance on the ARM module. FP Growth algorithm has been used for detecting students' associated behaviors. These common behaviors can also be adjusted according to students' exam scores. Thus, the behavior of successful students and unsuccessful students on the platform can be compared. For instance, with FP Growth algorithm, it can be found that most of the students who are successful on subject X, first enter subject X's lecture and then enter the subject Y's lecture. In such cases, it can be concluded that subject Y's lecture has a positive effect on subject X. These types of student behaviors can be found with FP Growth algorithm on the ARM module and create new rules (patterns) on the rule engine in order to be detected with the CEP module. However, the rules that have been found by the ARM module can be seen and managed by teachers and experts from the admin panel. They can add these rules to the rule engine and activate them. The developed CEP module works while students are studying on the platform. The ARM module is used every other day to obtain different rules. In this way, student behaviors can be controlled real time and differences in their behavior can be tracked.

It is very important to take actions instantly to increase the success of students based on the results obtained with the CEP and ARM modules. Hence, the options to reach students via Pop-up, SMS and E-mail have been considered. If detected rules are supposed to reach the student instantly Pop-up option can be considered. Otherwise, email option can be considered. The module called Action Executor has features to handle different notification options or transferring data across the modules. This module works with CEP and Rule Engine. System is triggered by the detection of the pattern and sends feedback to students based on the rules defined in the rule engine. In some cases, it saves data for machine learning methods.

In addition to instant actions, students are divided into segments with various clustering techniques to be presented to the evaluation of teachers and experts. The Clustering Module was originally developed through student behaviors from a demo e-learning platform and designed as improvable with new student actions. K-Means, Bisecting K-Means and Gaussian Mixture algorithms are used for clustering. Thus, student clusters (segments) can be evaluated with different algorithms. User actions on the platform are stored in the database and used to create new clustering models every other day. Clustering results obtained are stored in the database and made accessible through the admin panel. The results are displayed to experts and teachers with different visualization and reporting options.

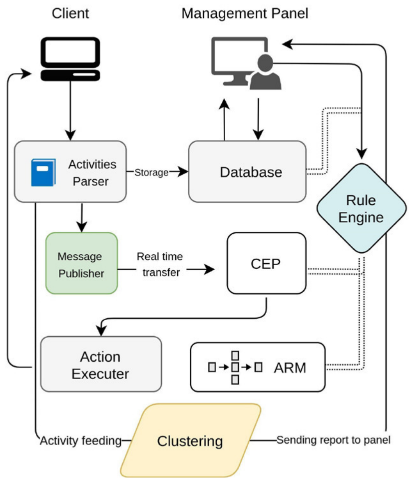


Fig. 1. System Architecture

Speed performance of ARM and Clustering modules can vary depending on the number of students enrolled in e-learning platforms. Along with new data from students, the data used for ARM and Clustering algorithms are updated every other day. This will cause the data size to increase and the algorithms to run slowly over time. For this reason, distributed system architecture is used and performance of ARM and Clustering modules on single node and multi node machines were evaluated as speed oriented. The system architecture shown in Figure 1 has been designed considering latency and scalability. Performance reports of the architecture on single node and double node are discussed in Section 5.

IV. PROTOTYPE

In order to implement the proposed system architecture and performance evaluation specified in the methodology section, the e-learning platform and admin panel prototypes in which different modules can be controlled have been developed. The e-learning platform has lectures on various topics, exercises and exam options as well as different course options. While the e-learning platform was developed with PHP on Apache Server, the admin panel was developed using ReactJS framework on Node.js. These two different platforms can be managed under a single domain via Nginx Proxy Server. In addition, MongoDB was used to manage the developed modules and store the processed student actions. Data transfers between the demo e-learning platform and the admin panel are provided through the NodeJS API services through different modules.

Apache Server Log files are parsed and stored with parameters such as session ID and user ID so that student actions can be used on different modules without slowing down the system. The log parser running in real time was developed using Python Programming Language. All requests on the server are saved in a customized format. The most important part in parsing the log file where all the requests are stored is that the student actions can be parsed individually. Therefore, the Log Parser works only with certain requests and rules that save certain data which comes with the requests. These rules are modified so that they can be created from the admin panel. Kafka service was used to send the data parsed by the log parser to other modules in real time. In addition, user actions are stored with the NodeJS API service so that the data in MongoDB can be accessed from the admin panel. While the data is transmitted to the modules through Kafka topics, it can be monitored on the admin panel with the help of MongoDB. The architecture of this system is shown in Figure 2.

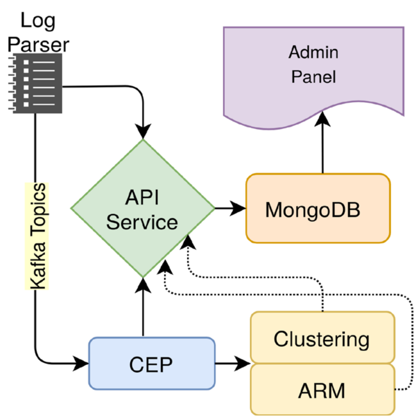


Fig. 2. API Service Diagram

Student activities obtained by the Log Parser with defined rules are saved with certain codes. In this way, various actions can be defined in the modules and processing can be performed according to these actions. Table 1 shows the activities and sample data in these activities. In addition to the data specified in Table I, “user ID” and “session ID” are also collected for each action.

TABLE I. ACTIVITIES AND DATA IN ACTIVITIES

ACTIVITY	DATA
VISIT.LOGIN	Login Data
ACTION.LOGIN	Login Data
VISIT.MATERIAL	Material ID, Lecture ID
EXIT.MATERIAL	Material ID, Lecture ID, Participation Rate
ACTION.MATERIAL	Material ID, Lecture ID, Action Result Data
START.EXAM	Material ID, Lecture ID
FINISH.EXAM	Materiel ID, Lecture ID, Exam Result Data

A. Complex Event Processing Module

CEP module developed on Apache Flink is fed by student actions extracted by the Log parser via Kafka topic. These actions are sent in JSON format. The aim of the CEP module is to recognize certain patterns of student activities. These patterns can be managed with the rule engine and accessed from the admin panel. New rules in the rule engine can be created from the admin panel, and the created rules, the expiry date and activity of the rules can be managed and updated. In this way, it is ensured that all pattern rules can be managed efficiently. The Rule Engine interface is shown in Figure 3.

It is aimed to increase student success with the rule patterns in Apache Flink. For instance, patterns as an expected scenario of a course can be defined in the rule file. When the student acts in accordance with the defined scenario, Apache Flink accepts the pattern and sends the related notification to the Action Executor module with details. The student is then notified by the Action Executor.

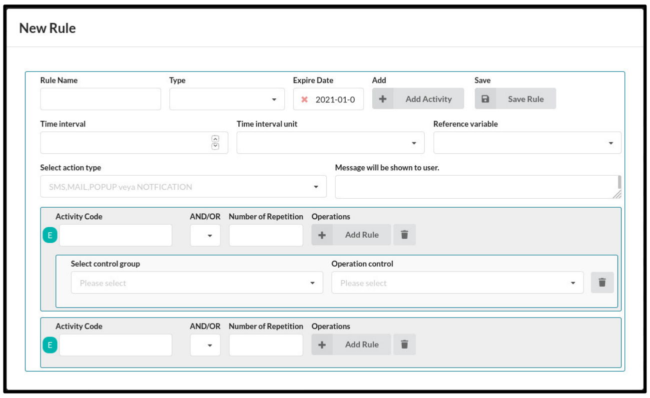


Fig. 3. Rule Creation and Management Screen in Rule Engine

B. Association Rule Mining Module

The patterns specified in the Rule Engine for the Complex Event Processing module are determined by education specialists. Although specialists can manually analyze student success from their actions, big amounts of data, various student actions don't allow specialists to analyze all data. In addition, it is possible for each student to follow different learning paths. For this reason, it is very important to monitor the behavior of the students in the platform and to find the common behaviors of all students. The common behaviors can be analyzed by showing them to the education specialists and these behaviors can be defined in rules to increase the success. In this way, the common behaviors of the students in the platform can be determined with the help of the ARM module.

The most important part of the ARM module is the way students' common behaviors are extracted. In this study, since the aim is to increase student success, the association rules were extracted based on the end-of-lecture exams. In this way, students' common behaviors can be analyzed according to their exam success. Predefined sequential actions of a student can be tracked through pattern rules via the CEP module. Thus, the CEP module was also used to obtain data for the ARM module. The CEP module determines all the activities that a student does from the first time he/she enters a subject until the subject's exam. Students can enter other lectures between a lecture and its exam. With the help of the association rules, related lectures of the lectures can be obtained. The sequential actions detected by the CEP module are shown in Figure 4.

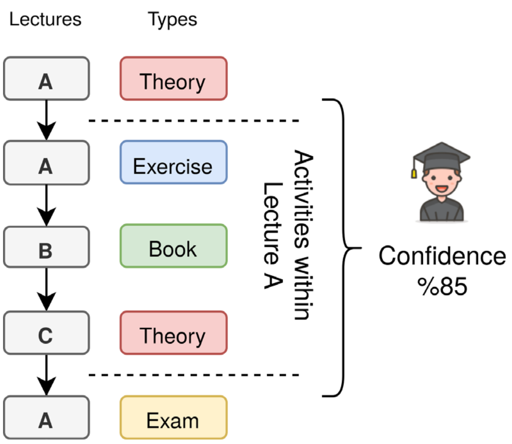


Fig. 4. Extracting ARM Data via CEP Module

Figure 4 shows the activities of a student from the beginning of the lecture A to the subject until he / she takes the exam. While a student was in lecture A, this student also entered the exercise of lecture A, the book of lecture B and the lecture C. This sequence of actions (pattern) is recognized and processed by the CEP module. In this way, with the help of the ARM module, frequent sequences are determined by processing the activities of all students. Assuming that the scenario shown in Figure 4 occurs in the same way on 85 students out of 100 students, this indicates that a student who started the lecture A and solved his/her exercise needs book B and the animation of lecture C with a probability of 0.85. In this way, specific lectures on the e-learning platform can be added to the Rule Engine by extracting the association rules from the materials. Thus, with the help of the CEP module, a student who enters lecture A and solves the exercise of lecture A can be recommended to take a look at lecture B and the lecture C.

The ARM module was developed on Apache Spark using the FP Growth algorithm. Action sequences (patterns) recognized by the CEP module are stored in HDFS. Simultaneously, data is also stored in MongoDB in order to be accessible from the admin panel. With the help of the ARM module, the data in HDFS are obtained every other day on the platform by using Apache Spark. The results are displayed in the admin panel along with the "confidence" values. Association rules displayed in the admin panel can be added as new rules to the Rule Engine managed by experts.

C. *Clustering Module*

On the platform, a clustering module has been developed to examine the students' behavior in different segments. With this clustering module, students are divided into clusters according to their behavior on the platform, such as city, school, classroom and lessons. These behaviors of the students have been extracted by considering their performance in various materials within lectures. The attributes used when creating clusters are mainly: The participation rate of lecture material, the success rate in the exercises, and the overall participation rate.

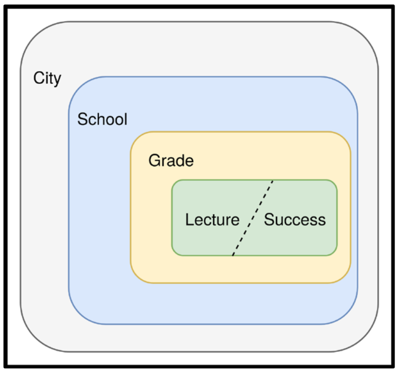


Fig. 5. Macro and Micro Pivots

E-learning platforms can be used for personal use as well as institutional use by public and private schools. Therefore, segments are evaluated with certain pivots instead of all students in the e-learning platform. The segments handled in different pivots are two types: "micro" and "macro". Macro segmentation is done by considering all students in a city or all students enrolled in a school. Micro segmentation is done over the grade levels of the students. In this way, students in different locations, schools and grade levels can be evaluated according to the separate clusters. In addition, all pivots can be created by associating them with the lecture and success rate. Students can be separated by pivots according to their success in certain topics, and differences in behavior between successful and unsuccessful students can be found. Macro and Micro structure, lecture and success divisions are summarized in Figure 5.

Student actions data used in the clustering module is obtained using CEP module. After the lecture exam, the rate of completion of the lecture, the success rate in the exercises, the participation rate of all materials and the success rate in the lecture exam are determined with the data transferred from the Log Parser to the CEP module. The detected behavior data stored on HDFS and MongoDB. Student behavior data on HDFS are processed every other day with the Clustering Module and divided into clusters with pivots.

Considering the data collected every day, it is highly probable that both the increase in data size and the change in data values day by day. Clustering Module has been developed in distributed system architecture to prevent performance from being negatively affected by data increase. Performance results of the Clustering Module running on HDFS and Apache Spark is discussed in the "Performance Evaluation" section. Considering the changes in data amount, different clustering techniques and optimum cluster number finding methods were used. The cluster module gets results with various clustering techniques in distributed system architecture and stores these results in MongoDB. The results stored in MongoDB are visualized in the admin panel.

K-Means, Gaussian Mixture and Bisecting K-Means algorithms are used in the Clustering Module. These algorithms can yield different results in the same data.

Therefore, by evaluating different results, it can be determined clearly which cluster students belong to. Another important point in the clustering module is that the optimum cluster number and optimum seed values can be determined. Accordingly, optimum cluster numbers and optimum seed values are obtained with Elbow and Silhouette methods.

Matplotlib library was used to visualize cluster results. Micro segmentation was performed by using the "Success" and "Course ID" attributes as pivots. A separate clustering was made according to each different value of the "Success" and "Course ID" attributes. The results that have been obtained from the K-Means algorithm by using K-Means & Elbow methods to find optimum seed and optimal cluster number is shown in Figure 6. The different colors in the images show different clusters, and the cross symbols show the centers (centroids) of these clusters. The behavior of students who are successful for a specific lesson can be easily interpreted on the platform from this type of visualization.

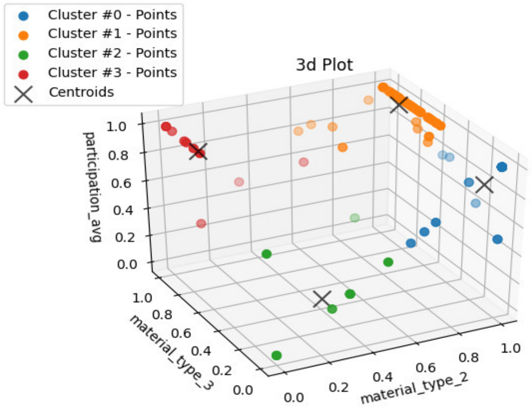


Fig. 6. Example Clustering Result for 3 Features

V. PERFORMANCE EVALUATION

The speed performances of the Clustering Module and ARM modules developed on distributed system architecture have been tested with different data sizes. Performance results of the modules developed using Spark and HDFS were compared on single node and double node machines. Experimental setup of single node and double node is given in Figure 7. System information of master and slave nodes used in performance evaluation is shown in Table 2.

The results of the performance test carried out with the both single and double node HDFS and Spark installation for the ARM module are shown in Figure 8. The data size was increased exponentially from 1 MB to 10 GB, and the speed of completely extracting the association rules was tested through the student behavior data of the ARM module. When the obtained results are examined, 1 MB of data is processed in an average of 9.54 seconds, while 10 GB of data is processed in an average of 519.03 seconds. Considering that the ARM module operates every other day, it can be said that the developed module works with enough performance.

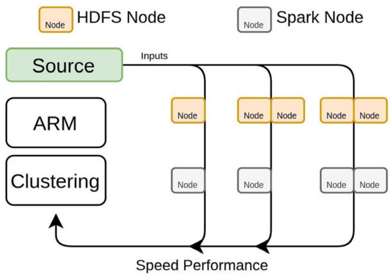


Fig. 7. Experimental Setup of Performance Evaluation

TABLE II. SYSTEM INFORMATION OF NODES

	Master Node	Slave Nodes 1 & 2
Operating System	Ubuntu 18.04.4	
CPU	Intel(R)Core (TM) i5-7200U CPU @ 2.50GHz	
Number of Cores	2	1
Virtual / Physical	Physical	Virtual
Memory	10240 MB	2048 MB
Memory Used	"Not Necessary"	1024 MB

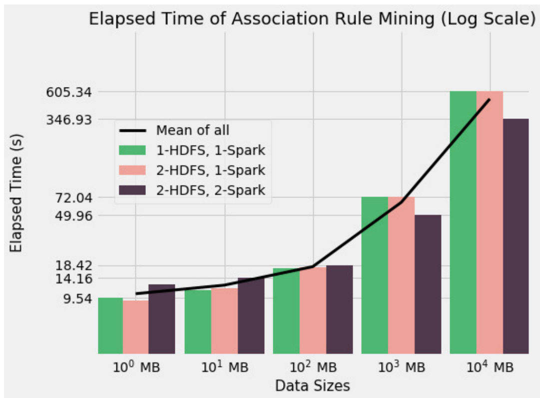


Fig. 8. Performance Results for ARM module on Single and Double Node

As shown in Figure 8, as data grows, the increase in the amount of spark nodes becomes more essential. When data is small, e.g. 1 MB, there is not much difference between single and double nodes. Since HDFS is used for storing data only, changes in the number of nodes running HDFS don't affect the results much. However, if our data is huge and we need stability, then multi-node HDFS would be a good solution. Spark, on the other hand, affects the results significantly. As data grows, its effect can be seen more clearly.

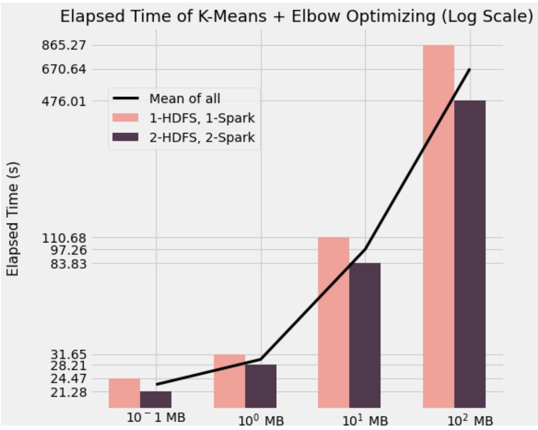


Fig. 9. Performance Results for Clustering Module on Single and Double Node

K-Means Clustering result with datasets 100KB, 1MB, 10MB, 100MB is shown in Figure 9. Figure clearly indicates that as data grows, multi-node processing is getting much more important. Also, when data size is 100MB, although the number of nodes was doubled, the elapsed time decreased by more than twice. This shows the effectiveness of distributed structure.

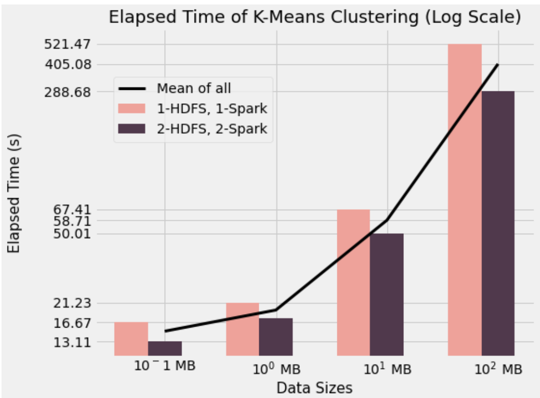


Fig. 10. Performance Results for Optimizing (Finding Optimum Cluster & Seed Values) Module on Single and Double Node

K-Means and Elbow methods are used together to calculate the number of optimum k (number of clusters) and value of initial seeds. Since this is an unsupervised problem and we don't know how many segments are present in our data, optimizing the seeds and k was important. As shown in Figure 10, the rate of data growth directly affects the performance. Also, the cost of optimizing is more than the cost of clustering, because optimizing includes clustering multiple times. Optimizing module has parameters like: "number of seed values trying", "range of amount of k to be tried". When these parameters change, performance results are changed accordingly. In this case, "number of seed values trying" chosen as 3 and "range of amount of k to be tried" chosen as the range between 2 and 5.

VI. Conclusions and Future Studies

In this study, it is aimed to increase student success and improve their learning experiences by using CEP, ARM and Clustering modules. Accordingly, tests were applied on a demo e-learning platform using state-of-the-art technologies. It has developed modules in which students' actions on the system can be monitored and interpreted in real time. Features have been added to the demo e-learning platform for necessary feedback actions such as SMS, E-mail and Pop-up notification. In addition, with ARM and Clustering modules, such tools have been developed that make success-oriented inferences. Thus, students can be analyzed individually.

Besides the developed modules, an admin panel has been developed which the entire e-learning platform and the different features integrated can be controlled. In this way, teachers and experts are provided with the opportunity to review and make changes through an available interface. Thanks to this admin panel, education experts are provided with all possibilities, from the ability to create the patterns obtained in the CEP module to the message to be displayed to the user.

In addition to this study where modules that can detect student behavior data according to certain patterns, create different patterns with the ARM module and divide students into segments, an anomaly detection module can be added in future studies. Thus, it can be determined whether the students exhibit behavior different than expected in their learning processes and action can be taken according to the different situations obtained. Students can also be evaluated through their unexpected behavior during the learning process.

Acknowledgment

This study was supported by Tubitak Teydeb Project ID: 3189164 Grant. We thank Morpa R&D Center for providing the computational facilities and datasets that made this study possible.

References

[1] S. Liaw, H. Huang, and G. Chen, "Surveying instructor and learner attitudes toward e-learning," Computers & Education, vol. 49, no. 4, pp. 1066–1080, 2007.

[2] F. Hussain, "E-learning 3.0 = E-learning 2.0 + Web 3.0?", IADIS International Conference on Cognition and Exploratory Learning in Digital Age, CELDA (Report Paper) , 2012.

[3] S. B. Aher, L.M.R.J. Lobo, "Best Combination of Machine Learning Algorithms for Course Recommendation System in E-learning", International Journal of Computer Applications, 41(6) , 2012.

[4] D. C. Luckham, "The Power of Events: An Introduction to Complex Event Processing in Distributed Enterprise Systems", Addison-Wesley Longman Publishing Co., Inc., Boston, MA, 2001.

[5] G. Cugola and A. Margara, "Processing flows of information," ACM Computing Surveys, vol. 44, no. 3, pp. 1–62, 2012.

[6] N. Mehdiyev, J. Krumeich, D. Enke, D. Werth, and P. Loos, "Determination of Rule Patterns in Complex Event Processing Using Machine Learning Techniques," Procedia Computer Science, vol. 61, pp. 395–401, 2015.

[7] S. Chen, J. Jeng, and H. Chang, "Complex Event Processing using Simple Rule-based Event Correlation Engines for Business Performance Management," The 8th IEEE International Conference on E-Commerce Technology and The 3rd IEEE International Conference on Enterprise Computing, E-Commerce, and E-Services (CEC/EEE'06), 2006.

[8] F. Esposito, O. Licchelli, G. Semeraro, "Discovering Student Models in e-learning Systems", Journal of Universal Computer Science, 10 (1), pp. 47-57, 2004.

[9] R. Sison, M. Shimura, "Student Modeling and Machine Learning", International Journal of Artificial Intelligence in Education (IJAIED), 1998 , 9, pp.128-158, 2008.

[10] N. Thai-Nghe, T. Horvath, L. Schmidt-Thieme, "Factorization models for forecasting student performance", Proceedings of the 4th international conference on educational data mining, Eindhoven, The Netherlands, July 62011

[11] K. Pliakos, S.-H. Joo, J. Y. Park, F. Cornillie, C. Vens, and W. V. D. Noortgate, "Integrating machine learning into item response theory for addressing the cold start problem in adaptive learning systems," Computers & Education, vol. 137, pp. 91–103, 2019.

[12] M. Hussain, W. Zhu, W. Zhang, S. M. R. Abidi, and S. Ali, "Using machine learning to predict student difficulties from learning session data," Artificial Intelligence Review, vol. 52, no. 1, pp. 381–407, 2018.

[13] J. Roldán, J. Boubeta-Puig, J. L. Martínez, and G. Ortiz, "Integrating complex event processing and machine learning: An intelligent architecture for detecting IoT security attacks," Expert Systems with Applications, vol. 149, p. 113251, 2020.

[14] M. Cesarini, M. Monga, and R. Tedesco, "Carrying on the e-learning process with a workflow management engine," Proceedings of the 2004 ACM symposium on Applied computing - SAC '04, 2004.

[15] O. Zaiane, "Building a recommender agent for e-learning systems," International Conference on Computers in Education, 2002. Proceedings., 2002.

16 D. Jin, S. Shi, Y. Zhang, H. Abbas, and T.-T. Goh, “A complex event processing framework for an adaptive language learning system,” Future Generation Computer Systems, vol. 92, pp. 857–867, 2019.

17 Jung, J., Park H., 2020. SAX-ARM: Deviant event pattern discovery from multivariate time series using symbolic aggregate approximation and association rule mining, Expect Systems with Applications, 141, https://doi.org/10.1016/j.eswa.2019.112950

18 K. Vougas, T. Sakellaropoulos, A. Kotsinas, G.-R. P. Foukas, A. Ntargaras, F. Koinis, A. Polyzos, V. Myrianthopoulos, H. Zhou, S. Narang, V. Georgoulias, L. Alexopoulos, I. Aifantis, P. A. Townsend, P. Sfikakis, R. Fitzgerald, D. Thanos, J. Bartek, R. Petty, A. Tsirigos, and V. G. Gorgoulis, “Machine learning and data mining frameworks for predicting drug response in cancer: An overview and a novel in silico screening process based on association rule mining,” Pharmacology & Therapeutics, vol. 203, p. 107395, 2019.

19 Baeth, M.J. et al. (2019). Detecting misinformation in social networks using provenance data, CONCURR COMP-PRACT E, 31(3).

20 Baeth M. J. et al. (2018) An approach to custom privacy policy violation detection problems using big social provenance data, CONCURR COMP-PRACT E, 30(21).

21 Baeth, M.J. et al. (2017). Detecting misinformation in social networks using provenance data, SKG-17.

22 Baeth, M.J. et al. (2015). On the Detection of Information Pollution and Violation of Copyrights in the Social Web, SOCA-15.

23 Dundar, B. et al. (2016) A Big Data Processing Framework for Self Healing Internet of Things Applications, SKG-16.

24 Aktas, M.S. et al. (2019), Provenance aware run-time verification of things for selfhealing Internet of Things applications, CONCURR COMP-PRACT E, DOI: 10.1002/cpe.4263.

25 Aktaş M.S., (2018) Hybrid cloud computing monitoring software architecture, CONCURR COMP-PRACT E, 30(21).

26 Aktas M.S. (2019) Detecting Complex Events With Real Time Monitoring Infrastructure On Event-Based Systems, Pamukkale Univ Muh Bilim Derg. 2019; 25(2): 199-207.

27 Fox, G. et al. (2006). Real Time Streaming Data Grid Applications. Distributed Cooperative Laboratories: Networking, Instrumentation, and Measurements. Editors: Davoli, F. Plazzo, S, Zappatore, S., pp. 253-267.

28 Riveni, M. et al. (2019). Application of provenance in social computing: A case study, CONCURR COMP-PRACT E, 31(3).

29 Tas, Y. et al. (2016) An Approach to Standalone Provenance Systems for Big Provenance Data, SKG-16.

30 Aktas M.S. et al. (2010). High performance hybrid information service architecture, CONCURR COMP-PRACT E, 22(15).

31 Aktas M.S., et al. (2008) XML metadata services, CONCURR COMP-PRACT E, 20 (7).

32 Aktas, M.S. et al. (2007). Fault tolerant high-performance Information Services for dynamic collections of Grid and Web services, FUTURE GENER COMP SY, 23(3).

33 Pierce, M.E. et al. (2008). The QuakeSim project: Web services for managing geophysical data and applications, PURE APPL GEOPHYS, 165(3-4).

34 Aydin, G. et al. (2005). SERVOGrid complexity computational environments (CCE) integrated performance analysis, GRID-05.

35 Aktas, M. et al. (2006). iSERVO: Implementing the International Solid Earth Research Virtual Observatory by Integrating Computational Grid and Geographical Information Web Services, PURE APPL GEOPHYS, 163(11-12).

36 Aydin, G. et al (2008). Building and applying geographical information system Grids, CONCURR COMP-PRACT E, 20 (14).

37 Oh, S. et al. (2010) Mobile Web Service Architecture Using Context-store, KSII T Internet Info, Volume 4.

38 Nacar, M.A. et al. (2007) VLab: collaborative Grid services and portals to support computational material science, CONCURR COMP-PRACT E, 19 (12).

39 Aktas, M.S. et al. (2004). A web based conversational case-based recommender system for ontology aided metadata discovery, GRID-04, pp:69-75.

40 Aktas, M, (2007) A Federated Approach to Information Management in Grids. INT J WEB SERV RES, 7(1).

41 Fox, G. et al, (2006) Grids for real time data applications. Parallel Processing and Applied Mathematics, Vol:3911, Book Editors: Wyrzykowski, R and Dongarra, J and Meye, N and Wasniewski, J.

Position Papers of the Federated Conference on Computer Science and Information Systems pp. 45–49
DOI: 10.15439/2020F123
ISSN 2300-5963 ACSIS, Vol. 22

Improving unloading time prediction for Vehicle Routing Problem based on GPS data

Emir Žunić [1,2], Amar Kurić [3,1], Sead Delalić [3,1]
[1]Info Studio d.o.o., Sarajevo, Bosnia and Herzegovina
[2]Faculty of Electrical Engineering at University of Sarajevo, Bosnia and Herzegovina
[3]Faculty of Science at University of Sarajevo, Bosnia and Herzegovina
emir.zunic@infostudio.ba, amar.kuric@pmf.unsa.ba, delalic.sead@pmf.unsa.ba

***Abstract*—The problem of transport optimization is of great importance for the successful operation of distribution companies. To successfully find routes, it is necessary to provide accurate input data on orders, customer location, vehicle fleet, depots, and delivery restrictions. Most of the input data can be provided through the order creation process or the use of various online services. One of the most important inputs is an estimate of the unloading time of the goods for each customer. The number of customers that the vehicle serves during the day directly depends on the time of unloading. This estimate depends on the number of items, weight and volume of orders, but also on the specifics of customers, such as the proximity of parking or crowds at the unloading location. Customers repeat over time, and unloading time can be calculated from GPS data history. The paper describes the innovative application of machine learning techniques and delivery history obtained through a GPS vehicle tracking system for a more accurate estimate of unloading time. The application of techniques gave quality results and significantly improved the accuracy of unloading time data by 83.27% compared to previously used methods. The proposed method has been implemented for some of the largest distribution companies in Bosnia and Herzegovina.**

Keywords— GPS tracking, GPS data analysis, Vehicle Routing Problem, Machine Learning

I. Introduction

THE problem of transport routes optimization and optimal utilization of the transport fleet is a researched problem which is constantly and continuously researched due to its importance. The Vehicle Routing Problem (VRP) is a class of problems in which it is necessary to find the optimal route by which a vehicle from an available vehicle fleet visit the number of customers (delivery points), starting from the central depot and returning to the same location after the completion of customer service. The optimal route is primarily the one with the minimum cost of serving all customers [1]. These optimization problems become extremely complex if a large number of customers need to be served. If many real limitations are added, such as customer time windows, goods unloading times, ways of packing goods in vehicles, predefined capacity, working hours and diverse vehicle fleet, fixed and variable vehicle costs, these problems become a real challenge to solve. These limitations drastically reduce the number of available approaches, models and algorithms that could be applied to a complex set of input data.

With the progress of logistics processes in the early 1950s [1], there has been a large amount of research focusing on their various applications. The importance of logistics management has grown significantly in recent years with the globalization of this process. Logistics tries to optimize existing distribution processes. One of the most important elements in logistics chains is the transport system. According to numerous studies, transport accounts for a third of the total logistics cost, and transport systems significantly affect the performance of the complete logistics system. Transport is necessary in the complete process of production of goods, from production to delivery of goods to end customers. Only in the case of good coordination between all components it is possible to get the maximum benefit for distributors and manufacturers. Without a well-developed transport system, logistics planning cannot reach its full potential. Therefore, it is indisputable that quality transport systems can increase efficiency, reduce operating costs, and increase the quality of service. Success in solving the problem of vehicle routing can significantly improve the processes in the transport part of each company's business.

In order for any system for optimization of transport routes to be usable by a certain company, it is necessary to determine the appropriate input parameters of the algorithm (as accurately as possible), such as parameters for customers, vehicles, restrictions, etc. One of the most important parameters that is very difficult to determine is the time of service (unloading of goods) for each customer. For these purposes, an approximate method of determining the time of unloading was proposed in [2] [3], which is based on a relation that depends on the number of ordered items, weight and volume of the customer's order. However, a real example of a distribution company has shown that this parameter can vary significantly, and that it can be determined more accurately based on the analysis of available historical GPS data and modern machine learning methods. The time of unloading is determined more realistically for each customer, whereby several modern machine learning algorithms have been implemented. After that, the voting system selects the results with the highest reliability. The resulting unloading time then becomes the part of the implemented transport optimization system, and the final transport routes are fully feasible in a real environment, which is the most important fact for any company whose transport is an integral segment. These facts were the motivation to implement several algorithms for more accurate determination of unloading time, and compare the results. On the other hand, in most scientific research in the field of solving VRP problems, this parameter is taken as known in advance, which is not a common case in the real-world application.

The paper consists of five sections. In this first section, an introduction is presented with a defined problem and motivation for solving it. Section 2 presents a detailed review of the research literature. In the third section, the implementation and used techniques are presented and described in detail, while in the fourth section, the obtained results are presented. In the last section, the conclusions of the paper are presented, as well as guidelines for future research.

II. Related Work

The Vehicle Routing Problem belongs to a class of NP-hard problems. This means that no deterministic algorithm will provide an optimal solution in real time. Over the years, many heuristic algorithms have been developed for different variations of the problem. The paper [4] describes the results of research over 50 years in the field of vehicle routing. In [5], different metaheuristic approaches for solving the VRP have been described. In papers [6] and [7], recent progress in the field is described. Many different approaches and algorithms have been widely used, such as: Simulated annealing [8], Tabu search [9], Genetic algorithm [10], Bat algorithm [11], Firefly algorithm [12] etc. When solving the vehicle routing problem, it is necessary to adjust a number of parameters and input data for the algorithm, which can be a difficult problem for real application [3].

In the paper [13], the concept of a smart warehouse management system is described, which is based on a series of optimization algorithms and the application of historical data to improve business. However, for the successful operation of distribution companies, it is necessary to optimize the operation of all segments, which especially refers to transport as one of the most expensive operations.

The idea of using GPS and geographic data from history for optimization processes permeates other scientific and industrial fields, such as the music and event planning industry [14], [15], social event detection [16], or even coronavirus tracking [17] etc.

In [18], the methods for improving the performance of the vehicle routing algorithms based on the GPS data have been described. In the same paper, the algorithm for using the GPS data to detect deliveries is described. When using the GPS data, it is necessary to ensure the accuracy. In [19], the innovative algorithm for anomaly detection in GPS data is described. The algorithm is inspired by the QRS complex detection algorithms in ECG signals.

III. Case study

The desired functionality is realised through four stages, each of which is delegated to a separate module: `data_preparation`, `model_building`, `prediction`, `service`. The figure 1 contains a diagram describing the means by which these components interact with one another as well as with the database and the client utilizing the service. What follows afterwards is an overview of their implementation and their respective roles in the system.

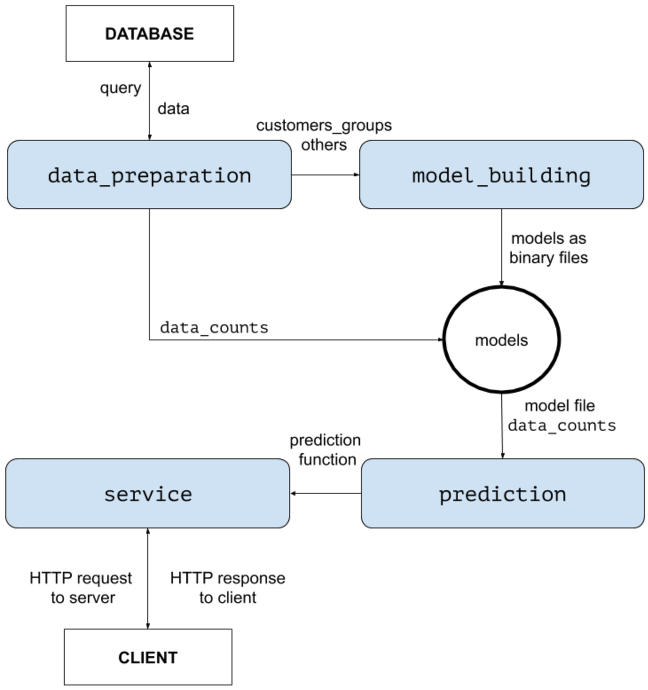


Figure 1: Schematic depiction of application workflow

The `data_preparation` step is mainly responsible for fetching required data from the database. Each fetched record contains the following for a particular delivery: customer's numeric ID, number of articles, total weight, total volume and time of unloading. A delivery fulfills a customer's order. Orders are also present in the database. Every order contains one or more articles each having a weight and a volume. The total weight of a delivery is the sum of the individual weights of all articles within the corresponding order. The total volume is obtained in the same manner. The unloading time is calculated based on the GPS history data. The algorithm calculates the length of all stops in customer's range. If one stop belongs to more than one customer, the unloading time is proportionally divided by the estimated unloading time for each customer in range. The detailed algorithm for unloading time detection from GPS data is described in [18].

Since inspection of data uncovered a number of undoubtedly incorrect records, they are removed from the pool using a criterion of either an impossibly low weight-to-volume ratio or an impossibly high time of unloading. After this, the number of records for each respective customer is extracted and saved as `data_counts`. In addition, this module defines the minimum number of data points a customer must have available for a separate model to be built for them. All customers with less data points are aggregated in the `others` object, so a single model can be built. This choice was made to prevent building models on too few data points. The grouping of the original query result by customer ID is stored in `customers_groups`.

The `model_building` module builds required models based on data processed in the previous stage. Algorithm 1 outlines the procedure.

Algorithm 1: Model-building

```
estimators=estimators to test;
params=parameters to test for each estimator;
foreach customer ∈ customers_iter do
    cv=appropriate cross-validation method;
    scoring=neg_root_mean_square_error;
    best_estimator=None;
    best_score=-∞;
    scaler=None;
    foreach est ∈ estimators do
        current_scaler=None;
        if est needs scaling then
            current_scaler=scaler object;
            scale inputs using current_scaler;
        find parameter from params[est] which
          maximises scoring metric;
        current_best=score for found parameter;
        if current_best>best_score then
            best_estimator=est;
            best_score=current_best;
            scaler=current_scaler;
    end
    save best_estimator, scaler, best_score to file in
      "models" directory;
end
```

At the time of writing, estimators being considered are linear regression, ridge regression, lasso regression, `K` nearest neighbors regression, random forest regression and SVM regression (using linear kernel).

Cross-validation method is selected based on the number of data points for a given customer: leave-one-out is used if less than 60 are available and 10-fold cross-validation otherwise. Root mean square error is chosen as a criterion to compare models for two reasons. First, the objective is to maximise predictive power. Second, r2, a frequently used scoring metric, is a measure of the reduction in variance accounted for by the independent variables and is, as such, extremely sensitive to outliers at low numbers of data points. Moreover, given that certain models require all input variables to be equally scaled, it is necessary to perform normalization prior to model evaluation. Several known normalization methods were tested during development leading to a conclusion that this selection has no significant impact on model performance. A method which utilizes quartiles was chosen due to its resilience to outliers. The reason for not fully removing outliers is the difficulty of detecting them caused by the absence of sufficient data points per customer necessary to assess the distribution of input variables. The large quantity of customers in the database prompt the model-building process to be a lengthy one. Hence, it is scheduled to automatically execute on a weekly basis, and the resulting models are stored as binary files. The accompanying normalizing method, as well as the root mean squared error and the r2 score, are stored along with the best-performing model for each customer.

The `prediction` module implements a prediction function which, for a given customer ID, number of articles, total weight and volume of delivery, returns the predicted value of unloading time, the number of data points the prediction is based on and a 1-10 score quantifying the confidence in the prediction. Number of data points is obtained from the `data_counts` file. This is done since records generated later than the most recent model building do not need to be considered. The corresponding model object is obtained from its binary file. Normalization is performed on passed arguments if demanded by the model. Confidence score is calculated based on the r2 and root mean squared error also contained in the model object in the following manner. The intervals $[0, 1]$ and $[0, 12]$ are divided linearly into 10 segments. The r2 score is assigned a 1-10 score on the basis of the segment it belongs to. Similarly, the root mean squared error is assigned a 1-10 score as well. In both cases, a greater score corresponds to a better performing model. These two scores are then averaged (at the time of writing, both are assigned an equal weight of 0.5) which produces the final confidence score. Confidence is established by the use of two different evaluation metrics since inspection of results discovered that, while both are indicative of predictive power, they do not necessarily correlate with one another.

The final component (`service`) provides an interface for services which other components can use. A HTTP request is made containing the customer ID, number of articles, total weight and volume of delivery as parameters. The response contains the result of the prediction function in JSON format. This service can be used as a part of the VRP solver.

IV. Results and discussion

Slow accumulation of data points per customer proved to be the main difficulty for every aspect of development, result collection and analysis included. For this purpose, several model files generated by a previous execution of the model-building module were saved. At a later time, the database was queried for the data required for predictions. Therefore, the data contains records that were not present at the time of model-building execution. This section will briefly discuss the results of applying the saved models to (at the time of writing) up to date data for two particular customers.

Figures 2 and 3 show scatter plots depicting the relationship of each input feature (number of articles, total weight and total volume) to the dependent variable (time of unloading) for each customer separately. In the case of Customer 1, a clear and fairly strong linear relationship can be recognized. The algorithm selected linear regression as the best-performing model. The absence of a linear relationship regarding Customer 2 is also reflected in the algorithm's model choice - in this case, random forest regression was selected. In both instances, the models yielded satisfactory results: root mean squared error of 6.12 and 4.05 minutes for customers 1 and 2 respectively. These values are not significantly higher than the respective errors for data sets the models were built on (as a matter of fact, the mean error for customer 2 decreased with the addition of new records), indicating that the models were not overfit.

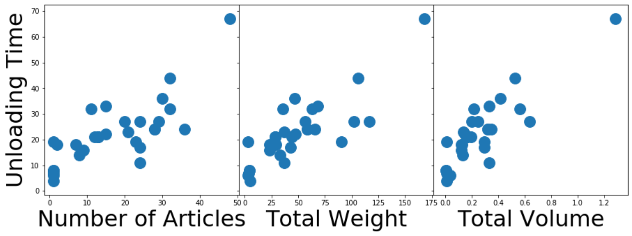


Figure 2: Scatter plots for customer 1

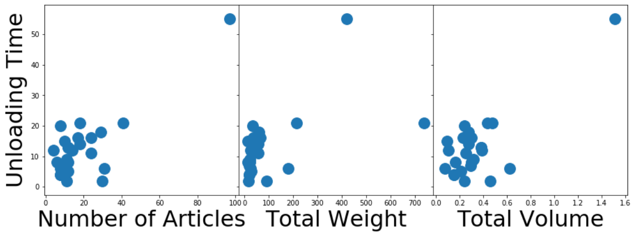


Figure 3: Scatter plots for customer 2

Table I summarises the results of a larger-scale test. It was conducted in a similar manner to two previously discussed customer-specific tests. Models built during development for the 33 customers with the most records were saved and applied to up to date data. A prediction is deemed accurate if it differed from the correct value by either no more than 3 minutes or no more than 20%. Percentage of improved results refers to the percentage of instances in which the algorithm yielded a better result than the previously used prediction formula described in [20]. That formula is obtained on the experimental way and depends of several parameters for each customer: (i) Number of articles, (ii) Total ordered volume, (iii) Total ordered weight, and (iv) Predefined unloading time constant. The correction factor is added after the calculation of the unloading time, and it is determined based on the previously available historical data for the appropriate customer. In the cases where the algorithm was outperformed by formula, the differences in predictive power were significantly smaller than those in cases where the algorithm performed better. It is expected that the accuracy will increase with time, so it can be stated that this approach gave significantly better results compared to the previous one.

It is worth noting that the process of estimating unloading time from GPS data itself uses the predictions: when a vehicle makes a single stop in close proximity to multiple customers and serves them, the total time expended is divided among these customers in proportion to their predicted unloading times. There is thus reason to believe that further improvement of predictions will lead to more accurate estimates in the database.

TABLE I: RESULTS

Property	**Value**
Number of models built	33
Min. number of data points	19
Max. number of data points	38
Total number of data points	807
Percentage of improved results	**83.27%**
Percentage of accurate predictions	63.57%

V. CONCLUSION AND FUTURE WORK

The paper describes an innovative way to improve the vehicle routing process. Improvement is achieved by analyzing GPS data and earlier deliveries. The obtained data were used with modern machine learning techniques, which improved the estimation of unloading time at customers. Based on the customer data, weight, volume and number of items in the order, an estimate of unloading time is created which is used as input data to resolve the VRP.

The described technique is used as part of the transport management system for some of the largest distribution companies in Bosnia and Herzegovina, and improvements over the standard statistical estimate are noticeable. Therefore, research in this area can significantly improve the vehicle fleet routing process.

In the future, it is planned to implement additional parameters to create the model, such as dispatcher and driver feedback for the estimated time, and a number of others improvements.

REFERENCES

[1] Dantzig, G. B., and Ramser, J. H. (1959). The truck dispatching problem. Management science, Vol. 6(1), 80-91. doi: 10.1287/mnsc.6.1.80
[2] Žunić, E., Đonko, D., and Buza., E. (2020). An adaptive data-driven approach to solve real-world vehicle routing problems in logistics. Complexity. Hindawi. doi: 10.1155/2020/7386701
[3] Žunić, E., and Đonko, D. (2019, September). Parameter setting problem in the case of practical vehicle routing problems with realistic constraints. In 2019 Federated Conference on Computer Science and Information Systems (FedCSIS) (pp. 755-759). IEEE. doi: 10.15439/2019F194
[4] Laporte, G. (2009). Fifty years of vehicle routing. Transportation science, 43(4), 408-416. doi: 10.1287/trsc.1090.0301
[5] Gendreau, M., Laporte, G., and Potvin, J. Y. (2002). Metaheuristics for the capacitated VRP. In The vehicle routing problem (pp. 129-154). Society for Industrial and Applied Mathematics. doi: 10.1137/1.9780898718515.ch6
[6] Braekers, K., Ramaekers, K., and Van Nieuwenhuyse, I. (2016). The vehicle routing problem: State of the art classification and review. Computers Industrial Engineering, 99, 300-313. doi: 10.1016/j.cie.2015.12.007
[7] Osaba, E., Yang, X. S., and Del Ser, J. (2020). Is the Vehicle Routing Problem Dead? An Overview Through Bioinspired Perspective and a Prospect of Opportunities. In Nature-Inspired Computation in Navigation and Routing Problems (pp. 57-84). Springer, Singapore. doi: 10.1007/978-981-15-1842-3_3
[8] Chiang, W. C., and Russell, R. A. (1996). Simulated annealing metaheuristics for the vehicle routing problem with time windows. Annals of Operations Research, 63(1), 3-27. doi: 10.1007/BF02601637
[9] Gendreau, M., Hertz, A., and Laporte, G. (1994). A tabu search heuristic for the vehicle routing problem. Management science, 40(10), 1276-1290. doi: 10.1287/mnsc.40.10.1276

[10] Baker, B. M., and Ayechew, M. A. (2003). A genetic algorithm for the vehicle routing problem. Computers Operations Research, 30(5), 787-800. doi: 10.1109/ICECTECH.2010.5479956

[11] Osaba, E., Yang, X. S., Fister Jr, I., Del Ser, J., Lopez-Garcia, P., and Vazquez-Pardavila, A. J. (2019). A discrete and improved bat algorithm for solving a medical goods distribution problem with pharmacological waste collection. Swarm and evolutionary computation, 44, 273-286. doi: 10.1016/j.swevo.2018.04.001

[12] Osaba, E., Yang, X. S., Diaz, F., Onieva, E., Masegosa, A. D., and Perallos, A. (2017). A discrete firefly algorithm to solve a rich vehicle routing problem modelling a newspaper distribution system with recycling policy. Soft Computing, 21(18), 5295-5308. doi: 10.1007/s00500-016-2114-1

[13] Žunić, E., Delalić, S., Hodžić, K., Beširević, A., and Hindija, H. (2018, November). Smart warehouse management system concept with implementation. In 2018 14th Symposium on Neural Networks and Applications (NEUREL) (pp. 1-5). IEEE. doi: 10.1109/NEUREL.2018.8587004

[14] Delalić, S., Chahin, M., and Alihodžić, A. (2019, October). Optimal City Selection and Concert Tour Planning Based on Heuristic Optimization Methods and the Use of Social Media Analytics. In 2019 XXVII International Conference on Information, Communication and Automation Technologies (ICAT) (pp. 1-6). IEEE. doi: 10.1109/ICAT47117.2019.8939040

[15] Delalić, S., Alihodžić, A., and Selmanović, E. (2019, October). Innovative Usage of Online Platforms Analytics on Event Planning based on the Genetic Algorithm with Greedy Approach. In 2019 XXVII International Conference on Information, Communication and Automation Technologies (ICAT) (pp. 1-6). IEEE. doi: 10.1109/ICAT47117.2019.8938919

[16] Zhou, X., and Chen, L. (2014). Event detection over twitter social media streams. The VLDB journal, 23(3), 381-400. doi: 10.1007/s00778-013-0320-3

[17] Vaughan, A. (2020). Tracking down coronavirus. doi: 10.1016/S0262-4079(20)30834-4

[18] Žunić, E., Hindija, H., Beširević, A., Hodžić, K., and Delalić, S. (2018, November). Improving Performance of Vehicle Routing Algorithms using GPS Data. In 2018 14th Symposium on Neural Networks and Applications (NEUREL) (pp. 1-4). IEEE. doi: 10.1109/NEUREL.2018.8586982

[19] Žunić, E., Delalić, S., Hodžić, K., and Tucaković, Z. (2019, July). Innovative GPS Data Anomaly Detection Algorithm inspired by QRS Complex Detection Algorithms in ECG Signals. In IEEE EUROCON 2019-18th International Conference on Smart Technologies (pp. 1-6). IEEE. doi: 10.1109/EUROCON.2019.8861619

[20] Žunić, E., Delalić, S., and Đonko, Dž. (2020). Adaptive multi-phase approach for solving the realistic vehicle routing problems in logistics with innovative comparison method for evaluation based on real GPS data. Transportation Letters. doi: 10.1080/19427867.2020.1824311

Joint 40^{th} IEEE Software Engineering Workshop and 7th International Workshop on Cyber-Physical Systems

THE IEEE Software Engineering Workshop (SEW) is the oldest Software Engineering event in the world, dating back to 1969. The workshop was originally run as the NASA Software Engineering Workshop and focused on software engineering issues relevant to NASA and the space industry. After the 25^{th} edition, it became the NASA/IEEE Software Engineering Workshop and expanded its remit to address many more areas of software engineering with emphasis on practical issues, industrial experience and case studies in addition to traditional technical papers. Since its 31^{st} edition, it has been sponsored by IEEE and has continued to broaden its areas of interest.

One such extremely hot new area are Cyber-physical Systems (CPS), which encompass the investigation of approaches related to the development and use of modern software systems interfacing with real world and controlling their surroundings. CPS are physical and engineering systems closely integrated with their typically networked environment. Modern airplanes, automobiles, or medical devices are practically networks of computers. Sensors, robots, and intelligent devices are abundant. Human life depends on them. CPS systems transform how people interact with the physical world just like the Internet transformed how people interact with one another.

The joint workshop aims to bring together all those researchers with an interest in software engineering, both with CPS and broader focus. Traditionally, these workshops attract industrial and government practitioners and academics pursuing the advancement of software engineering principles, techniques and practices. This joint edition will also provide a forum for reporting on past experiences, for describing new and emerging results and approaches, and for exchanging ideas on best practice and future directions.

Topics

The workshop aims to bring together all those with an interest in software engineering. Traditionally, the workshop attracts industrial and government practitioners and academics pursuing the advancement of software engineering principles, techniques and practice. The workshop provides a forum for reporting on past experiences, for describing new and emerging results and approaches, and for exchanging ideas on best practice and future directions.

Topics of interest include, but are not limited to:

- Experiments and experience reports
- Software quality assurance and metrics
- Formal methods and formal approaches to software development
- Software engineering processes and process improvement
- Agile and lean methods
- Requirements engineering
- Software architectures
- Design methodologies
- Validation and verification
- Software maintenance, reuse, and legacy systems
- Agent-based software systems
- Self-managing systems
- New approaches to software engineering (e.g., search based software engineering)
- Software engineering issues in cyber-physical systems
- Real-time software engineering
- Safety assurance & certification
- Software security
- Embedded control systems and networks
- Software aspects of the Internet of Things
- Software engineering education, laboratories and pedagogy
- Software engineering for social media

Technical Session Chairs

- **Bowen, Jonathan,** Museophile Ltd., United Kingdom
- **Hinchey, Mike** (Lead Chair), Lero-the Irish Software Engineering Research Centre, Ireland
- **Szmuc, Tomasz,** AGH University of Science and Technology, Poland
- **Zalewski, Janusz,** Florida Gulf Coast University, United States

Program Committee

- **Ait Ameur, Yamine,** IRIT/INPT-ENSEEIHT, France
- **Banach, Richard,** University of Manchester, United Kingdom
- **Challenger, Moharram**
- **Cicirelli, Franco,** Universita della Calabria, Italy
- **Ehrenberger, Wolfgang,** Hochschule Fulda, Germany
- **Gomes, Luis,** Universidade Nova de Lisboa, Portugal
- **Gracanin, Denis,** Virginia Tech, United States

- **Havelund, Klaus,** Jet Propulsion Laboratory, California Institute of Technology, United States
- **Hsiao, Michael,** Virginia Tech, United States
- **Nesi, Paolo,** DSI-DISIT, University of Florence, Italy
- **Pullum, Laura,** Oak Ridge National Laboratory, United States
- **Sanden, Bo,** Colorado Technical University, United States
- **Sekerinski, Emil,** McMaster University, Canada
- **Sojka, Michal,** Czech Technical University, Czech Republic
- **Trybus, Leszek,** Rzeszow University of Technology, Poland
- **van Katwijk, Jan,** Delft University of Technology, The Netherlands
- **Vardanega, Tullio,** University of Padova, Italy
- **Velev, Miroslav,** Aries Design Automation, United States
- **Zhu, Huibiao,** Software Engineering Institute - East China Normal University

Position Papers of the Federated Conference on Computer Science and Information Systems pp. 53–57
DOI: 10.15439/2020F203
ISSN 2300-5963 ACSIS, Vol. 22

An Architectural Design for Measurement Uncertainty Evaluation in Cyber-Physical Systems

Wenzel Pilar von Pilchau*, Varun Gowtham||, Maximilian Gruber‡, Matthias Riedl†, Nikolaos-Stefanos Koutrakis¶, Jawad Tayyub§, Jörg Hähner*, Sascha Eichstädt‡, Eckart Uhlmann¶, Julian Polte¶, Volker Frey§ and Alexander Willner||

*University of Augsburg, Augsburg, Germany, Organic Computing Group

‡PTB, Berlin, Germany, Presidential Staff

¶Fraunhofer IPK, Berlin, Germany, Production Machines and System Management

†ifak e.V., Magdeburg, Germany, ICT & Automation

§Endress + Hauser, Maulburg, Germany, Technology Development

||Fraunhofer FOKUS, Berlin, Germany, Open Communication Systems

***Abstract*—Several use cases from the areas of manufacturing and process industry, require highly accurate sensor data. As sensors always have some degree of uncertainty, methods are needed to increase their reliability. The common approach is to regularly calibrate the devices to enable traceability according to national standards and Système International (SI) units - which follows costly processes. However, sensor networks can also be represented as Cyber Physical Systems (CPS) and a single sensor can have a digital representation (Digital Twin) to use its data further on. To propagate uncertainty in a reliable way in the network, we present a system architecture to communicate measurement uncertainties in sensor networks utilizing the concept of Asset Administration Shells alongside methods from the domain of Organic Computing. The presented approach contains methods for uncertainty propagation as well as concepts from the Machine Learning domain that combine the need for an accurate uncertainty estimation. The mathematical description of the metrological uncertainty of fused or propagated values can be seen as a first step towards the development of a harmonized approach for uncertainty in distributed CPS in the context of Industrie 4.0. In this paper, we present basic use cases, conceptual ideas and an agenda of how to proceed further on.**

***Index Terms*—sensor networks, measurement uncertainty, Cyber-Physical Systems, Industrie 4.0, IIoT, digital twin, asset administration shell, edge computing**

I. Introduction

THE GOAL of Industrie 4.0 (I4.0) is to drive the formation of an automated factory with cooperation from Cyber Physical Systems (CPS). I4.0, in other words, is aiming to close the gap between the contrasting worlds of Operation Technology (OT) and the Information Technology (IT). The field of OT predominantly addresses the field of manufacturing and process industry concerning the operation of manufacturing assets such as machines and process knowledge and intends to automate such processes through the means of computing systems keeping safety, reliability and economy. The IT intends to make OT more efficient and transparent by using and adapting concepts of data processing and enable new business models.

To this end, the concept of a Digital Twin (DT) aims to create a virtual representation/twin of a physical asset, such that a DT can be used by professionals on the IT side to comprehend field level complexities of the machine.

In a control loop sequence comprising of "sense-decide-actuate", the sensing stage requires that sensors measuring physical properties are reliable and available. The reliability of a sensor can be established by a calibration traceable to a known reference and based on Système International (SI) units. As a result, a measurement uncertainty can be associated with the measured values from that sensor. This is one of the core principles in the field of metrology - measurement science. Establishing reliability of CPS thus requires integrating metrological principles in the data life-cycle from the physical measurement to the Digital Twin and the operational decisions in I4.0. This raises several challenges also for metrology institutes, see [1].

The intent of this paper is to propose a reference architecture for the purpose of representing physical sensing devices as their digital counterparts. We propose a system which:

1) Harvests sensor data from calibrated and reliable sensors through edge devices.
2) Enriches the data by adding several other non-reliable sensors in order to extend the dimensions of measurement through sensor fusion.
3) Pre-processes the sensor data to record characteristics for the purpose of building a mathematical model of the sensor.
4) Transforms the mathematical model to a digital twin of the sensor.

To quantify the quality of features generated by the application of complex procedures to measurement values, the sensor uncertainty needs to be propagated by specialized approaches. In the field of metrology many methods do exist, but so far aren't available for direct and easy application in I4.0

and CPS. To bridge this gap, methods and sensors will be encapsulated as agents, providing modular and uncertainty-aware functionality that is abstracted from the user. Each sensor agent communicates with other agents - forming a multi-agent-system. From a higher perspective these agents represent a DT of the actual sensor network. A standardized communication along the whole supply chain is organized in an Asset Administration Shell (AAS).

In this work-in-progress paper we present our state of development alongside the presentation of our ideas and some concepts how to proceed further on. We present an architectural design for the identification and propagation of measurement uncertainties in CPSs, especially in sensor networks. Therefore, we use the concepts of DTs and AASs and combine them with methods from the domain of Organic Computing (OC).

The remainder of the paper is structured as follows. We give a brief overview of related work in Section II. In the subsequent Section III we present our use cases, a first architectural design and sketch the planned evaluation phase. The paper is closed with a short summary in Section IV.

II. Related Work

In order to place the contribution of the paper in context and identify the gap the work is intended to fill, we provide a short literature survey.

In the field of I4.0, academic articles propose directions that can be taken to enable digitization of factories through the use of DTs and applying the Edge Computing (EC) paradigm. Modeling concepts were proposed to transform manufacturing towards DT concepts [2]. Impact of EC in the form of a roadmap for manufacturing based on key performance indicators was analyzed [3, 4]. The formalization of DTs through EC paradigms along with cloud computing brings together centralized and decentralized computing [5]. The suitability of recent developments in EC technologies towards realizing a flexible and distributed open manufacturing ecosystems was studied [6, 7]. A survey on the applicability of DTs and their applications opens several research opportunities [8]. The importance of reliable sensor devices and synchronized data exchanges has been stressed [9–12]. Furthermore, for fields that apply or require sensor fusion, there is an increased requirement of not only the reliability of the sensor but also its temporal and measurement uncertainties [13–16].

Sensor technology has evolved to support multiple use cases. Particularly in I4.0, the use cases of condition monitoring and machine learning are interesting. Condition monitoring approaches have been proposed to monitor industrial assets leading to anomaly detection [17] and analytics purposes [18–20]. Machine learning methods have been further proposed to forecast performance of industrial assets based on the collected sensor data [13, 21]. The trend in I4.0 has led to emergence of CPS as a key enabler [22, 23].

Our approach shows similarities to all the mentioned research topics, but as all of them set their focus on one specific field, our idea concerns the combination of all these things. Namely the incorporation of measurement uncertainty in CPSs, especially sensor networks, and the combination of these with EC technology and the concept of DTs.

III. Status quo

A. Use Cases

We identified several use cases from the area of manufacturing as well as the process industry. These uses cases are presented in this section.

1) Manufacturing use cases: Use cases from the Robert Bosch GmbH (Bosch) are situated in the ARENA2036[1] and comprise the field of versatile manufacturing. As this concept describes the changing focus from mass production to the manufacturing of few or even single parts and the fast adoption to changing requirements (e.g. yield), machines are getting used in different production chains, depending on the actual demand. To assign resource consumption (energy, CO_2, air pressure, etc.) to single parts, corresponding sensors need to be distributed over the whole production chain(s) to collect appropriate data. The collected data (in combination with the already gathered knowledge) can then be used to get insights of the condition of the machines (condition monitoring). Further on, the time a single part needs for its production can be assigned to it in an accurate way. In the end all of these use cases should be combined with a concluding process result monitoring (e.g. pictures or video stream, audio, vibration, etc.) to achieve the most accurate production cost estimation of a single piece (in different dimensions, e.g. money, power, CO_2, etc.).

As the sensors are distributed along the whole production chain, there arise several challenges that need to be addressed:

1) **Time synchronization**: As parts are identified to be on one machine for a concrete time, the sensor data from exactly this time needs the be related to the corresponding sensors.
2) **Uncertainty propagation**: Every sensor has its own uncertainty, but if measurement values are combined and propagated along the production chain, it needs to be assured, that these uncertainties are reliable.

2) Process industry use cases: The Use Cases of Endress+Hauser SE & Co KG (E+H) are situated in two distributed test facilities simulating real process industry environments. As digitization and Industrial Internet of Things (IIoT) more and more finds its way into the process industry, so far unsolved problems like improvement of capacity without capex, optimization and output of the processes and increase of the productivity through predictive maintenance of sensor devices and assets surrounded by sensor swarms are coming into focus. In the process industry a certain number of sensors is already installed for the purpose of controlling the process and secure the safety. The data of these sensors will be channeled through or bypassed around the control system. With the enrichment of data from additional (monitoring) sensors not dedicated to the control of the process we can generate a Digital Twin of the physical sensor network in the digital world. By utilization of

[1] https://www.bosch.com/research/know-how/success-stories/arena2036/

Machine Learning (ML) and OC it is planned to generate higher information out of the network which cannot be derived from the data of the single sensors or out of the control system. A major question also will be the calculation of the measurement accuracy of a sensor swarm and the measurement information in the IT world. A possible use case is the generation of a more abstract insight into the process then the bare measurement values given by a single sensor. New models for predictive maintenance of sensors based on the data of the swarm and predictive maintenance information for active assets surrounded by a swarm of sensors will be a field of research.

Similar to the use cases from the manufacturing, we face several challenges:

- **Time synchronization**: A swarm of different sensors that combine its data raises the need for an accurate time synchronization.
- **Uncertainty propagation**: As the sensors can be distributed along the whole process, and the data can traverse several fusion operations, it is necessary to have reliable propagation mechanics for the corresponding uncertainty.

B. Approach

The proposed approach to accomplish the defined goals splits into two main blocks: (1) uncertainty and (2) reference model.

1) Uncertainty: It is of interest to enable metrological traceability of measurement values and derived quantities in the emerging field of IIoT. Although calibrations by an accredited laboratory could provide this kind of information, it is often neglected in the data acquisition and data processing of current IIoT systems [24].

We propose to enhance measured sensor values with the available (dynamic) calibration information - e.g. from a digital calibration certificate - to provide an uncertainty value for every measured sensor value. The combination of an incoming stream of measurement data and the calibration information will take place within the DT of the sensor. Metrological data processing in successive processing steps is then enabled by requesting the enriched sensor data (value, uncertainty, quantity, unit) from the DT. Moreover, to ease the correct metrological data processing, methods for common sensor fusion operations need to be developed/provided. These methods are required to be in line with the uncertainty propagation according to [25]. Examples for sensor fusion operation are: averaging, low-pass-filtering, data-labeling with propagated uncertainty of the label and high quality virtual sensor from multiple lower quality sensors.

Because of the high number of sensors used in IIoT systems, information redundancy between sensors is expectable. The redundant information can be exploited to overcome another issue tied with high sensor counts – costly and time-consuming calibration of all installed sensors. We therefore want to develop methods to re-calibrate sensors "in the field" in compliance with National Metrology Institute (NMI)-standards.

2) Reference Model: The architectural design takes into account the fact that the sensors are installed in field devices, which are connected to the control system via a communication network. This can be designed as an industry-specific fieldbus system such as PROFIBUS for Process Automation, HART (wired or wireless) or it can already be based on IT solutions. It is planned that a collection service (see Fig. 1) will take up the data from the field level. The implementation can base on a distributed system as described in [26] or on a monitoring and supervisory control platform such as ifakFAST[2]. Fieldbus-specific services are triggered in the configured time interval in which the process values are to be provided. In addition to the process values, specific attributes such as unit, measuring range adjustment or standardization can be queried. In the data collector, the recorded values are provided with time stamps. If several data collectors are used on different computer nodes in a system, the local times of the computer nodes are synchronized with each other via the Precision Time Protocol (PTP), so that further processing takes place on a uniform time basis. Virtual sensors can be created in the data collector based on certain rules and provide newly calculated virtual sensor values in the intended cycle.

Higher level processing is to be based on AAS. For this purpose, the recorded measured values and their time stamps are mapped into the sub-model of an AAS [27], which still has to be defined. The implementation is done by mapping the AAS model into an Open Platform Communications United Architecture (OPC UA) information model. In this way, the evaluation can access online data or evaluate recorded data offline. In parallel, the data can also be transferred very specifically to cloud Application Programming Interfaces (APIs).

A DT can either comprise a single device or a sensor network and to ease its configuration the *Observer-Controller-Architecture* [28] from the OC domain is used. This highly flexible approach is split into two main parts: the Observer and the Controller. As the former can be used for data pre- and/or post-processing, the latter acts as an interface to react onto observed data (e.g. ML).

C. Evaluation

We plan an evaluation in two phases:

Phase 1 will serve as a first evaluation in a safe environment to identify errors and test the general approach for correctness. To ensure the given requirements, the first phase will entirely take place in simulations. Possible simulation frameworks are: DOME[3], ifakFAST, Assets2036[4], OpenAAS[5], BaSys40[6] and Met4FoF[7]. One or more of these frameworks will be used depending on the corresponding use cases and an ongoing utility study.

Phase 2 will take place in the real world. Therefore, we build concrete demonstrators at: Bosch, E+H and Fraunhofer Institute for Production Systems and Design Technology (IPK).

[2]https://github.com/ifakFAST
[3]https://www.ifak-ts.com/pf/ifak-dome/
[4]https://github.com/boschresearch/assets2036-submodels
[5]https://acplt.github.io/openAAS/
[6]https://www.basys40.de/
[7]https://zenodo.org/record/3404800

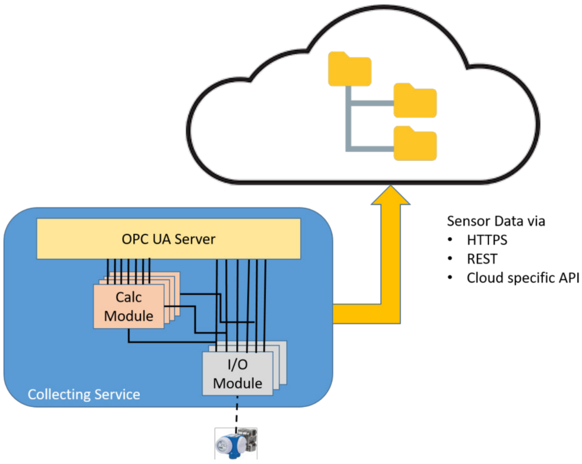


Fig. 1: Data collection from field level

These implementations of the use cases will generate real data for the methods and provide a direct feedback for them. Phase 2 is also split in two parts, the first evaluation round comprises the installation of the demonstrators as well as the testing of the developed approaches. After the first round, gathered knowledge will be used to improve the architecture and the methods. A second round of evaluation will then test the newer versions.

IV. Conclusion and Future Work

This paper presents our approach to the challenges that arise within sensor networks regarding uncertainty of sensor measurements. In collaboration with Bosch and E+H several use cases from the fields of discrete manufacturing and the process industry were identified. The use cases cover the monitoring of resource consumption, the generation of high level metrics using raw data, the occurrence of drifts in a sensor network and predictive maintenance. To achieve the objectives set in the use cases, we propose an approach comprising of a method to manage uncertainty using metrological traceability and a reference model for the architectural design utilizing concepts such as DTs and AAS'. Furthermore, the architecture will be implemented using methods of OC. To evaluate our concept we intend to initially simulate our approach and ultimately build testbeds at Bosch, E+H and IPK. The objective is to raise the level of metrics generated by sensors and ensure their reliability. The presented work will provide potential benefits for industrial users.

V. Acknowledgments

Research for this paper was financed by the Federal Ministry of Education and Research (BMBF) project FAMOUS[8]. We thank our project partners for their contributions and their collaboration to this research work.

[8]http://famous-project.eu/

References

[1] Sascha Eichstädt. *Metrologie für die Digitalisierungvon Wirtschaft und Gesellschaft*. 2017. DOI: 10.7795/310.20170401DE.

[2] Qinglin Qi, Dongming Zhao, T. Warren Liao, and Fei Tao. "Modeling of Cyber-Physical Systems and Digital Twin Based on Edge Computing, Fog Computing and Cloud Computing Towards Smart Manufacturing". In: *Volume 1: Additive Manufacturing; Bio and Sustainable Manufacturing*. June 2018. DOI: 10.1115/msec2018-6435.

[3] Dimitrios Georgakopoulos, Prem Prakash Jayaraman, Maria Fazia, Massimo Villari, and Rajiv Ranjan. "Internet of Things and Edge Cloud Computing Roadmap for Manufacturing". In: *IEEE Cloud Computing* 3.4 (2016), pp. 66–73. DOI: 10.1109/mcc.2016.91.

[4] Mathias de Brito, Saiful Hoque, Ronald Steinke, and Alexander Willner. "Towards Programmable Fog Nodes in Smart Factories". In: *1st International Workshops on Foundations and Applications of Self* Systems (FAS*W)*. Augsburg: IEEE, Sept. 2016, pp. 236–241. DOI: 10.1109/FAS-W.2016.57.

[5] Qinglin Qi and Fei Tao. "A Smart Manufacturing Service System Based on Edge Computing, Fog Computing, and Cloud Computing". In: *IEEE Access* 7 (2019), pp. 86769–86777. DOI: 10.1109/access.2019.2923610.

[6] Zhi Li, W.M. Wang, Guo Liu, Layne Liu, Jiadong He, and G.Q. Huang. "Toward Open Manufacturing". In: *Industrial Management & Data Systems* 118.1 (2018), pp. 303–320. DOI: 10.1108/imds-04-2017-0142.

[7] Yan Lu, Frank Riddick, and Nenad Ivezic. "The Paradigm Shift in Smart Manufacturing System Architecture". In: *IFIP Advances in Information and Communication Technology*. IFIP Advances in Information and Communication Technology. Springer International Publishing, 2016, pp. 767–776. DOI: 10.1007/978-3-319-51133-7_90.

[8] Yuqian Lu, Chao Liu, Kevin I-Kai Wang, Huiyue Huang, and Xun Xu. "Digital Twin-Driven Smart Manufacturing: Connotation, Reference Model, Applications and Research Issues". In: *Robotics and Computer-Integrated Manufacturing* 61 (2020), p. 101837. DOI: 10.1016/j.rcim.2019.101837.

[9] Karthick Thiyagarajan, Sarath Kodagoda, and Nalika Ulapane. "Data-driven machine learning approach for predicting volumetric moisture content of concrete using resistance sensor measurements". In: *2016 IEEE 11th Conference on Industrial Electronics and Applications (ICIEA)*. June 2016. DOI: 10.1109/iciea.2016.7603783.

[10] C. Vázquez, A.B. Gonzalo, S. Vargas, and J. Montalvo. "Multi-Sensor System Using Plastic Optical Fibers for Intrinsically Safe Level Measurements". In: *Sensors and Actuators A: Physical* 116.1 (2004), pp. 22–32. DOI: 10.1016/j.sna.2004.03.035.

[11] Yadong Wan, Lei Li, Jie He, Xiaotong Zhang, and Qin Wang. "Anshan: Wireless Sensor Networks for Equipment Fault Diagnosis in the Process Industry". In: *2008 5th Annual IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks*. June 2008. DOI: 10.1109/sahcn.2008.46.

[12] Stig Petersen, Paula Doyle, Svein Vatland, Christian Salbu Aasland, Trond Michael Andersen, and Dag Sjong. "Requirements, drivers and analysis of wireless sensor network solutions for the Oil & Gas industry". In: *2007 IEEE Conference on Emerging Technologies & Factory Automation (EFTA 2007)*. Sept. 2007. DOI: 10.1109/efta.2007.4416773.

[13] Nico Kaempchen and Klaus Dietmayer. "Data synchronization strategies for multi-sensor fusion". In: *Proceedings of the IEEE Conference on Intelligent Transportation Systems*. Vol. 85. 1. 2003, pp. 1–9.

[14] Tobias Huck, Antje Westenberger, Martin Fritzsche, Tilo Schwarz, and Klaus Dietmayer. "Precise timestamping and temporal synchronization in multi-sensor fusion". In: *2011 IEEE Intelligent Vehicles Symposium (IV)*. June 2011. DOI: 10.1109/ivs.2011.5940472.

[15] Antje Westenberger, Tobias Huck, Martin Fritzsche, Tilo Schwarz, and Klaus Dietmayer. "Temporal synchronization in multi-sensor fusion for future driver assistance systems". In: *2011 IEEE International Symposium on Precision Clock Synchronization for Measurement, Control and Communication*. Sept. 2011. DOI: 10.1109/ispcs.2011.6070146.

[16] Yao-Win Hong and A. Scaglione. "A Scalable Synchronization Protocol for Large Scale Sensor Networks and Its Applications". In: *IEEE Journal on Selected Areas in Communications* 23.5 (2005), pp. 1085–1099. DOI: 10.1109/jsac.2005.845418.

[17] Gauri Shah and Aashis Tiwari. "Anomaly detection in IIoT". In: *Proceedings of the ACM India Joint International Conference on Data Science and Management of Data - CoDS-COMAD '18*. 2018. DOI: 10.1145/3152494.3156816.

[18] Eckart Uhlmann, Hakim Laghmouchi, Claudio Geisert, and Eckhard Hohwieler. "Smart wireless sensor network and configuration of algorithms for condition monitoring applications". In: *Journal of Machine Engineering* 17 (Jan. 2017), pp. 45–55.

[19] Niall O' Mahony, Trevor Murphy, Krishna Panduru, Daniel Riordan, and Joseph Walsh. "Adaptive process control and sensor fusion for process analytical technology". In: *2016 27th Irish Signals and Systems Conference (ISSC)*. June 2016. DOI: 10.1109/issc.2016.7528449.

[20] Eckart Uhlmann, Abdelhakim Laghmouchi, Claudio Geisert, and Eckhard Hohwieler. "Decentralized Data Analytics for Maintenance in Industrie 4.0". In: *Procedia Manufacturing* 11 (2017), pp. 1120–1126. DOI: 10.1016/j.promfg.2017.07.233.

[21] Eckart Uhlmann, Rodrigo Pastl Pontes, Claudio Geisert, and Eckhard Hohwieler. "Cluster Identification of Sensor Data for Predictive Maintenance in a Selective Laser Melting Machine Tool". In: *Procedia Manufacturing* 24 (2018), pp. 60–65. DOI: 10.1016/j.promfg.2018.06.009.

[22] Birgit Vogel-Heuser, Christian Diedrich, and Manfred Broy. "Anforderungen an Cps Aus Sicht Der Automatisierungstechnik / Requirements on Cps From the Viewpoint of Automation". In: *at - Automatisierungstechnik* 61.10 (2013). DOI: 10.1524/auto.2013.0061.

[23] Edward A. Lee. "Cyber Physical Systems: Design Challenges". In: *2008 11th IEEE International Symposium on Object and Component-Oriented Real-Time Distributed Computing (ISORC)*. May 2008. DOI: 10.1109/isorc.2008.25.

[24] Sascha Eichstädt and Björn Ludwig. "Metrologie für heterogene Sensornetzwerke und Industrie 4.0". In: *tm - Technisches Messen* 86.11 (Nov. 26, 2019), pp. 623–629. DOI: 10.1515/teme-2019-0073.

[25] JCGM. *Guide to the expression of uncertainty in measurement*. 2008.

[26] G. Persico, H. Raddatz, D. L. Tran, M. Riedl, P. Varutti, and M. Tekkalmaz. "Communication Solutions for the Integration of Distributed Control in Logistics Systems". In: *IECON 2019 - 45th Annual Conference of the IEEE Industrial Electronics Society*. Vol. 1. 2019, pp. 4203–4208. DOI: 10.1109/IECON.2019.8927834.

[27] H. Zipper and C. Diedrich. "Synchronization of Industrial Plant and Digital Twin". In: *2019 24th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA)*. 2019, pp. 1678–1681. DOI: 10.1109/ETFA.2019.8868994.

[28] Holger Prothmann, Sven Tomforde, Jürgen Branke, Jörg Hähner, Christian Müller-Schloer, and Hartmut Schmeck. "Organic Traffic Control". In: *Organic Computing — A Paradigm Shift for Complex Systems*. Basel: Springer Basel, 2011, pp. 431–446. DOI: 10.1007/978-3-0348-0130-0_28.

4^{th} International Conference on Lean and Agile Software Development

THE evolution of software development life cycles is driven by the perennial quest on how to organize projects for better productivity and better quality. The traditional software development projects, which followed well-defined plans and detailed documentations, were unable to meet the dynamism, unpredictability and changing conditions that characterize rapidly changing business environment. Agile methods overcame these limits by considering that requirements are not static but dynamic, while customers are unable to definitively state their needs up front. However, the advent of agile methods divided the software engineering community into opposing camps of traditionalists and agilists. After more than a decade of debate and experimental studies a majority consensus has emerged that each method has its strengths as well as limitations, and is appropriate for specific types of projects, while numerous organizations have evolved toward the best balance of agile and plan-driven methods that fits their situation.

In more recent years, the software industry has started to look at lean software development as a new approach that could complement agile methods. Lean development further expands agile software development by adopting practices from lean manufacturing. Lean emphasizes waste elimination by removing all nonvalue-adding activities.

TOPICS

The objective of LASD is to extend the state-of-the-art in lean and agile software development by providing a platform at which industry practitioners and academic researchers can meet and learn from each other. We are interested in high quality submissions from both industry and academia on all topics related to lean and agile software development. These include, but are not limited to:

- Combining lean and agile methods for software development
- Lean and agile requirements engineering
- Scaling agile methods
- Distributed agile software development
- Challenges of migrating to lean and agile methods
- Balancing agility and discipline
- Agile development for safety systems
- Lean and agility at the enterprise level
- Conflicts in agile teams
- Lean and agile project production and management
- Collaborative games in software processes
- Lean and agile coaching
- Managing knowledge for agility and collaboration
- Tools and techniques for lean and agile development
- Measurement and metrics for agile projects, agile processes, and agile teams
- Innovation and creativity in software engineering
- Variability across the software life cycle
- Industrial experiments, case studies, and experience reports related to all of the above topics
- Gamification
- Affective Software Engineering

TECHNICAL SESSION CHAIRS

- **Przybyłek, Adam,** Gdansk University of Technology, Poland

PROGRAM COMMITTEE

- **Ahmad, Muhammad Ovais,** Karlstad University, Sweden
- **Akman, Ibrahim,** Atilim University, Turkey
- **Ali, Sikandar,** China University of Petroleum, China
- **Almeida, Fernando,** University of Porto & INESC TEC, Portugal
- **Alshayeb, Mohammad,** King Fahd University of Petroleum and Minerals, Saudi Arabia
- **Angelov, Samuil,** Fontys University of Applied Sciences, The Netherlands
- **Bagnato, Alessandra,** SOFTEAM R&D Department, France
- **Belle, Alvine Boaye,** École de Technologie Supérieure, Canada
- **Ben Ayed Elleuch, Nourchène,** Higher Colleges of Technology, ADW, United Arab Emirates
- **Bernhart, Mario,** Vienna University of Technology, Austria
- **Bhadauria, Vikram,** Texas A&M International University, United States
- **Binti Abdullah, Nik Nailah,** Monash University Malaysia, Malaysia
- **Biró, Miklós,** Software Competence Center Hagenberg and Johannes Kepler University Linz, Austria
- **Blech, Jan Olaf,** Aalto University, Finland
- **Borg, Markus,** SICS Swedish ICT AB, Sweden
- **Buchalcevova, Alena,** University of Economics, Prague, Czech Republic
- **Buchan, Jim,** Auckland University of Technology, New Zealand

- **Buglione, Luigi,** Engineering Ingegneria Informatica SpA, Italy
- **Chatzigeorgiou, Alexandros,** University of Macedonia, Greece
- **Cruzes, Daniela,** SINTEF ICT, Norway
- **Daszczuk, Wiktor Bohdan,** Warsaw University of Technology, Poland
- **Dejanović, Igor,** Faculty of Technical Sciences, Novi Sad, Serbia
- **Derezinska, Anna,** Warsaw University of Technology, Institute of Computer Science, Poland
- **Diebold, Philipp,** Fraunhofer IESE, Germany
- **DUTTA, ARPITA,** IIT Kharagpur, India
- **Escalona, Maria Jose,** Universidad de Sevilla, Spain
- **Essebaa, Imane,** Hassan II University of Casablanca, Morocco
- **Fagerholm, Fabian,** University of Helsinki, Finland and Blekinge Institute of Technology, Finland
- **García-Mireles, Gabriel Alberto,** Universidad de Sonora, Mexico
- **Ghofrani, Javad,** HTW Dresden University of Applied Sciences, Germany
- **Goczyła, Krzysztof,** Gdańsk University of Technology, Poland
- **GODBOLEY, SANGHARATNA,** NIT ROURKELA, India
- **Gonzalez Huerta, Javier,** Blekinge Institute of Technology, Sweden
- **Górski, Janusz,** Gdańsk University of Technology, Poland
- **Gregory, Peggy,** University of Central Lancashire, United Kingdom
- **Hanslo, Ridewaan,** Council for Scientific and Industrial Research, South Africa
- **Heil, Sebastian,** Chemnitz University of Technology, Germany
- **Hohenstein, Uwe,** Siemens AG, Germany
- **Hohl, Philipp,** ZF Friedrichshafen AG, Germany
- **Ikonen, Marko,** Projektivarikko Oy, Finland
- **Janes, Andrea,** Free University of Bolzano, Italy
- **Järvinen, Janne,** F-Secure Corporation, Finland
- **Jarzębowicz, Aleksander,** Gdansk University of Technology, Poland
- **Jovanović, Miloš,** University of Novi Sad, Serbia
- **Kakarontzas, George,** Aristotle University of Thessaloniki, Greece
- **Kaloyanova, Kalinka,** Sofia University, Bulgaria
- **Kanagwa, Benjamin,** Makerere University, Uganda
- **Karolyi, Matěj,** Institute of Biostatistics and Analyses, Faculty of Medicine, Masaryk University, Brno, Czech Republic
- **Karpus, Aleksandra,** Gdańsk University of Technology, Poland
- **Kassab, Mohamad,** Innopolis University, Russia
- **Katić, Marija,** Birkbeck, University of London, United Kingdom
- **Khlif, Wiem,** University of Sfax, Tunisia
- **Knodel, Jens,** Fraunhofer IESE, Germany
- **Kropp, Martin,** University of Applied Sciences and Arts Northwestern Switzerland, Switzerland
- **Kuvaja, Pasi,** University of Oulu, Finland
- **Laanti, Maarit,** Nitor, Finland
- **Lehtinen, Timo O. A.,** Aalto University, Finland
- **Lenarduzzi, Valentina,** Tampere University, Finland
- **Liebel, Grischa,** University of Gothenburg, Sweden
- **Luković, Ivan,** University of Novi Sad, Serbia
- **Lunesu, Ilaria,** Università degli Studi di Cagliari, Italy
- **Mahnič, Viljan,** University of Ljubljana, Slovenia
- **Mangalaraj, George,** Western Illinois University, United States
- **Marcinkowski, Bartosz,** Department of Business Informatics, University of Gdansk, Poland
- **Mazzara, Manuel,** Innopolis University, Russia
- **Mesquida Calafat, Antoni-Lluís,** University of the Balearic Islands, Spain
- **Miler, Jakub,** Faculty of Electronics, Telecommunications And Informatics, Gdansk University of Technology, Poland, Poland
- **miller, gloria,** Skema Business School, Germany
- **Misra, Sanjay,** Covenant University, Nigeria
- **Mohapatra, Durga Prasad,** NIT ROURKELA, India
- **Morales Trujillo, Miguel Ehecatl,** University of Canterbury, New Zealand
- **Mordinyi, Richard,** Vienna University of Technology, Austria
- **Muñoz, Mirna,** Centro de Investigación en Matemáticas, Mexico
- **Muszyńska, Karolina,** University of Szczecin, Poland
- **Ng, Yen Ying,** Nicolaus Copernicus University, Poland
- **Nguyen-Duc, Anh,** University College of Southeast Norway, Norway
- **Noyer, Arne,** University of Osnabrueck and Willert Software Tools GmbH, Germany
- **Oktaba, Hanna,** National Autonomous University of Mexico, Mexico
- **Ortu, Marco,** University of Cagliari, Italy
- **Oyetoyan, Tosin Daniel,** SINTEF Digital, Norway
- **Özkan, Necmettin,** Kuveyt Turk Participation Bank, Turkey
- **Panda, Subhrakanta,** Birla Institute of Technology and Science, Pilani, India
- **Pereira, Rui Humberto R.,** Instituto Politecnico do Porto - ISCAP, Portugal
- **Poth, Alexander,** Volkswagen AG, Germany
- **Przybyłek, Michał,** University of Warsaw, Poland
- **Ramsin, Raman,** Sharif University of Technology, Iran
- **Ristić, Sonja,** University of Novi Sad, Faculty of Technical Sciences, Serbia
- **Rossi, Bruno,** Masaryk University, Czech Republic
- **Rybola, Zdenek,** FIT CTU in Prague, Czech Republic
- **Salah, Dina,** Sadat Academy, Egypt
- **Salnitri, Mattia,** University of Trento, Italy

- **Schön, Eva-Maria,** HAW Hamburg, Germany
- **Sedeno, Jorge,** University of Seville, Spain
- **Senapathi, Mali,** Auckland University of Technology, New Zealand
- **Shkroba, Illia,** Polish-Japanese Academy of Information Technology, Poland
- **Sikorski, Marcin,** Polish-Japanese Academy of Information Technology, Poland
- **Śmiałek, Michał,** Politechnika Warszawska, Poland
- **Soares, Michel,** Federal University of Sergipe, Brazil
- **Soria, Álvaro,** ISISTAN Research Institute, Argentina
- **Spichkova, Maria,** RMIT University, Australia
- **Springer, Olga,** Gdańsk University of Technology, Poland
- **Stålhane, Tor,** Norwegian University of Science and Technology, Norway
- **Stettina, Christoph Johann,** Leiden University, The Netherlands
- **Szymański, Julian,** Gdańsk University of Technology, Poland
- **Taibi, Davide,** Free University of Bolzano, Italy
- **Tarhan, Ayca,** Hacettepe University Computer Engineering Department, Turkey
- **Theobald, Sven,** Fraunhofer IESE, Germany
- **Thomaschewski, Jörg,** University of Applied Sciences Emden/Leer, Germany
- **Torrecilla Salinas, Carlos,** University of Seville, Spain
- **Unterkalmsteiner, Michael,** Blekinge Institute of Technology, Sweden
- **Wardziński, Andrzej,** Gdańsk University of Technology, Poland
- **Weichbroth, Paweł,** Gdańsk University of Technology, Poland
- **Werewka, Jan,** AGH University of Sci. and Technology, Poland
- **Winter, Dominique,** University of Applied Sciences Emden/Leer, Germany
- **Wróbel, Michał,** Gdańsk University of Technology, Poland
- **Yilmaz, Murat,** Çankaya University, Turkey
- **Zarour, Nacer Eddine,** University Constantine2, Algeria
- **Łukasiewicz, Katarzyna,** Gdańsk University of Technology, Poland

Position Papers of the Federated Conference on Computer Science and Information Systems pp. 63–69
DOI: 10.15439/2020F210
ISSN 2300-5963 ACSIS, Vol. 22

Towards Trustworthy Horizontal Integration in Industry 4.0 Based on DLT Networks

Nikola Todorović, Marko Vještica, Vladimir Dimitrieski, Miroslav Zarić, Nenad Todorović, Ivan Luković
Faculty of Technical Sciences, University of Novi Sad, Novi Sad, Serbia
Email: {nikola.todorovic, marko.vjestica, dimitrieski, miroslavzaric, nenadtod, ivan}@uns.ac.rs

***Abstract*—In recent years, Industry 4.0 has promoted the enhanced horizontal integration of value chain participants, aiming to improve the efficiency and effectiveness of Cross-Organizational Business Processes. In this paper, we discuss transparency and data privacy challenges that occur with the introduction of a high level of horizontal integration. Private, permissioned Distributed Ledger Technology systems and smart contracts can be used to address these challenges and enhance the integration of business processes across the entire value chain. To make this possible, we propose a creation of a Model-Driven Software Development approach based on a Domain-Specific Modeling Language that would enable automatic generation of smart contracts. Generated smart contracts could then be used by collaborating parties to supervise the state of production and contract fulfillment in a trustworthy and secure way.**

I. Introduction

WITH THE introduction of smart devices, warehouse systems, and production facilities capable of exchanging information autonomously, manufacturers started establishing global networks in the form of Cyber-Physical Systems (CPS). These systems are leading the way for the fourth industrial revolution [1]. Interconnected autonomous and cooperative entities enable closer collaboration between business parties within a value chain when executing Cross-Organizational Business Processes (CBPs) [2] [3]. Closer collaboration provides new possibilities and mutual benefits for involved parties and allows for improvements in their operational and business performance [4]. For instance, it increases the capability of value chains to manufacture small, customized batches of products cost-effectively [5] [6]. As an example, within the car manufacturing industry, this would mean that customers no longer have to choose from a set of manufacturer-defined option packages for a vehicle model, but would instead be able to mix and match individual components to meet their specific needs [7]. Although production of highly-customized goods is, to some extent, possible with current collaboration levels, it implies significantly higher prices and longer delivery times.

Facilitating CBPs implies integrating different IT systems to enable the interoperability of production systems of the involved parties. In the domain of Industry 4.0, this is referred to as Horizontal Integration – integration of various IT systems used in manufacturing and business planning processes that involve an exchange of materials, energy, and information [8]. Although beneficial, horizontal integration introduces two opposing challenges for the execution of CBPs – the protection of highly sensitive corporate data and a need for an appropriate level of transparency for the correct attribution of legal liability [1]. If not adequately managed, sensitive data exchanged to coordinate production and logistic activities between different companies could be misused by malicious members of the chain. Strict authorization rules must be imposed to protect sensitive data and to regulate whom and under what circumstances may obtain shared data. Contrarily, manufacturing facilities may be subject to a liability action for faults in their performance as part of the value chain. A lack of structural transparency could make it almost impossible to explicitly determine who performed a particular action, resulting in uncertainty regarding legal liability. Correct attribution of liability should be facilitated by the provision of precise documentary evidence concerning the different manufacturing steps and system statuses.

A method and a software solution for the secure, transparent, and trustworthy enactment and integration of CBPs must be utilized to address data protection and transparency challenges and support trust-building among CBP partners. One proposed approach is the use of Distributed Ledger Technology (DLT) platforms and blockchain technologies with smart contracts for the implementation of the horizontal integration, with end-to-end engineering spanning across the entire value chain [9]. DLT is a type of a distributed database, while blockchain represents a distributed data structure that implements DLT, and comprises cryptographically linked blocks that contain immutable records of network transactions [10]. Because data records stored in a block are immutable and contain an immutable hash of data stored in a previous block in a chain, data cannot be counterfeited or forged once recorded into a blockchain. Using a DLT platform would improve structural transparency within the value chain and increase trust between included members because it enables entities to have shared control over the access to and evolution of data. The transactions on the platform are generated and validated using smart contracts, computer programs whose execution is guaranteed by system rules, and for which the outcome of execution is verifiable and auditable by all network participants. Smart contracts have a potential to improve coordination within the value chain by automatically verifying that the production process actions are executed according to the contracted specification.

DLT platforms usually provide low-level, general-purpose programming languages for implementing smart contracts. This is not always suitable in the context of Industry 4.0 because the manual specification of smart contracts would reduce the capability of value chains to synchronize and adapt their production in a timely manner. Moreover, it would mean that process and quality engineers, responsible for the production specification, need to be proficient in these languages. These problems could be mitigated by (i) raising the level of abstraction and providing them with a modeling language that is based on concepts and notations they are familiar with and already use in their domains, and then (ii) relying on automatic generation of smart contracts [11].

Our research aims to establish a methodological approach for horizontal integration that would create conditions for a trustworthy and traceable production. We propose a highly conceptualized architecture based on DLTs and smart contracts that would enable a formal description and execution of collaborative production processes. The architecture needs to be centered around a Domain-Specific Modeling Language (DSML) that would enable modeling interoperability requirements and implementation details [12]. The proposal needs to be facilitated by a software solution in which the Model-Driven Software Development (MDSD) principles and DSMLs are used to (i) specify contracted cross-organizational production processes formally and (ii) automatically generate smart contracts that observe the execution of production and store production records in an immutable distributed ledger. The described architecture would enable a trustworthy and secure analysis of records of events that occurred during the production and would allow parties to derive conclusions and determine if there are any discrepancies between negotiated and executed process steps.

The presented work is structured as follows. After the introduction, in Section II we discuss different challenges and requirements for a DSML regarding the notational aspects and execution significance of CBP models used to facilitate the automatic generation of smart contracts. Section III provides a context of collaboration in the domain of Industry 4.0 for which an MDSD approach will be used. In Section IV, we present an MDSD approach for the automatic generation of smart contracts. In conclusion, the proposal is summarized, and the authors give an outlook on predicted outcomes of the proposed investigation.

II. Research Challenges and Related Work

Collaboration within Industry 4.0 implies the execution of cross-organizational production processes between multiple independent parties that are part of a value chain. The execution includes entities from these parties involved in high-level interactions, directed at joint endeavors with the end-goal to deliver highly customized products to end-users cost-effectively and in a timely manner [13]. These entities produce multiple datasets, owned by the involved parties and maintained within their respective production systems. Production systems need to be integrated to share the common data and provide a mutual understanding of records generated during the execution of CBPs. Thus, the interoperability concerns for those systems, i.e., the capability of systems to exchange data and share information and knowledge, must be addressed [14].

One of the leading frameworks that facilitate interoperability in the domain of Industry 4.0 is the ATHENA Interoperability Framework (AIF) [8] [15]. The primary goal of AIF is to provide a generic solution that enables collaborative modeling and execution of CBPs and to be applicable to many different domains [16]. AIF takes a multidisciplinary approach for facilitating CBPs by merging three research areas that support the development of interoperability of enterprise solutions: (i) enterprise modeling, which is used to define interoperability requirements and supports solution implementation, (ii) architectures and platforms which provide implementation frameworks, and (iii) ontology to identify interoperability semantics in the enterprise. Because AIF uses a generic approach for enabling CBPs, the solution is based on languages and technologies suitable for the application in most scenarios and use cases.

The intended research should try to facilitate interoperability between different production systems by utilizing concepts identified in AIF and offering improvements in the way CBPs are modeled in the domain of Industry 4.0. Modeling of production processes in the domain of Industry 4.0 is essential in order to understand, control, and optimize process operations, and has been an important topic of our previous research [20]. Different notational aspects of CBP models, concerned with their expressiveness and visual representation, and the execution significance that concerns their computability by a machine, should be examined while considering different characteristics of the proposed DLT monitoring platform. This is discussed in Section II-A. Our research should also promote trust-building between parties involved in the value chain by utilizing DLT platforms based on blockchain and smart contracts. Different aspects of DLT platforms that have significance for the enactment and integration of CBPs are addressed in Section II-B.

A. Modeling Cross-Organizational Business Processes

Various research challenges should be taken into consideration during the proposed investigation on modeling CBPs. On one hand side, modeling of CBPs implies the ability of a DSML to describe production process specifications in a sufficiently detailed and understandable way to enable the execution of the process. On the other hand side, these specifications should be displayed to related parties through different process interfaces that facilitate understanding of collaboration within the value chain while preserving confidentiality of private, internal enterprise information. One of the most significant challenges for a DSML will be to devise a way to connect private production processes with openly exposed process interfaces and map different representations of intra-organizational processes at the cross-organizational business process level [3]. Additionally, the modeling language should provide users with an ability to model details needed on the execution level, e.g., showing invoked smart contracts and executed transactions, while separating CBP modeling from specific deployment architectures.

Preserving private data while integrating production processes with collaborating parties is a significant security concern for parties involved in a value chain. Some of the production data, e.g., an actor that performed a particular action or details about work instructions that were followed to perform a specific activity, should be revealed only in case of a legal dispute. Thus, raw production data must be aggregated, anonymized, and shared only with select parties involved in a specific production execution. Three different process types should be investigated and customized for use in the domain of Industry 4.0 to allow secure exposure of private process data to related parties: (i) private processes, that represent internal production processes executed by an organization, (ii) interface processes, used to coordinate internal actions with activities of external partners while concealing private data, and (iii) CBPs, used to describe how parties collaborate within a value chain. These process types and dependencies between them are shown in Fig. 1, created based on the Fig. 1 from [3]. In the figure, different process types are separated using dashed lines, while dependencies between them are depicted using red dotted arrows.

Private processes, displayed as the top layer in Fig. 1, should model production process specifications that are executed inside an organization. Modeling of private production processes is an important research topic within Industry 4.0 [17], but it is still not sufficiently covered with the existing studies [18]. Because of an increase in a production process complexity in Industry 4.0, production process models should help process designers think about production processes at a higher abstraction level and be more focused on modeling production process steps to minimize errors during processes specification. Formal production process models would enhance manufacturing flexibility and allow for more precise and domain-specific simulations and would provide means for better integration of humans in production processes in a way that is prescribed by the Lean manufacturing principles [19]. From a notational aspect of a DSML, private production process models need to be specified by using a language that includes concepts for representing materials, products, services, devices, human workers, communication between them, and all process steps and tasks needed to create a product. A notation should also enable describing how tasks described in a private process are aggregated and anonymized to allow mappings between private processes and interface processes. Aggregation and anonymization specifications would enable a formal transformation of data shared with collaborating business parties during production execution.

Interface processes, depicted as an additional layer beneath private processes in Fig. 1, can be used to provide an abstraction of private processes sufficient to coordinate internal actions with activities of external partners while concealing private data [21] [22]. An interface process is shared only with a contracting party and should specify tasks that should be performed by a manufacturer when executing the contracted production. Interface Process 1 shows that interface processes comprise anonymized and aggregated tasks, e.g., operator roles and machine types are used instead of specific actors. This layer should also specify constraints that should be followed and quality control inspections that need to be performed during the production execution. Interface processes will be used as a basis for the creation of suitable private processes

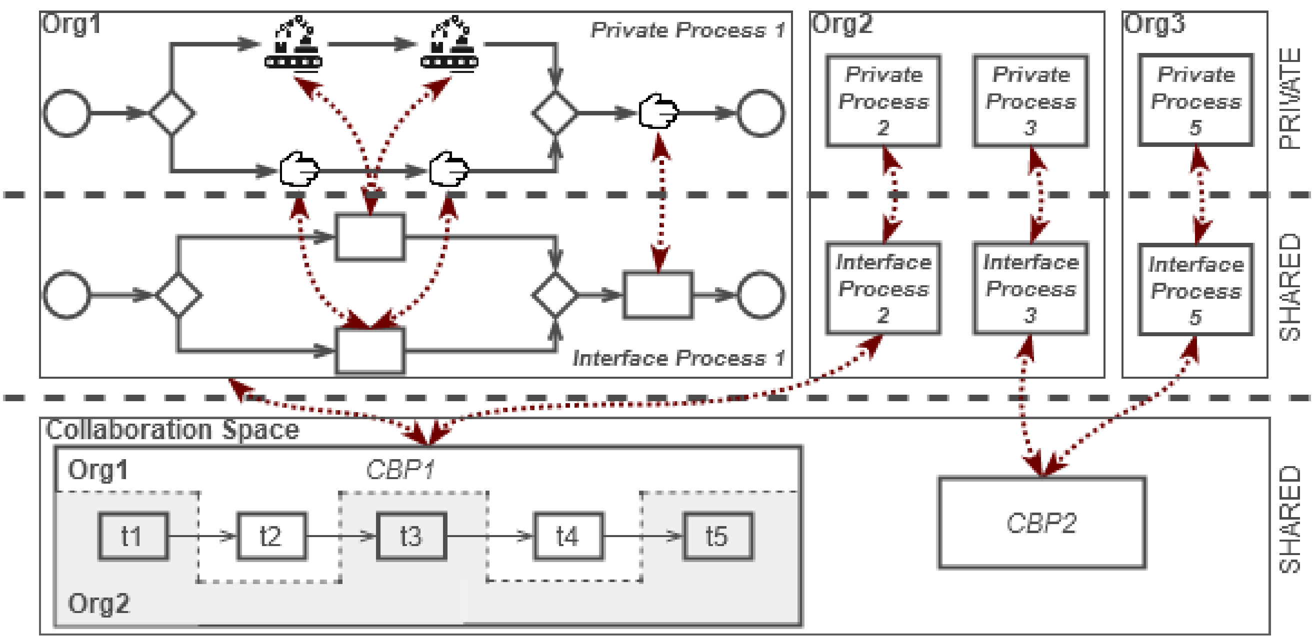


Fig. 1. Dependencies between different process types

and for the generation of smart contracts that will monitor the executed production.

The third layer in Fig. 1 depicts Collaboration Space, where cross-organizational business processes, created by integrating different process interfaces exposed by collaborating parties, can be used to describe how parties collaborate within a value chain. The collaboration should be based on a distributed process model where parties manage their own part of the overall production process [3]. From a high-level viewpoint, a CBP model should specify how the partner processes are interweaved and what tasks each of the parties must perform as agreed in their contract. This is shown with CBP2, created based on Interface Processes 1 and 4, where tasks t2 and t4 are performed by Org1, while Org3 performs t1, t3, and t5. A CBP model should also specify roles of the involved parties, milestones, i.e., critical points used to determine the state of a task, and messages that are transferred during process execution. The specifications of CBPs can be used to create smart contracts for trustworthy monitoring of the enactment of CBPs.

B. *Execution Platform*

Records of events occurred during the execution of manufacturing processes, provided by machines and operators that take part in the production, are stored and maintained within the production systems of parties involved in the value chain. An execution platform that facilitates horizontal integration should provide mechanisms that guarantee a secure and transparent distribution of records to related parties in order to achieve a common understanding of these events. The architecture recommended by AIF should be expanded to encourage the use of a DLT platform for information sharing and to support trust-building between parties.

The network for Interoperability Development of Enterprise Applications and Software (IDEAS) identified a list of Quality Attributes which highlight technical requirements that should be taken into consideration when developing software that promotes enterprise interoperability [23]. We selected three most important attributes for sharing data during the enactment of CBPs in Industry 4.0: (i) security, which describes the ability of a solution to protect enterprise resources and control access to them; (ii) scalability, that represents the ability of a solution to adjust to an increased number of production tasks; and (iii) performance, the ability of a solution to quickly execute a business task and to retrieve and return information in a timely fashion.

To satisfy these requirements, we propose the use of a private, permissioned, consortium-based DLT platform for storing CBP records. These platforms are administered by a set of identified participants operating under a governance model that enforces a certain degree of trust [10] [24]. Private DLT networks impose restrictions on 'read' access to the ledger, i.e., who can access the network and see transactions. Moreover, permissioned networks allow only a selected set of parties to make changes to the distributed ledger. When it comes to how and to whom the data propagates across the chain, a multi-channel data diffusion model should be used, where transactions and transaction-related data are broadcast to select parties involved in a specific production. Because of this, each node in the network would store only data about transactions with which it is involved. The role of smart contracts, generated based on production process specifications, is to monitor event records and validate that the production execution is conducted according to the contracted specifications. The consensus over the state of the ledger is achieved by relying on the specified endorsement policies designed in a manner that achieves consistent and reliable understanding between participants.

Scalability and performance concerns must also be considered to enable a sufficiently reliable data transfer between integrated parties. Machines used in the production generate a large amount of data that needs to be processed by the blockchain network with low latency. By relying on the identities of participants, a permissioned blockchain can use more traditional Crash Fault-Tolerant (CFT) or Byzantine Fault-Tolerant (BFT) consensus protocols, that are more suitable for scaling the transaction throughput in the network [25].

Several existing solutions consider a use of DLT platforms for the enactment of CBPs [26] [27]. These solutions use smart contract generation to facilitate the collaborative processes integrated using the DLT network. In these solutions, authors present a tool that takes business process specification as an input and generates smart contracts that are then deployed on a public DLT network named Ethereum [28]. Described methods have several limitations regarding a use in Industry 4.0. A use of a public DLT network like Ethereum may not fit the high data security requirements of the Industry 4.0 domain. Instead, enterprise solutions that rely on a private, consortium federated DLT network could be used to protect highly sensitive corporate data. Scalability and performance may also become a concern with the use of a public DLT network, like Bitcoin or Ethereum, where each transaction needs to be processed by every single node in the network. For instance, Ethereum supports up to 15 transactions per second. This creates a severe bottleneck for the execution of production processes in Industry 4.0, where machines involved in the manufacturing generate transactions at a much higher pace. To the best of our knowledge, none of the existing solutions considers high security, performance, and scalability requirements in a unified way. Since these requirements are critical for the application of a solution in Industry 4.0, we propose an investigation of a solution for an architecture based on private, permissioned DLTs and smart contracts that would be suitable for the selected domain.

III. Collaboration Context

A system based on the proposed architecture would reside between collaborating parties with their factories. Such system would receive an order, create a smart contract on which all collaborators agree and forward the appropriate information to a factory for production. The scope of the proposed research is entirely in the cyber world of the Cyber-Physical Systems, and the factory's cyber and physical parts are considered a black box. From the project's standpoint, information systems of the "black box" factory, e.g., Enterprise Resource Planning (ERP) and Manufacturing Execution System (MES), need to be able to receive and store a production process specification together with other production order details such as quantity or desired time of production. In addition to these inputs, factory information systems need to provide a digital output on the work in progress, i.e., information on the currently executed steps of production processes, and data from the factory equipment.

Two steps need to be completed to generate a smart contract automatically. As a first step, a process designer must formally specify a production process specification based on a production order, which includes a product specification. After that, as a second step, a smart contract needs to be generated out of the formal production process specification, containing all necessary actions, i.e., contract clauses that should be performed by the manufacturer in order to produce the end product.

A formal specification of production processes is needed to model production processes with all the details required in every process step. Production process specification is often used as a basis for production coordination between different contractors within the value chain. For example, suppliers within the car manufacturing industry that follow the Advanced Product Quality Planning (APQP) framework are mandated to have a formally stated production process specification approved by the customer [29]. Our goal is to utilize these specifications and supplement them with additional data to gather enough information to generate smart contracts that monitor a described production process and facilitate value chain collaboration.

The formal specification of the production process must be empowered with a model-driven methodology to make it possible and easy to generate smart contracts from production process models, which will assure that all of the agreed production steps are executed.

IV. MDSD Approach to Horizontal Integration

To promote trustworthy collaboration between parties involved in a value chain, we propose a solution in which MDSD principles and DSMLs are used to model CBPs and automatically generate smart contracts. MDSD approach is a part of the Model-Driven paradigm, where models represent a primary artifact at all system development stages and are connected and organized at different abstraction levels. Some of the goals of MDSD are to: (i) increase software system developing speed through automatization and centralized representation of knowledge, (ii) improve software quality through formalization, and (iii) increase reusability of models [30]. The goal of DSMLs in MDSD is to bring modeling concepts closer to users familiar with an application domain so that they can specify their solution with less time compared to General Purpose Modeling Languages (GPMLs) [31]. We believe that an MDSD approach and DSMLs will have an essential role in increasing the capability of value chains to synchronize and adapt their production in a timely manner when executing CBPs.

The solution should be based on three process types described in detail in Section II-A. A high-level overview of the approach is given in Fig. 2. Process designers are responsible for specifying Interface Process Models (IPMs) based on a production process specification contracted with collaborating parties. IPMs represent a high-level technical description of a production process that should include specification of (i) process steps, (ii) actor types or specific resources, e.g., machines, robots, and humans, which should execute process steps, (iii) input and output products, i.e., products like raw materials, components, or finished goods, and (iv) quality constraints, i.e., constraints that refer to quality assurance, and (v) execution constraints, e.g., constraints regarding operator safety in production. Based on an IPM, a smart contract generator (SC Generator) can be used to generate smart contracts. Generated smart contracts will be used to monitor if an organization has performed the production of goods according to the contracted specification.

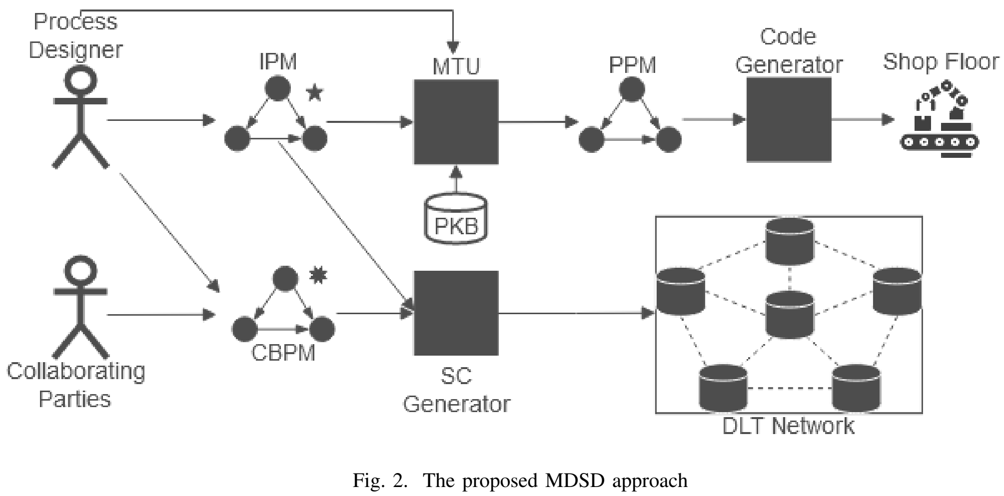


Fig. 2. The proposed MDSD approach

Private Process Models (PPMs) could be created by enriching IPMs and adding data about available resources and the necessary transport activities. A process designer should interact with a Private Knowledge Base (PKB) using a Model Transformation Utility (MTU) to create a PPM that includes the following information that enables process execution: (i) specific resources which should execute process steps, and (ii) logistic information for product and resource movement. Also, a process designer should add details that enable mapping between an IPM and a PPM. These details should define which steps from PPM are aggregated and how, and what represents private data that should not be revealed to related parties. Based on these details, the appropriate event records could be sent to smart contracts during the production execution.

A code generator can be used to generate instructions to resources in the production, and production could then be started. Generated code needs to be human-readable if instructions are sent to mobile devices of human workers or machine-readable if instructions are sent to robots.

A CBP Model (CBPM) is created to coordinate a production between different parties involved in a value chain. For this reason, process designers need to specify (i) which party executes a particular task in the CBP, (ii) what critical points used to determine the state of a task, and (iii) messages that are transferred during process execution. While an IPM can be used to generate smart contracts used to monitor a process executed by a single organization, a CBPM can be used by SC Generator to generate smart contracts that monitor the enactment of CBPs. Monitoring the enactment of CBPs implies observing communication between involved parties and tracking the state of each task.

Once smart contracts are generated, smart contracts should be stored in DLT to which all involved parties have access. The factory information system could then send appropriate signals and information about the fulfillment of specific production criteria, which would automatically trigger actions specified as a part of the stored smart contract. Collaborating parties could then oversee the state of production and contract fulfillment by looking at the immutable store.

V. Conclusion

In this paper, we have proposed an approach for a secure and transparent enactment of CBPs based on DLTs and smart contracts, used for tamper-proof monitoring of the production execution. We have identified and outlined challenges and requirements regarding notational aspects and execution significance for modeling CBPs in Industry 4.0 to facilitate the automatic generation of smart contracts using an MDSD approach. The approach should be based on a DSML that enables the specification of (i) private processes, that represent internal production processes executed by an organization, (ii) view processes, used to coordinate internal actions with activities of external partners while concealing private data, and (iii) CBPs, used to describe how parties collaborate within a value chain. Smart contracts, generated using MDSD principles, should be stored in an immutable distributed ledger and used for monitoring the production performance. Collaborating parties could then supervise the state of production and contract fulfillment by looking at the records of events that occurred during the production. This would promote the understanding of collaboration within the value chain while preserving the confidentiality of private, internal enterprise information.

Predicted outcomes of the proposed research are a system prototype and a new innovative method for trustworthy and automatic monitoring of the enactment of collaboration between parties involved in a value chain. The proposed approach will be tested on a collaboration example from a car manufacturing industry, designed with industry experts and based on openly accessible data. The anticipated value for parties involved in a value chain is a new approach to provide increased safety and transparency during the enactment of collaboration as contracts are automated and tamper-proof. The expected scientific implication is a new methodological approach for horizontal integration that would create conditions for a trustworthy and traceable production.

Acknowledgment

This research paper has been supported by the Ministry of Education, Science and Technological Development through the project no. 451-03-68/2020-14/200156: “Innovative scientific and artistic research from the FTS domain."

References

[1] Kagermann, H., Helbig, J., Hellinger, A., & Wahlster, W. (2013). Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Securing the future of German manufacturing industry; final report of the Industrie 4.0 Working Group. Forschungsunion.

[2] Monostori, L. (2014). Cyber-physical production systems: Roots, expectations and R&D challenges. Procedia Cirp, 17, 9-13, https://doi.org/10.1016/j.procir.2014.03.115

[3] Lippe, S., Greiner, U., & Barros, A. (2005). A survey on state of the art to facilitate modelling of cross-organisational business processes. XML4BPM, 1, 7-22.

[4] Flynn, B. B., Huo, B., & Zhao, X. (2010). The impact of supply chain integration on performance: A contingency and configuration approach. Journal of operations management, 28(1), 58-71, https://doi.org/10.1016/j.jom.2009.06.001

[5] Shafiq, S. I., Sanin, C., Szczerbicki, E., & Toro, C. (2016). Virtual engineering factory: Creating experience base for industry 4.0. Cybernetics and Systems, 47(1-2), 32-47, https://doi.org/10.1080/01969722.2016.1128762

[6] Critical Manufacturing, and IYNO. (2017) “The New MES: Backbone of Industry 4.0.”

[7] Schmitt, G. R. A., Bettinger, C., & Rock, G. (2018). Glencoe–A Tool for Specification, Visualization and Formal Analysis of Product Lines. Transdisciplinary Engineering Methods for Social Innovation of Industry, 4, 665-673.

[8] Lu, Y. (2017). Industry 4.0: A survey on technologies, applications and open research issues. Journal of industrial information integration, 6, 1-10, https://doi.org/10.1016/j.jii.2017.04.005

[9] Fernández-Caramés, T. M., & Fraga-Lamas, P. (2019). A review on the application of blockchain to the next generation of cybersecure industry 4.0 smart factories. IEEE Access, 7, 45201-45218, https://doi.org/10.1109/ACCESS.2019.2908780

[10] Hileman, G., & Rauchs, M. (2017). 2017 global blockchain benchmarking study. Available at SSRN 3040224.

[11] France, R., & Rumpe, B. (2007, May). Model-driven development of complex software: A research roadmap. In Future of Software Engineering (FOSE’07) (pp. 37-54). IEEE, https://doi.org/10.1109/FOSE.2007.14

[12] Vještica, M., Dimitrieski, V., Pisarić, M., Kordić, S., Ristić, S., & Luković, I. (2019, Nov) Towards a formal description and automatic execution of production processes. In Proceedings of 2019 IEEE 15th International Scientific Conference on Informatics, Poprad, Slovakia (pp. 463–468), https://doi.org/10.1109/Informatics47936.2019.9119314

[13] Ferreira, F., Faria, J., Azevedo, A., & Marques, A. L. (2016, October). Industry 4.0 as enabler for effective manufacturing virtual enterprises. In Working Conference on Virtual Enterprises (pp. 274-285). Springer, Cham, https://doi.org/10.1007/978-3-319-45390-3_24

[14] Chen, D., Doumeingts, G., & Vernadat, F. (2008). Architectures for enterprise integration and interoperability: Past, present and future. Computers in industry, 59(7), 647-659, https://doi.org/10.1016/j.compind.2007.12.016

[15] Berre, A. J., Elvesæter, B., Figay, N., Guglielmina, C., Johnsen, S. G., Karlsen, D., ... & Lippe, S. (2007). The ATHENA interoperability framework. In Enterprise interoperability II (pp. 569-580). Springer, London, , doi: 10.1007/978-1-84628-858-6_62

[16] Ruggaber, R. (2006). Athena-Advanced technologies for Interoperability of heterogeneous enterprise networks and their applications. Interoperability of enterprise software and applications, 1, 459-60, https://doi.org/10.1007/1-84628-152-0_45

[17] Da Xu, L. (2011). Enterprise systems: state-of-the-art and future trends. IEEE Transactions on Industrial Informatics, 7(4), 630-640, doi: 10.1109/TII.2011.2167156

[18] Petrasch, R., & Hentschke, R. (2016, July). Process modeling for Industry 4.0 applications: Towards an Industry 4.0 process modeling language and method. In 2016 13th International Joint Conference on Computer Science and Software Engineering (JCSSE) (pp. 1-5). IEEE, https://doi.org/10.1109/JCSSE.2016.7748885

[19] Shah, R., & Ward, P. T. (2003). Lean manufacturing: context, practice bundles, and performance. Journal of operations management, 21(2), 129-149, https://doi.org/10.1016/S0272-6963(02)00108-0

[20] Vještica, M., Dimitrieski, V., Pisarić, M., Kordić, S., Ristić, S., & Luković, I. (2020) An Application of a DSML in Industry 4.0 Production Processes. In IFIP Advances in Information and Communication Technology, Novi Sad, Serbia, pp. 441-448, https://doi.org/10.1007/978-3-030-57993-7_50

[21] Schulz, K. A., & Orlowska, M. E. (2004). Facilitating cross-organisational workflows with a workflow view approach. Data & Knowledge Engineering, 51(1), 109-147, https://doi.org/10.1016/j.datak.2004.03.008

[22] Liu, D. R., & Shen, M. (2001, April). Modeling workflows with a process-view approach. In Proceedings Seventh International Conference on Database Systems for Advanced Applications. DASFAA 2001 (pp. 260-267). IEEE.

[23] Chen, D., & Doumeingts, G. (2003). European initiatives to develop interoperability of enterprise applications—basic concepts, framework and roadmap. Annual reviews in control, 27(2), 153-162, https://doi.org/10.1016/j.arcontrol.2003.09.001

[24] Wüst, K., & Gervais, A. (2018, June). Do you need a blockchain?. In 2018 Crypto Valley Conference on Blockchain Technology (CVCBT) (pp. 45-54). IEEE.

[25] IBM. (2020) Hyperledger Fabric Documentation. https://hyperledgerfabric.readthedocs.io/en/release-1.4/ Accessed April 14, 2020.

[26] Weber, I., Xu, X., Riveret, R., Governatori, G., Ponomarev, A., & Mendling, J. (2016, September). Untrusted business process monitoring and execution using blockchain. In International Conference on Business Process Management (pp. 329-347). Springer, Cham.

[27] Klinger, P., & Bodendorf, F. (2020). Blockchain-based Cross-Organizational Execution Framework for Dynamic Integration of Process Collaborations. In 15th International Business Informatics Congress, https://doi.org/10.30844/wi_2020_i2-klinger

[28] GitHub. Ethereum White Paper: A Next-Generation Smart Contract and Decentralized Application Platform. https://github.com/ethereum/wiki. Accessed January 25, 2020.

[29] Stamatis, D. H. (2018) Advanced Product Quality Planning: The Road to Success.

[30] Dimitrieski, V. (2017) Model-Driven Technical Space Integration Based on a Mapping Approach. Ph.D. Thesis, University of Novi Sad, Faculty of Technical Sciences, Serbia.

[31] Mernik, M., Heering, J., & Sloane, A. M. (2005) When and how to develop domain-specific languages. ACM Comput. Surv., vol. 37, no. 4, pp. 316–344, doi: 10.1145/1118890.1118892.

Author Index