SoftCOM 2020 PhD Forum

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SoftCOM 2020 PhD Forum

Foreword

The PhD Forum, hosted by the 28th International Conference on Software, Telecommunications and Computer Networks – *SoftCOM 2020*, in Split, Croatia, took place, for the first time ever, as an online event.

Over the months preceding the conference, the SoftCOM organizing team had closely monitored the development of the COVID-19 pandemic, and consulted with the healthcare officials and local authorities to ensure that the conference can provide a safe and productive meeting environment. Finally, the decision was made to run SoftCOM as a virtual conference, and thus the PhD Forum had to reinvent itself in line with its main idea – to provide a scientifically relevant and socially engaging, interactive event for PhD students and other conference participants.

The overall concept of the PhD Forum program remained the same as in previous years, with the necessary adjustments for the online format.

To be included in the SoftCOM 2020 PhD Forum programme, doctoral students were invited to submit a two-page extended abstract for review. The submissions were evaluated by the PhD Forum Program & Organizing Committee members, based on relevance to the conference, innovativeness, and quality of (written) presentation. A total of 8 submissions were finally accepted, and the final versions are now included in this booklet.

The authors of accepted extended abstracts then each prepared a poster for the (virtual) poster display, and a 2-minute video presentation with a brief outline of one's doctoral research work, to provide an introduction to the poster. Posters and video presentations were uploaded to the Whova virtual conference management platform, used by SoftCOM 2020.

At the actual online poster session, supported by Whova and Zoom, the session chairs Maja Škiljo and Mirko Sužnjević, welcomed the authors and session participants, and briefly introduced the program of the PhD Forum and the voting procedure for selecting the best poster. Next, all video presentations prepared by the authors were played one after the other, followed by a short break during which all the session participants were invited to individually view the posters and prepare questions for the students. The session resumed with a Q&A (questions and answers) part, in which the doctoral students answered the questions that were submitted by the audience through the online chat feature, and an open discussion, moderated by the session chairs.

The winner of the best poster was determined by the members of the audience in a secret ballot vote, which was facilitated by the online platform. The winner was Iva Topolovac, a doctoral student at the University of Zagreb.

I would like to thank the General Chair of the SofCOM 2020 conference, Dinko Begušić, and all the members of the Steering and the Program & Organizing Committees, for their help in making this year's event possible under difficult and challenging circumstances. I would also like to give special thanks to Maja Škiljo and Mirko Sužnjević for their outstanding commitment, and quickly pulling together a successful first-ever virtual PhD Forum.

Maja Matijašević, University of Zagreb
Steering Committee Chair

AR-based Serious Game for Improving Social Inclusion of People With Disabilities

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***Abstract*—Nowadays, one of the prominent challenges of our society is social inclusion of people with disabilities. This research, in its core, aims towards providing people with disabilities tools for overcoming everyday challenges and barriers therefore improving their day to day life. Aim of the research is to model the application for enforced learning of people with disabilities, i.e., to implement such application without limitations on the application customizability. The developed model was used in the implementation of the *leARn to cook* application which is an AR-based serious game that serves as a visual cookbook and uses game-based elements to encourage user engagement therefore appearing more attractive to people with disabilities.**

***Index Terms*—serious games, people with disabilities, social inclusion, cookbook, accessibility, Down syndrome**

I. Introduction

Even though people with disabilities (PWD) are often referred to as a single population, disability is complex, dynamic, multidimensional, and contested, as described by the World Health Organisation. Hence, it is important to recognise the diversity and heterogeneity of this population. Each person has unique preferences and responses to his or hers condition requiring different approaches in learning and acquiring new skills. This is also the case with people with Down Syndrome, a condition in which a person has an extra chromosome. Down syndrome is the most common chromosomal disorder, affecting one in each seven hundred babies born [1].

There are a number of health related concerns in people with Down syndrome. Mental health issues include: impulsive, hyperactive and anxious behaviours, fatigue and mood related problems, depression, shorter concentration span, regression with decline in loss of cognitive skills, diminished interests and coping skills and many others [2]. These issues affect their abilities to perform daily tasks, as well as their ability to learn new skills. Research indicates that people with Down syndrome can more easily acquire knowledge and improve their skills if small instructional steps are taken [3]. Presenting everyday tasks in the form of instructions and dividing them into smaller, simpler tasks is highly beneficial in facilitating their everyday lives.

Furthermore, digital game-based learning has been proven to have a positive impact on the way people with Down syndrome perform in certain tasks [4]. This approach to learning combines interactive entertainment and utilises digital educational games - serious games. Serious games are games which, besides entertainment, have other purposes that focus on enhancing existing or acquiring new skills [5].

Aforementioned has lead us to form a research question as: *"How to model and implement a serious game in order to increase the quality of life for the people with Down syndrome?"*

Digital game-based learning can help people with other disabilities as well. A competence network "ICT-AAC" targeted for people with complex communication needs provides services that include means for learning, communication and entertainment. A variety of serious games are provided and can be found on the projects official website[1]. The serious game described in this paper is a part of the project "Innovative Solutions based on Emerging Technologies for Improving Social Inclusion of People with Disabilities (INNOSID)[2]" as one of the many deliverables aimed at answering the needs of PWD and improving social inclusion of PWD.

II. Methodology

The methodology of the research follows the usual methodology of the software development life cycle. The first step is to understand the end user's needs that drive the application's purpose altogether referred to as the application domain. The knowledge about the domain was acquired in close cooperation with the Croatian Down Syndrome Association[3]. The association was also one of the main providers of the functionality requirements, since they are well acquainted with the needs of the PWD and have the necessary knowledge on how to form the learning process and which accessibility features are required for the application to be suitable for PWD. Regarding the application's purpose, one of the main inspirations was an existing application, *Accessible chef*[4]. The application is not suitable for the mobile devices, lacks multiple accessibility features, as well as the game component which is one of the main functionality requirements. In discussion with the parents of children with Down Syndrome it has been determined that, in order to get the attention of children with Down Syndrome, an entertainment element needs to be present to engage the user as much as possible, and therefore, we decided to base

[1] http://www.ict-aac.hr/projekt/index.php/en/applications
[2] http://sociallab.fer.hr/innosid/
[3] http://www.zajednica-down.hr/index.php/en/
[4] https://accessiblechef.com/

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the games implemented in the application on the augmented reality (AR) technology.

The next phase of the methodology is the implementation of the application while taking into a consideration all functionality requirements. The game was implemented using Unity and Google AR technologies that provided certain flexibility in terms of new features and additional ideas regarding the application purpose. The application was developed in couple of phases following the final phase of the methodology, with testing after each iteration. The application features were discussed with the parents of children with Down Syndrome and the feedback was extremely positive. The testing procedure was performed with the parents, having in mind to include children in the future.

Future phases of the methodology include evaluation with end users and experts from the field of education and rehabilitation, upgrading the application according to this information and adding new features apart from the currently provided cookbook, since the designed application is highly customizable.

III. Use case: leARn to cook

Application *leARn to cook* is a multi platform AR-based serious game consisting of three main parts:

- visual recipe generation,
- visual recipe overview, and
- two AR games.

The main menu of the application is presented in Figure 1. New recipes can be created in the **Gallery** part of the application. Recipes are grouped in categories, e.g., breakfast, lunch, or dinner, and the user can add custom categories. Besides category, each recipe has a name and a list of ingredients, tools, and actions. Furthermore, each action is broken down to a list of steps to lower the recipe complexity. Ingredients, tools, and steps are represented with graphical symbols related to AAC (Alternative and Augmentative Communication). Symbols have either a name or a short description and an image providing visual stimulation and making each recipe a visual recipe. While creating the recipe the user can use the existing symbols or add custom symbols from his or hers gallery or camera.

Recipes can be edited, printed, and deleted. By choosing to print a recipe the application generates an *easy-to-read* type of file with the visual recipe ingredients, tools and actions. The generated file has a specific layout allowing the user to read, i.e., view the recipe from left to right. Recipes generated by the application break the usual meal preparation in smaller tasks providing clear instructions that are easy to follow.

Apart from having the visual recipe printed out, the user can view the recipe on-screen by selecting the **Cook** part of the application, which is also designed to enforce learning by allowing the user to scroll symbols from left to right.

The AR-based games *Learn* and *Find* serve as the **gaming component** for the enforced learning process bringing an improvement in comparison to the existing solutions. Before starting the games the user has to print out markers to be scanned during playtime. The game Learn provides information about the ingredients. The user can scan the ingredient symbol to see a 3D model representation and to find out interesting facts about it. The game Find has an objective to find, i.e., scan specific ingredients or tools in a specific order.

Fig. 1. Screenshot of the main menu

IV. Conclusion

As stated in the Section I, we developed the application that serves as a highly customizable cookbook containing game-based elements for generating visual recipes designed specifically for PWD, i.e., Down syndrome. Based on the severity of the disability, the recipes can be created with different level of complexity making the application accessible to everyone.

The most important outcome is the developed model for implementing the aforementioned application. This model can be used in the implementation of applications for learning about jobs that can be divided in smaller tasks performed subsequently and that can be described with graphical symbols, e.g., instructions for hoteliers or bartenders. Therefore, the model can be used to improve various aspects of the lives of PWD and increase their social inclusion, which is one of the important challenges the research community is tackling today.

The future work includes the application evaluation with experts and end users as well as implementing changes according to the newly gathered requirements.

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CudDNN Convolution Algorithms on Nvidia GPU

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***Abstract*—— The task of this paper is to implement a convolution on the graphics proces unit to analyze the memory requirements of deep neural networks for object detection. Convolutions are one of the most basic components of many modern architectures based on deep learning. They have been implemented from classification models such as VGG Net to object detection systems such as Mask-RCNN. Although these and other deep learning models have proven to be extremely successful in their particular task, they also take a long time to train with conventional hardware. In this paper, we present convolution algorithms provided by the cuDNN, the library used most of deep learning frameworks.**

Keywords— convolution, deep learning, CUDA, graphic proces unit, cuDNN

I. INTRODUCTION

In the late 20th century, many machine learning models and various types of neural networks were developed. Until recently, many of them were virtually inapplicable, primarily due to the lack of computational power. The same was the case with convolutional neural networks on which Y. LeCun is the greatest name and one of the pioneers of applied convolutional networks. Convolution is a mathematical operation that computes the integral of the product of a function f with the reversed and translated version of a function g. It may be understood as a weighted moving average of f, where g are the weights (1.):

$$(f * g)(x) = \int_{-\infty}^{\infty} f(u)g(x-u)du \qquad (1)$$

A discrete convolution features a similar definition, with the two input functions being discrete sequences (2.):

$$(f * g)[n] = \sum_m f[m]g[n-m] \qquad (2)$$

Convolution, by means of deep learning, is an operation between two parameters - an input array and a convolutional kernel array, respectively. The convolutional kernel array is typically much smaller than the input array and iterates through the input array. It computes a weighted sum of the current input element and its neighboring input elements at each iteration. The result is placed in the output array. For example, in image processing, if we use an RGB 2D image as the original signal and apply convolution to it with another signal, called a filter or kernel, the output signal may have the property of containing all the edges of the original image. The image edges can represent object boundaries, changes in lighting, changes in material properties, discontinuity in-depth, etc. [4]. Convolutional layers are composed of a set of 3D filters-kernels and receive a set of 3D inputs-batches. The convolution is performed on each input–filter pair, resulting in a set of 3D outputs. The convolution of an input–filter pair generates one X-Y plane of the output.
The results of the convolutions of one particular input with all the filters are stacked in the Z direction, generating the corresponding 3D output. The same process is applied to all the inputs of the batch, resulting on a set of 3D outputs. The sets of inputs, filters, and outputs may be seen as 4D arrays, also known as ‘‘tensors’’, corresponding to the 3 dimensions of each input/filter/output, plus the dimension to identify each of these within the set.

Convolutional layer is creating by adding an offset array called bias onto the convolution outputs to subsequently apply a non-linear activation function, such as sigmoid or ReLU as in fully-connected layers. Convolutional networks used for intelligent image processing require significantly more customizable parameters and multiplication of matrices compared to other neural networks [1].

Deep learning and intelligent image processing gained popularity in the 2010s after the development of software to use graphics processors (GPU) for numerical and scientific calculations. The goal of this paper is to implement a convolution on the Nvidia CUDA GPU [2] using the CudNN framework. CuDNN is a CUDA library that abstracts various high-performance deep learning kernels, such as convolutions or activations. The basic programming model consists of describing the operands to the kernels, including their shape and memory layout, describing algorithms, allocating memory for cuDNN [3].

II. IMPLEMENTATION OF CONVOLUTION USING CUDNN

The results of convolution memory requirements in this paper were obtained using Nvidia GTX 1660 Super 6GB using CUDA 10.1, and the operating system is Linux Ubuntu 16.04.

The cuDNN program for convolution it is based on: transferring an image and a filter from a host to a device, setting the execution configuration, calling the kernel function for the convolution operations and transferring the convolution result from the device (GPU) to the host (CPU).

The image over which the convolution was performed is loaded using the OpenCV library. The procedures for all tools and programming languages are not described in detail in this paper; each language requires a separate chapter and in-depth description. We use three data to describe convolution operation: the input tensor, the output tensor and the kernel tensor. CuDNN provides quite a lot of flexibility for to the description of tensors. Several algorithms may be used to compute a convolution on cuDNN. A GEMM-based algorithm transforms the inputs and filters to be able to execute high-performance matrix operations.

The following algorithms are based on arithmetic strength reducing the number of multiplications while increasing the number of additions. One of these is based on FFT operations, computing the convolution in the frequency domain. The other relies on Winograd's minimal filtering algorithms-signal processing to apply finite impulse response (FIR) filters. In this paper, all the previously outlined algorithms are tested, but without significant improvement in performance, and for further implementation, a method was used where CuDNN automatically selects the most optimal algorithm.

III. RESULTS

At this point, we need to allocate the required resources for the convolution. The number of buffers and memory requirements for each buffer will differ depending on which algorithm we use for the convolution. In this case, we need four buffers for the workspace, the input and output image as well as the kernel.

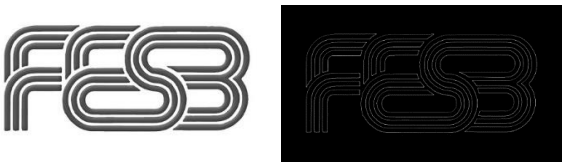
The first three we allocate on the device directly (workspace, input, output), we first allocate the kernel to the host and then copy it to the GPU device. The kernel used for convolution is an edge detector. The template uses a 3 x 3 kernel and is copy it the three input and three output dimensions of the actual kernel buffer. That is, the same pattern three times, once for each channel of the input image (red, green, and blue), and that whole kernel three times, once for each output feature map we want to produce. We save the obtained image, which was convoluted, from the GPU device to the host (CPU).

The convolution was implemented and tested with s tested with single-precision (FP32) and half-precision (FP16) input data and kernels, but without significant improvements in reducing memory usage.

At the convolution output, we measure how much memory requirements for a particular input image. Information on memory usage is important for analyzing the convolutional layer's memory needs in object detection networks such as the Faster RCNN.

In the future, the goal of implementing this program is to implement a convolutional network that can detect high-resolution images obtained from drones and execute object detection programs directly on the drone, on limited hardware such as Nvidia Jetson Nano and Javier AGX.

The input image and result in the evaluation is shown in Fig.1.



(a.) (b.)

Fig.1.Results of convolution on GPU (a.) input image, (b.) output image

Input size (*px*)	Alloc.memory (*Mb*)
9 x 9	0,015625
256 x 256	0,373500
512 x 286	1,125015
2000 x 2000	34.3323
4000 x 3000	68,6646

Fig.2.Allocating CUDA memory after convolution

IV. RESULTS

In this paper, we implemented the convolution using the cuDNN library, and analyze the memory requirements on CUDA. Convolution is a fundamental part of most deep neural networks, and it is essential to create optimal convolutional layer for the construction of new and improvement of existing architectures. It is also shown in part how frameworks like TensorFlow and PyTorch (partially) allow a much higher level of program abstraction. Also, these frameworks provide a much simpler approach in building networks to the developer. Convolution analysis implemented using cuDNN will be used to improve the object-detecting architecture- Faster-RCNN further. Namely, with high-resolution images on which it is necessary to detect objects, there is a problem of lack of memory, which is especially pronounced if we work with edge hardware like Nvida Jetson Nano.

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Energy Detection in MIMO Cognitive Radio Networks

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***Abstract*— Cognitive radio as a concept is based on the ability to detect and share the underutilized spectrum. For the realization of the cognitive radio concept, energy detection as one of the spectrum sensing methods is broadly considered, because of its low computational complexity and implementation costs. The energy detection accuracy of the primary user signal is susceptible to noise uncertainty variations and the accuracy of the dynamic threshold adaptation. One of the prominent techniques for improving the spectrum utilization in wireless networks is the Multiple-Input Multiple-Output technique. In this paper, the influence of Multiple-Input Multiple-Output technique on the energy detection of signals transmitted using orthogonal frequency division multiplexing is investigated for different signal to noise ratios. Obtained results show a significant impact of noise uncertainty variations, dynamic threshold adaptations, MIMO configurations and sampling densities during the sensing, on the probability of signal detection.**

Keywords—MIMO, energy detection, cognitive networks, OFDM, wireless, SNR, probability, signal, power, sensing

I. INTRODUCTION

Cognitive radio networks (CRN) based on spectrum sensing represent intelligent wireless communication technology dedicated to more efficient exploitation of the available frequency spectrum. Various methods have been proposed in the literature for spectrum sensing. Energy detection (ED) as one of the non-cooperative methods of spectrum sensing is broadly considered due to its low computational complexity and simple implementation [1-3].

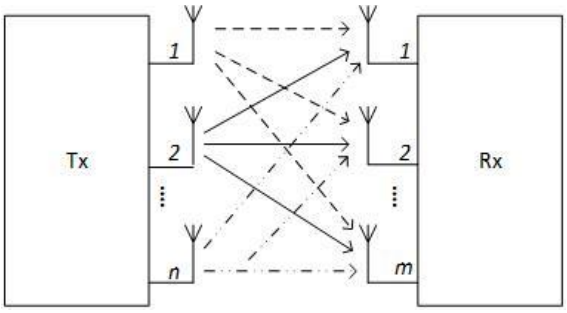

Fig. 1. The basic structure of the MIMO system

Multiple-Input Multiple-Output (MIMO) orthogonal frequency division modulation (OFDM) is the dominant access technology for the 4th and 5th generation (4G and 5G) broadband wireless communication systems. OFDM combined with MIMO may improve the performance of the wireless communication system in terms of spectral efficiency, capacity, reliability and quality of service (QoS).

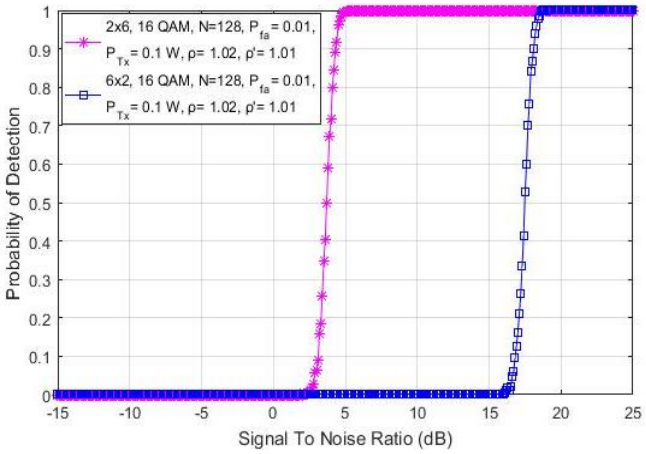

Fig. 2. SNR vs. probability of detection for an asymmetric MIMO system with OFDM as the modulation scheme

An example of the MIMO system is presented in Fig. 1. [4]. In this paper, the performance of the MIMO spectrum sensing for the ED method is evaluated by the Space-Time Block Codes (STBCs) using the Matlab simulation toolbox (version R2016a). STBC is a complex orthogonal space-time code where multiple transmit and single or multiple receive antennas are used for sending multiple copies of the same data or messages over independent and faded transmission paths [5, 6]. The goal of performed simulation analysis is to show how MIMO transmission impacts the ED probability of signals received in environments with different signal to noise ratio (SNR) levels.

II. SIMULATION RESULTS AND DISCUSSION

A. *Influence of MIMO techniques on the energy detection process*

The analysis is performed for *nxm* MIMO system, where *n* defines the number of transmitting (Tx) chains with corresponding antennas of primary user (PU) and *m* defines the number of reception (Rx) chains with corresponding antennas of the secondary user (SU). In Fig. 2, the relationship between SNR and the probability of detection (P_{di}) for the OFDM system concerning the different number of antennas on Tx and Rx side (MIMO *2x6* and *6x2*) has been presented. The results are obtained for equal: the number of samples (N=128), transmit power ($P_{Tx} = 0.1$ W), probability of false alarm ($P_{fa} = 0.01$), noise uncertainty NU (ρ=1.02) and dynamic threshold DT factor ($\rho' = 1.01$). Results presented in Fig.2 show that the probability of detection will be higher for a higher number of antennas on the receiver side.

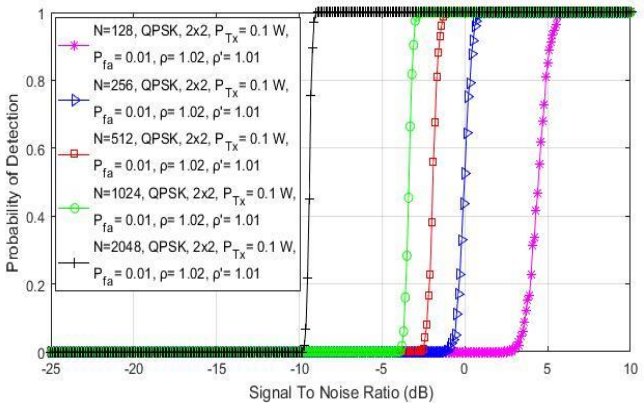

Fig. 3. Impact of SNR and number of samples on the probability of detection in MIMO *2x2* OFDM system

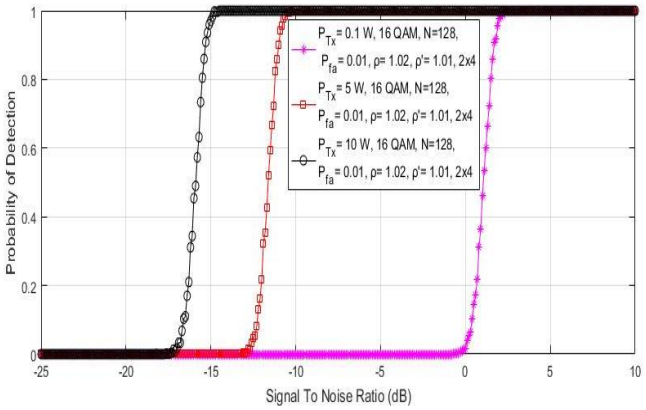

Fig. 4. SNR vs. probability of detection for OFDM signals transmitted in *2xm* MIMO system with *m= 2, 3* and *4*

For low values of SNR, the probability of detection is zero and for high values of SNR, it approaches one. The two ranges are connected by a narrow transitional range of SNR values. The location and the width of the transitional range of SNR values depend on the MIMO system parameters. This means that the *2x6* system has better ED performance when compared to *6x2* systems. The consequence of this can be found in the better detection accuracy for systems having a higher number of Rx chains and corresponding antennas.

B. Influence of the number of samples on the MIMO energy detection process

The influence of the number of samples (N) on the probability of detection(P_{di}) for the MIMO *2x2* OFDM system has been presented in Fig. 3. The results for the fixed probability of false alarm equal to P_{fa} =0.1, DT factor ρ′= 1.01, and transmission at Tx power level of 0.1 W in channels with fixed NU variation ρ= 1.02 are obtained and presented in Fig. 3. The obtained results show that the lower probability of detection will be achieved for a lower number of samples and lower SNR and vice versa. This means that the number of samples impacts on the probability of detection, since a higher number of samples means more dense sensing periods during which detection has been performed.

C. Impact of different Tx powers on MIMO energy detection process

Further analysis was dedicated to the presentation of the impact of the different values of transmitting (Tx) power on ED capabilities. In Fig. 4., the influence of SNR on the probability of OFDM signal detection, for three different Tx power levels (0.1 W, 5 W and 10 W) over a channel with equal channel conditions are presented. The results confirm that the level of PU Tx power at the location of the SU has an impact on the probability of detection in OFDM systems. As expected, for higher levels of Tx power, the probability of detection will be higher and vice versa. Higher probabilities of detection are the consequence of the higher Tx power levels which generate higher energy on the Rx antennas of SUs. The SU with a higher number of Rx antennas obtains better results in terms of probability of detection since a higher number of Rx chains and corresponding antennas can detect higher levels of signal energy at the location of SU.

III. CONCLUSION

In this work, the impact of MIMO transmission on the performance of ED of OFDM signals in CR networks was analyzed. Obtained results indicate that MIMO as a prominent wireless transmission technique in modern communication systems has an impact on the ED of OFDM signals. Results also show that the implementation of MIMO transmission can improve the ED process. It can be concluded that the probability of signal detection increases when a higher number of Rx antennas are used by SUs in the ED process. Also, it is shown that the probability of PU signal detection increases if a higher number of samples is used in the process of OFDM signal detection. Furthermore, results indicate that for higher levels of Tx power, the probability of detection will be higher due to a higher level of received energy at Rx antennas of SU. The overall results of analyses show that the MIMO technique can be a promising candidate for the improvement of ED performance in modern communication systems. Further research will be dedicated to the analyses of the interdependence among the probability of signal detection and the probability of false alarm in MIMO OFDM systems.

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Impact of Video Segmentation on Switching in Adaptive Streaming

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***Abstract*— Many parameters like stalling and switching influence the Quality of Experience (QoE) in adaptive streaming. Adaptive streaming algorithms use switching between different representations in order to adapt to changing network conditions. Both the segmentation process and the adaptation logic can be improved while taking into account the QoE and the switching frequency and depth. Although high switching frequency can affect the QoE, the users are more annoyed by the high average switching depth. Segment-Aware Rate Adaptation and Basic adaptation algorithm were used for testing the impact of video segmentation on switching in adaptive streaming. The proposed segmentation achieves the tradeoff between the switching frequency and the average switching depth. The switching frequency is in most test cases higher, but the average switching depth is in all cases lower which improves users QoE.**

Keywords—switching, adaptive streaming, segmentation, video quality, MPEG DASH

I. INTRODUCTION

MPEG Dynamic Adaptive Streaming over Hypertext Transfer protocol (MPEG DASH) is a standard developed to uniform and improve previously developed streaming technologies. MPEG DASH aims to provide smooth playback by varying between video segments encoded using various target coding bitrates and spatial resolutions [1]. Server side in MPEG DASH system is used to store the Media Presentation Description (MPD) file and all video sequences. Video sequences used in DASH systems should be encoded using various target coding bitrates and spatial resolutions and divided into video segments with lengths typically 2, 4, 6, 10 and 12 seconds. MPD file stores information about all adaptation sets and video representations available on the server. After reading the MPD file, the client starts downloading the first segment. The representation of each of the following segments is selected using the adaptation logic module [2]. Depending on the adaptive streaming algorithm, the representation for the next video is selected based on the available bandwidth, buffer-occupancy, segment size, bandwidth history. Novel adaptation algorithms are usually tested using one of the few available datasets like dataset presented in [3] that includes 17 to 20 representations of 5 video sequences. In previous work, the combinations of spatial resolutions and target coding bitrates were selected by analyzing Peak Signal-to-Noise Ratio (PSNR) [3]. Still, available datasets should be expanded and upgraded. The idea of this paper is to compare two segmentation schemes (a novel proposed scheme and the one from [3]) using two adaptation algorithms based on number of quality switching and the switching depth in order to improve the segmentation process and adaptation algorithms. The switching depth is the difference between the representation levels in the switching event. The switching can cause minimal variations in the Quality of Experience (QoE) [4]. Although switching events influence the QoE less than stalling and they help to minimize the occurrence of stalling events [5], QoE can be decreased in case of frequent quality switching. Although the QoE is influenced by the number of quality switches, the depth of switching has larger impact on the QoE. Also, user's QoE is more affected by down-switching compared to up-switching [6]. After introduction and overview of the available research, this paper presents the used test setup and the acquired test results. Section III gives concluding remarks.

II. TEST SETUP AND RESULTS

Video sequence Big Buck Bunny (BBB) [7] was used for testing purposes. First, BBB sequence was encoded in .y4m in different spatial resolutions: 320x240, 854x480, 1280x720 and 1920x1080 using FFmpeg [8]. x264 free software library was used to encode all sequences at test target coding bitrates [9]. Resulting .264 file were converted to .mp4 using MP4Box [10]. FFmpeg was used to upscale all encoded video sequences to 1920x1080 to match original video sequence and Structural Similarity index (SSIM) was calculated. In some cases for selected target coding bitrate, lower spatial resolution can have higher SSIM. The most suitable pairs of spatial resolutions and target coding bitrates were determined based on intersections of spatial resolution curves (SSIM and achieved coding bitrate dependency). The pairs of spatial resolutions and target coding bitrates that have highest values of SSIM were selected. MP4Box was used to segment all video sequences and generate MPD files. The number of segments depends only on the selected segment duration and the video sequence length, so it is equal in both the proposed segmentation and the segmentation presented in [3]. For testing purposes two adaptation algorithms were used: Segment-Aware Rate Adaptation (SARA) [1] and Basic adaptation algorithm (BAA). A-stream player [11] was used as a client application for testing purposes. Newly segmented videos were compared to ones presented in [3] using two test cases that limited available bandwidth using Wondershaper scripts. In the first test case

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bandwidth was increased in step-wise manner from 1 Mbps to 8 Mbps. The second test case had average bandwidth of 3 Mbps with short spikes of 10 Mbps. From Tab. I and Tab. II it can be seen that the total number of switching events is higher in proposed segmentation, but the average switching depth is lower. The number of switching is larger due to the larger number of representations available for the available bandwidth. Considering that the duration of BBB is 596 s, with BBA algorithm the switching occurs on average after every segment, and with SARA after 3.2 to 9 s of video sequence segmented with 2 s segment duration. From Fig. 1. and Fig 2. it can be seen that in the case of proposed segmentation for 10 s segment duration, although there are many quality switches, the average switching depth is lower compared to [3] segmentation and the majority of segments are downloaded in 720p and 1080p spatial resolution which ensures higher QoE because stepwise switching between segments on 1080p resolutions is not likely to be visible to users. Considering that the SARA has the phase when it changes the representations more aggressively, it has higher values of average switching depth, but lower number of switching compared to BAA. Similar results are obtained for 2 s and 6 s segment duration.

TABLE I. TOTAL NUMBER OF SWITCHING EVENTS

		Segment size					
		2s		6s		10s	
Algorithm	***Case***	***1***	***2***	***1***	***2***	***1***	***2***
Basic	[3] seg.	260	268	99	99	58	59
	Proposed seg.	297	297	98	98	59	59
SARA	[3] seg.	65	135	47	47	37	39
	Proposed seg.	153	181	52	49	38	29

TABLE II. AVERAGE SWITCHING DEPTH

		Segment size					
		2s		6s		10s	
Algorithm	***Case***	***1***	***2***	***1***	***2***	***1***	***2***
Basic	[3] seg.	1.18	1.07	1.11	1.12	1.08	1.13
	Proposed seg.	1.05	1.07	1.08	1.09	1.05	1.14
SARA	[3] seg.	1.88	1.93	2.66	2.40	2.23	2.59
	Proposed seg.	1.70	1.68	1.24	1.88	1.32	1.40

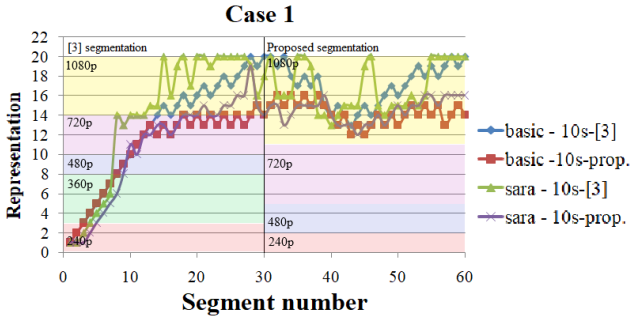

Fig. 1. Respresentation levels for 10s segment duration – case 1.

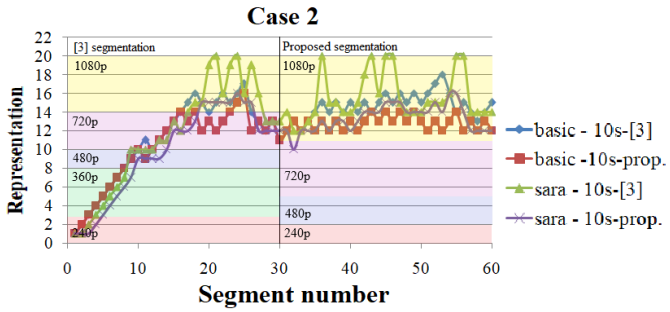

Fig. 2. Respresentation levels for 10s segment duration – case 2.

III. CONCLUSION

Although stalling influences the QoE more compared to switching, if the frequency of the switching or the average switching depth are too high, QoE can be affected. In order to improve available datasets and adaptation algorithms preliminary testing was done using the BBA and SARA algorithms, two network test cases and BBB video sequence. SARA has lower switching frequency, but higher average switching depth. Compared to [3] segmentation, proposed segmentation has higher switching frequency, but lower average switching depth. In future work the impact of switching frequency on QoE is going to be further tested and dataset with new segmentation is going to be proposed as well as new adaptation algorithm.

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Mobility as a Service: Stakeholders and Challenges

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***Abstract*—The process of urbanisation affects the transport network by creating various barriers that limit mobility between desired locations. There are many reasons, such as high investment costs and specific area constraints, why transport infrastructure is often not convenient to an increase in the number of vehicles. *Mobility as a Service* (MaaS) is a new mobility paradigm that takes advantage of information and communication technology to improve current mobility. MaaS is a concept which integrates various transportation services (public transport, bike-sharing, car-sharing, etc.) and offers them to users to fulfil their mobility needs. The paper defines the term MaaS and introduces the MaaS stakeholders. Additionally, the challenges that MaaS brings are summarised with an emphasis on data-related challenges. Finally, a research plan is listed and it is focused on data collection and MaaS simulation. All for the purpose of better understanding the relationships and interactions in MaaS.**

***Index Terms*—Mobility as a Service, stakeholders, challenges, data**

I. Introduction

Nowadays, the share of the urban population is constantly increasing [1]. That causes a reduction in the number of rural and mixed settlements and an increase in the number of cities. This process is known as the *urbanisation* process. According to the United Nations (UN), it was predicted that 68% of the world's population will live in urban areas by 2050 [1]. They also point out that sustainable development is key to successful urban growth management. Urbanisation process brings challenges in tackling housing, employment, education, transportation and infrastructure [1].

As it is mentioned, *transport* is greatly affected by the urbanisation process. A possible solution to transportation problems could be information and communication technology (ICT). It opens up opportunities and encourages the development of solutions for better utilisation of the existing transport infrastructure, optimisation of the transport network, more efficient use of vehicles and ultimately, uninterrupted travel.

Mobility as a service (MaaS) is a relatively new concept that, together with the help of ICT technology, wants to improve the current mobility [2]. Mobility as a service is a concept in which transportation options are integrated and offered to the user in order to meet their mobility needs and to improve transport efficiency [2]. It demands a digital platform where the provision of the transport and payment is managed [2]. The field of MaaS has become an increasingly interesting research field over last few years, as evident from the growing number of related papers in the scientific literature [3], [4].

The focus of this PhD research is to answer the following research question: *"What is the impact of MaaS on people, planet and profit?"*. Within the scope of this manuscript, we provided our own view of MaaS stakeholders (II-A) and listed MaaS challenges (II-B) with emphasis on data ones. Finally, conclusion and future steps of the research are explained.

II. Mobility as a Service

As the MaaS is new approach it is important to further explore the possible impacts and challenges of MaaS as well as the roles and relationships between MaaS stakeholders [4].

A. MaaS stakeholders

Taking into account existing studies [2]–[4] we decided to present MaaS stakeholders using a quadruple helix model. Generally speaking, model consists of four main entities academia, government, civil society and industry [5]. They collaborate and interact bi-directional, multi-layer and dynamic in order to make social innovation [5]. This general model is copied on the MaaS topic. The civil society is transformed to the passengers, industry to the transportation operators, while the academia and government are unchanged. The social innovation, for which they are collaborating, is MaaS. Figure 1 represent MaaS stakeholders in quadruple helix model.

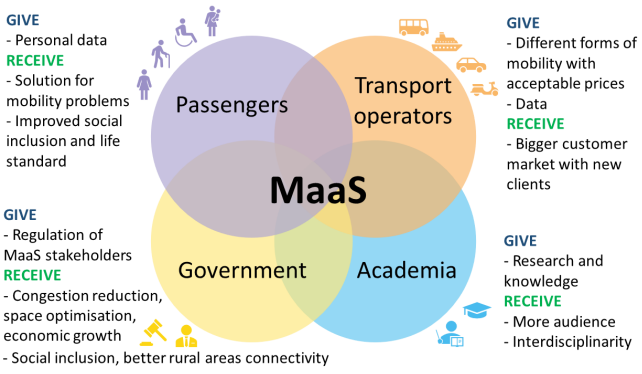

Fig. 1. Quadruple helix model of MaaS main stakeholders (with information of what they give and receive from MaaS)

The *academia* contributes to the MaaS ecosystem with scientific researchers. The acquired knowledge can be applied for MaaS development and improvement [3]. At the same time, academia from MaaS gets an interdisciplinary component to the research and opportunity to reach more audiences [3].

Passengers are the main users of the ecosystem. They expect that MaaS will resolve the congestion problem and other accompanying things such as less waiting time, cost reduction and similar [4]. Additionally, MaaS can improve social inclusion and life standard of people with disabilities, elderly people, rural inhabitants, etc. by adapting to their needs [4]. While passengers can contribute with their personal data to the ecosystem [3].

Transport operators enriched the MaaS ecosystem with flexible, reliable and different forms of mobility that have acceptable prices [3], [4]. MaaS offers to transport operators impartiality system that brings a bigger customer market with new clients [3]. As well as the passengers, transport operators provide data for the good MaaS operation [3].

Finally, the *government* serves as a collaborator among actors [3]. With the involvement through regulations, subsidies and other available forms government has the ability to manage questionable issues such as data security, price and passenger protection [3]. Government interests in the MaaS ecosystem are congestion reduction, space optimisation, environment responsibility and sustainability, economic growth, social inclusion and better connectivity of rural areas [3], [4].

Beside these four main actors, there are also other stakeholders that contribute to the MaaS realisation. Some of them are investors, ticketing and payment services, IT providers, insurance companies, etc. [2], [3]. They are isolated because only few of them are somehow considered as the main stakeholders, while others are not crucial for the understanding of MaaS.

B. MaaS challenges

MaaS, as a novel approach, brings many challenges and some of them are listed as follows [2]–[4]: challenge regarding the acceptance of new mobility solution, gaining a critical mass of passengers and transport operators, passenger willingness to pay and willingness to ride and try live without a private car, a collaboration between public and private transport operators, service and vehicle fleet optimisation and relocation strategies and regulatory issue to make impartiality market competition.

Beside these challenges, data-related ones stand out. MaaS firmly relies and depends on data [4]. Data analysis can identify user behaviours and preferences, obtain information on available routes and vehicles, as well as identify critical points in transport, etc. [2]. Many transportation data is not open or shared, and those that are come from different sources and are inconsistent [2], [3]. Openness and standardisation of data is necessary for MaaS development. Additionally, data security and privacy is a challenge that needs to be addressed as well [2], [4].

Many of the above-mentioned topics can be explored only after the MaaS system is widely deployed in practice. This is perhaps not ideal as the implementation cost of the real-world system is significant and no real predictions have been made about the MaaS impact on current mobility [6]. However, there are also research opportunities which do not require the real-world MaaS system to be deployed. For example, to test the fundamental concepts surrounding MaaS, such as payment options, traffic behaviour, and others, one can use computational models for simulating the actions and interactions of the stakeholders [6].

In particular, we will explore the aforementioned research opportunities through the use of agent-based modelling and simulation in order to derive a computational model for studying the impact of MaaS from three pillars of sustainability (people, planet and profit) [6]. It is also important to notice that such a computational model, in order to be able to closely resemble the future real-world system such as MaaS, requires a quality set of data for instantiation and validation. That being said, the proposed research agenda is as follows: (i) design an agent-based model for MaaS, taking into account a heterogeneous nature of involved stakeholders and complexity of their interactions (Fig. 1), (ii) design and implement a serious game for collecting the relevant data, (iii) collect data from a serious game through crowd-sourcing, (iv) implement the computational model by combining the agent-based model with the collected data, (v) run simulation experiments to study the impact of MaaS from the three pillars of sustainability.

III. Conclusion and future work

The urbanisation process entails changes. That is also manifested in the transport sector. The current mobility is not capable of tackling these challenges, and the MaaS concept emerged as a solution. Inclusion of the stakeholders explanation makes the MaaS concept much easier to understand. As the MaaS is a complex concept it is good to simulate it in order to overcome future challenges. Therefore, future work will be based around collecting and analysing the MaaS-relevant data set in order to be able to develop and implement a computational model. The model would serve for studying the impact of MaaS in terms of three pillars of sustainability: people, planet and profit.

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Modelling and Validation of a Specialized Vehicle CAN Bus Simulator

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***Abstract*—Due to its characteristics and performance, Controller Area Network (CAN) bus is most extensively used in the development of specialized vehicles for agriculture, construction and municipal purposes, among others. It is challenging to test functionalities like fleet management and predictive maintenance which encompass data collection from multiple specialized vehicles, as such vehicles are commonly made-to-order. For this reason, simulators of specialized vehicle CAN bus systems are needed. In this paper, one such CAN bus simulator is proposed along with the description of the validation methods which were used to ensure its accuracy.**

***Keywords*—Controller Area Network, CAN bus, Specialized Vehicles, Simulation, Validation**

I. Introduction and Related Work

Controller Area Network (CAN) [1] is a serial communications bus mainly used for soft real-time in-vehicle communication between electronic control units (ECUs). CAN is extensively used in specialized vehicles which have to endure harsh conditions because of its high immunity to electrical interference, and ability to self-diagnose and repair data errors. Specialized vehicles include different construction, agriculture, marine, mining, and municipal vehicles such as street sweeper and cleaner vehicles. Generally, specialized vehicles and their components are not mass produced, but are made-to-order. This means that it is not simple to test such vehicle components integration and their communication over the CAN bus. This is where CAN bus system and components simulation is valuable, as it can be used to replace one or more vehicles or vehicle components in the testing process, extremely reducing the costs of testing.

Some solutions for CAN bus simulation already exist. Hofstee and Goense [2] have developed a program simulating a CAN-based tractor equipped with multiple data buses connected with each other. In contrast to our paper, they simulated all components in their entirety and no hardware was used except a computer running the simulation. Yao et al. [3] used CANoe, a system-level bus development tool, along with MATLAB to simulate vehicle motor torque and brake pressure. Zhou et al. [4] also used CANoe to construct a simulation and test environment for a vehicle body CAN bus. They created a simulated CAN network with sensor nodes simulating different signal values such as car speed and oil level. Freiberger et al. [5] used CANoe and a software gateway to capture data from a Volkswagen Polo, analyze it to determine which ECU is associated with which CAN ID, and reverse engineer an electro-hydraulic power steering (EHPS) pump by simulating its sensor data. In our paper, no industrial CAN simulating software such as CANoe is used. Also, we use a hardware CAN bus to output the results of the simulation, which was not done by any of the mentioned papers.

Simulating a specialized vehicle CAN bus usually has some requirements that are the consequence of the usage domain. It is useful for such requirements to be identified before development by the industry experts. To ensure its accuracy, the simulator also needs to be validated by comparing its output to data collected from a real vehicle. As no standardized methods of CAN simulation validation are available, appropriate methods of validation need to be determined.

II. CAN Bus Simulator

The main goal of the simulator is to replicate a vehicle CAN bus, enabling the vehicle equipment to be developed and tested without the vehicle being actually present to generate CAN data. The requirements which the simulator needs to satisfy to be applicable for specialized vehicle component simulation were established in collaboration with industry specialists from RASCO [6], a company manufacturing municipal equipment for road maintenance.

Users can input the simulation instructions to the simulator using a graphical user interface. The user input is processed and formed into a tuple describing the simulation of exactly one vehicle component which generates CAN data that changes over time. The simulations created by the users can also be stored in the database for repeated use. Multiple simulation tuples can be combined into a simulation scenario. For the simulation to be executed, a simulation scenario is analyzed and its simulation tuples are formed in a discrete time series. The discrete time series is used to execute the simulation and create a CAN message stream. This stream is outputted on a hardware *USB-CAN converter*.

The simulator was implemented in Java using the model-view-controller (MVC) software design pattern and Spring application framework. A graphical user interface used to collect user input was designed using Javascript and Bootstrap front-end framework. Finally, the USB to CAN conversion is done using PEAK-system's PCAN-USB, a CAN hardware interface for USB.

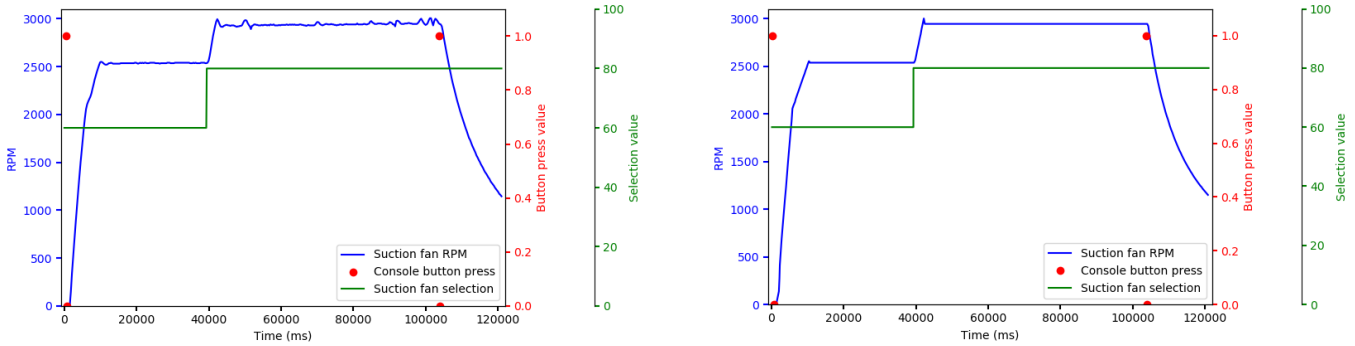

Fig. 1. The actual (left) and simulated (right) values of CAN bus parameters through time

III. Results and Validation

To validate the simulator, CAN data was captured on the Lynx compact sweeper vehicle developed by the RASCO company. The data was analyzed and three mutually dependent parameters were selected for simulation. The recorded values of the three parameters through the time span of a little more than two minutes can be seen on the left side of Figure 1. The figure shows how the three parameters (console button press, suction fan RPM and suction fan selection) influence one another through time. This entire scenario was recreated in the simulator in order to validate it. The output of the simulation can be seen on the right side of Figure 1. Upon visual inspection of the two graphs, we can notice that the most apparent difference is that the simulator is unable to generate oscillations which happen when RPM messages are continuously repeated. This problem is mitigated with the simulator sending an average value of the real-life messages generated in that period.

We used the following mathematical similarity measures to assess the precision of the simulator: cosine similarity of timestamps and values, dynamic time warping similarity and Frechet similarity. The validation results seen on Table I show that the simulator can indeed simulate a specialized vehicle CAN bus with a high degree of precision, as all but one similarity measures returned a score above 99.5%. After validation, the simulator was ready to be utilized in the use case of testing the *Platform for storage and analysis of the connected electric sweeper vehicle CAN bus data* described in [7].

TABLE I
Validation results

Variable	Console button press	Suction fan selection	Suction fan RPM
Cosine similarity of timestamps	99.999973%	99.999974%	99.999935%
Cosine similarity of values	100%	100%	99.994672%
Dynamic time warping similarity	99.987192%	99.971393%	99.588656%
Frechet similarity	99.970996%	99.861604%	98.190726%

IV. Conclusion and Future Work

This paper presents the modelling and development of a specialized vehicle CAN bus simulator and its validation using multiple mathematical similarity measures. The simulator's output was found to have a similarity with the output generated by a specialized vehicle of more than 99.9% in 9 out of 12 mathematical measurements, and was never lower than 98.0%. As the validation scores were satisfying, the simulator was deployed in the real life use case of testing the platform for storage and analysis of connected electric sweeper vehicle CAN bus data. In future work, we intend to enhance the simulator by adding several new functionalities to improve the validation score even further. We also plan to additionally examine the real-life use case with the emphasis on the connected vehicle data simulation.

V. Acknowledgement

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Roadmap for Development of Accessible Software Solutions Based on Emerging Technologies

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***Abstract*—New digital technologies can bring many benefits for society. However, developing technology is not enough; technology must be made accessible to enable equal participation in society for everyone, including people with disabilities. This paper reviews solutions based on emerging technologies (ET) for people with disabilities and proposes a roadmap for development of accessible software solutions based on ET. Also, future research direction towards accessibility of solutions based on augmented reality is pointed out.**

Keywords—emerging technologies, software development roadmap, augmented reality, people with disabilities, accessibility

I. INTRODUCTION

The society is witnessing daily progression of enabling technologies related to computing power, big data, connectivity of devices, performance of the Internet, etc. This leads us to a thinking of how to take advantage of these technological progresses for higher goals, i.e. to improve the quality of people's lives. One of the most vulnerable groups are people with disabilities (hereinafter PWD), who often experience social exclusion. To avoid having them excluded from the society, PWD need to have the appropriate access to digital infrastructure and accessible information and communication technology (ICT) [1]. The use of ICT can improve the quality of life of PWD by increasing access to education, employment, community activities etc. but only if they are considered in line with the CRPD [2] and if technology developers prioritize accessibility for all [1].

Emerging technologies (hereinafter ET) are defined as "new technologies that are currently developing or will be developed in the next five to ten years, and which will substantially alter business and social environment" [3]. These technologies usually refer to those whose development is ongoing and practical applications are still limited. Having that in mind, it is important that solutions based on ET are also available and accessible to PWD (and other vulnerable communities) to ensure equal opportunities for all. ET that could play a significant role in this domain include Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), Artificial Intelligence (AI), Robotics, Internet of Things and others. Innovative approaches are necessary if one wants to take a step closer to removing the barriers that lie ahead of an inclusive, sustainable, and accessible society. Solutions based on ET are often in their early stage of research and development (R&D), especially those whose domain of application is related to PWD, so the next research question imposes: *"How to approach the development of an accessible software solution based on emerging technology?"*. As an answer to this research question, this short paper proposes an approach that includes a roadmap designed for guiding the development of software solutions based on ET with accessibility specifics. Such a roadmap includes the major necessary steps to reach the desired outcome which is an accessible ET-based software solution.

II. REVIEW OF ET-BASED SOLUTIONS FOR PWD

Examples of solutions based on emerging technologies, such as VR, AR and MR, for improvement of PWD's quality of life follow next in order to give an idea of how big of an impact ET can have on PWD. First example is related to a research involving children with intellectual developmental disabilities (IDD) using VR device for immersion into a virtual environment [4]. The research aims at supporting therapies using a portable VR device with mobile application that tells story and has learning activities. The initial results proved the potential of VR as a valid support for IDD children. The authors in [5-8] describe the potential of mobile AR technology for supporting the learning process of children with different disabilities (IDD, autism, ADHD, reading difficulties). All solutions use marker-based AR that include scanning markers with camera after which a virtual object superimposes on the screen. The results show that a child's interaction with objects arouses curiosity and active participation and could increase motivation to learn and reduce frustration in children with disabilities. Investigation of AR's potential in the field of education and rehabilitation is in its early stages. To conduct this type of research, the prerequisite is to have a quality prototype with features that are easy to understand and use by users of different cognitive skills. One such AR-based software prototype for mastering vocabulary for children with complex communication needs (CCN) is described in [9]. Research described in [10] exploits the potential of wearable MR headset application as a new form of interventions for people with cognitive disability (CD). More precisely, this application helps people with CD to improve autonomy in everyday life by learning simple daily tasks in immersive and engaging way.

A key factor that is common for solutions described above is that a multidisciplinary approach is used in its development, i.e. therapists, psychologists, special educators, ICT engineers, are included in phases from requirements collection to evaluation of solution. On the other hand, mentioned papers describe solutions specific to certain type of disability meaning that requirements derived from their research are specific for that disability and cannot be applied in a more generalized way. Furthermore, it is important to mention that ET-based solutions for PWD are mostly proof of concept solutions or result of experimental studies, so they usually require further explorations. For example, solution described in [10], although having some forms of customizability implemented, for people with severe forms of CD was difficult to understand and execute some hand gestures needed for the proper use of solution. Having said that, accessibility features and guidelines for ET-based solutions impose as very important to be adequately addressed.

III. Roadmap for Development of Accessible Software Solution based on ET

This chapter describes a roadmap with all necessary phases for development of accessible software solution based on ET. The roadmap is inspired by the model of a prototype-driven software development process for augmentative and alternative communication (AAC) applications proposed in [11]. Such a model is directly applicable to the development of AAC software addressing the needs of people with CCN. Furthermore, the proposed development process includes all general software engineering best practices and extends them with specifics of AAC domain. The proposed roadmap, shown in Fig.1., extends the model by including the specifics related to the ET domain. The model is iterative, meaning that ET-based solution will go through several iterations within phases marked on the roadmap before production version is ready. The purpose of the roadmap is to answer how to approach development of an ET-based solution accessible to PWD.

The first phase is to make a foundational R&D *ET study* that identifies all possibilities and technological limitations of the certain ET, and allows to obtain the knowledge that can be applied for a specific goal, use or product. In case of a development of an ET-based product for PWD, this study should describe its overall vision and outline the purpose and positive impact the product could bring, who are the product's end-users, what needs of the target group does it address, what problem does it solve, the feasibility of its development as well as the business goals. An ET study serves as an input for *ET software requirements specification* phase. For defining all the features and behavior of an ET-based product, a multidisciplinary approach is needed. Depending on the specific group of end-users, experts from different fields should be included in this phase. PWD are a heterogeneous group of people whose needs as end-users can very much differ so this phase should include end-users or their representatives. Since the product is based on ET, the experts and end-users might not be familiar with all the features that ET offers. Thus, this phase requires an additional preparation to demonstrate the current capabilities of the ET and the way in which the technology can be used. Ideally, an *ET prototype demonstration* of functionalities which are key to that technology, as well as possible user interaction mechanisms, is shown to the end-users. After analyzing the user needs, software requirements are defined and inspected by a multidisciplinary team. This also includes the ET-specific guidelines for software design, such as ET-driven user interface mechanisms, graphical design, mechanisms of customization of the content to the individual user etc. This all serves as a reference to software designers in the *ET software design* phase. The highest priority should be put on the user needs in context of presentation and accessibility of the ET software product. After having the ET software design model which also specifies the appropriate software architecture, the *ET software construction* phase follows. Each ET software implementation differs considering the ET itself as well as the device, platform, or headset that will be used. The crucial last phase before the final ET software product is *ET software user evaluation* in which the experts and end-users are involved. They verify all functionalities and design principles used. After test users are satisfied with the product version, ET-based product is ready for release which includes a software solution and user guide to resolve all doubts users might have when dealing with new technology.

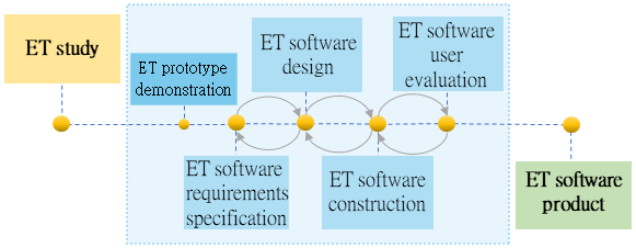

Fig. 1. Roadmap for development of software solution based on emerging technology

IV. Conclusion and Future Work

This short paper proposes a structural approach to development of an accessible software solution based on ET in a form of a roadmap with key phases. What differentiates this roadmap from usual software development roadmaps is that it puts emphasis on specifics related to ET and accessibility, i.e. needs of PWD as end-users. Guided with this roadmap, one should be able to perform necessary phases in the development process for ET-based products for PWD.

Future work will include roadmap elaboration for AR-based software solutions where the focus will be put on the accessibility of the solutions in the context of adjustability to every user. This will include the research on factors that can have an impact on better accessibility for every user, such as type and presentation of content as well as user interaction mechanisms. The possibility of incorporated AI methods that can automate accessibility tasks to tailor identified factors to every user will be investigated.

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New Geographic Information System Layers for Search and Rescue Missions Planning

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Abstract— **In this paper the methods used to develop a segmentation layer implemented as a new Geographic information system layer are described. To create a new layer, the passability and the type of terrain were taken into account. By applying two models of neural networks MaskRCNN and Unet, the recognition of dry stone walls and roads were achieved. The Geographic information system feature were applied to display isohypses and by combining all of the above, a new segmentation layer was created.**

Keywords — segmentation, QGIS, neural networks, deep learning

I. Introduction

In real life is impossible to analyze thousands of images taken by aerial vehicles in the short time, and the speed of detection of a lost person in the image is an important part of the search. The probability of finding a lost person and the search time are inversely proportional. It takes a long time for a human to detect a lost person on large number of photos, and tiredness makes it difficult to maintain attention so it's easy to reach missed goals. When planning search and rescue actions, a complex planning methodology based on experience and statistics is used. There are some similar approaches reported in literature because this is a current popular topic [1-4]. We approached the problem in such a way that for the purposes of system design new images were taken with the aerial vehicles, and a terrain map was created based on them, in real time. This increases the probability of data accuracy, because every year there are changes in vegetation, and consequently in passability, which is very important to us in our research. According to statistics made on the basis of data from the International Search & Rescue Incident Database - ISRID [5], when defining a search, the category of the lost person and the last point or location where the person was seen are taken into account. The last point a person was seen at, can be determined based on eyewitness statement, and the last known location can be a lost person's car or a GPS location of a cell phone, etc. The leader of the action determine in which way the search will be approached, by taking into account one of the points mentioned earlier and the other important circumstances that determine the initial planning point - IPP. The book [5] defines the categories of people and their characteristics that are important to consider when planning rescue. What is most useful, based on the statistics mentioned above, is the definition of several tables. Two of them are most important, the first showing the distance from the initial starting point, contain data on the percentage of people found within the area, expressed as the distance in miles from the IPP depending on the type of terrain. Second is showing the survival statistics depending on the type of person, terrain and time passed since the beginning of the search.

Given the previously mentioned available data, the next step is to determine the circle of the search area, to draw "stochastic circles". Radius is the distance in miles from the IPP taken from the table depending on what type of person is being search for. In order to be able to talk about accuracy it is necessary to take into account the passability of the terrain. To get that information, we must first know what type of terrain it is. It is determined whether it is hilly or flat terrain, whether there is forest vegetation, low vegetation or grass, whether there is a river, etc. The next step is to determine passability by applying consensus. The leaders of the action select a few rescuers that are more experienced and each of them makes their own assessment of the probability that the requested subject is in some segment. (TABLE I.)

TABLE I. Estimation Of The Probability That The Requested Subject Is In A Segment

SEGMENT	RESCUER A	RESCUER B	CONSENSUS
ROW	10%	10%	10%
SEGMENT 1	55%	45%	50%
SEGMENT 2	35%	45%	40%
TOTAL	100%	100%	100%

ROW refers to an area outside the selected search area, and the total should be 100%. This is called Probability of Area (POA). In the above example, POA (1) = 50%, and POA (2) = 40%.

II. Methods

During the development of prototype system and research, the rules were implemented in the MySQL database, and the method of applying consensus was used to determine the passability of the terrain. The results show a new segmentation layer that has been obtained and implemented in Quantum Geographic information system - QGIS. Before the segmentation process, a new orthogonal photo map of the terrain was created using images from our database, which were collected with the Phantom 3 professional drone. The testing was also performed based on [6]. The aim was to isolate a specific area from the new terrain maps and to make segmentation taking into account passability and relief type. The passability analysis refers to the motion of the person sought in the environment, based on the correlation of several of the elements as mentioned earlier. The stitching was performed after completing the image collection. Two methods were examined in the stitching process. In the first method the Image Compose editor with the additional rotation and position calculation was used, while Agisoft was used in the second method. In the Image Compose editor the angle of calculation was obtained by determining the center of the

stitched image, and extracting from that center an image of the same dimensions as the images of which it is composed. Using the exiftool tools, the longitude and latitude of each extracted image were extracted from the meta data, and then the mean of geo-lengths and latitudes was calculated. Based on the calculated values, an image was selected to match these values with its length and width, and it was further used for comparison with the acquired image. This method was ruled as unreliable, because it compares features in 2D instead of 3D and does not take into account geo-heights and depths. Because of this, the edges did not match best with the Bing map in the substrate set in QGIS, and a manually-responsive adjustment was necessary to match the edges. After testing, in order to get as accurate results as possible, we decided to use Agisoft, and MeanShift for segmentation, which gave us the first sublayer of the new layer. The database was completed based on data from the ISRID database, and the heuristic approach added values of terrain passability. An algorithm for the calculation of passability was developed, which analyzes neighboring fields for each field. The algorithm assigns values to the fields until all the neighbor fields have been calculated and all the edges have reached the minimum value, after which the resulting color segment is predefined, giving a second sublayer. To build the third sublayer, a module that recognizes dry walls and roads has been developed using deep learning. Two MaskRCNN and Unet neural network models were used, whereby 506 images were labelated at Supervisor for design and testing purposes, and augmented with the same set was expanded to 6071 images used for training.

III. Results

The processed images were collected in a non-urban area. A specific area was isolated and segmentation was made using the MeanShift algorithm (Fig. 1). A Bing map placed in the background of QGIS was used as a stich check.

Fig. 1. Segmentation obtained using the MeanShift algorithm

The passability and the type of relief were also taken into account during the creating a new layer. We used a heuristic approach to add the value of terrain passability. After that, an algorithm was developed that results in staining the segment in a predefined color (Fig. 2).

Fig. 2. Layer that defines passability

Fig. 3. Implementation of a new segmentation layer in QGIS

To build a new segmentation layer (Figure 3.) MaskRCNN and Unet neural network models were used, whereby 506 images were labelated at Supervisor for design and testing purposes, and augmented with the same set was expanded to 6071 images used for training.

IV. Conclusion

The main goal of the paper was to extract a certain area from the new terrain maps and make segmentation by taking a look on passability and type of relief and to implement the result as a new QGIS layer. The problem was approached in such a way that for the purposes of making the system, new images were taken by aerial vehicles and based on them a map of the terrain in the so-called. real-time thus increasing the probability of data accuracy. The stich was achieved by using Agisoft, because the method of using the Image Compose editor with additional calculation of rotation and position did not prove to be reliable. Layer that perform segmentation based on relief-type passability was developed. By applying in-depth learning, the recognition of dry stone walls and roads was made. By combining the QGIS feature to display isohypses and all of the above, the set goal was achieved. A new segmentation layer, that was not previously available in QGIS, was developed which significantly improves the quality of search and rescue actions.

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