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Using remote sensing to map in-field variability: Clustering Approaches

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***Abstract*— Precision Farming concept is spreading rapidly worldwide as a tool to enable farmers for profitable production while fulfilling environmental and food safety conditions. The introduction and application of precision technologies in agriculture has been motivated by the high degree of variability of agro-ecological conditions within fields. With increased use of precision agriculture techniques information concerning within field soil and crop variability is becoming increasingly important for effective crop management. As a result of new technological advances, more and more data is available. The safe and reliable transfer of different kinds of data into detailed information for management purposes is also of increasing importance. In this paper an overview is given on the use of remote sensing data in site-specific farming for assessing crop growth and yield variability. Many studies have been carried out to find an appropriate method to classify the high resolution remote sensing data within a field. According to the results of my research two classification approach - pixel-based and object-based (OBIA) - are presented. Image processing techniques including vegetation indices, segmentation, and classification were used in this research. The models presented in the article are suggested to be used for crop monitoring and supporting decision making.**

I. DATA GATHERING

Precision agriculture technology is a farm management system, which relies on various measurements, data collections and analysis, as well as decision making. Measurements include soil chemical and physical characteristics determination, grain yield and quality measurements, and several remotely sensed property determination. The base of precision agriculture is information on the spatial and temporal variability of soil and crop characteristics as well as the environment and external conditions [7, 10]. The data on the properties of soils, plants, occurrence of pests, obtained yield and meteorological parameters are needed to optimize field management [1, 2]. How to measure and map the spatially and temporally varied field parameters accurately and efficiently has been the focus of the researches in the field. In many studies remote sensing data are used as a source of information and GIS technology as tool for data analysis. Geographical information systems (GIS) are systems for the storage, analysis and presentation of spatial data. GIS can also support translation of the research findings into operational systems for use at farm level by providing a good platform for storage of base data, simple modelling, presentation of results, development of a user interface and, in combination with a global positioning system, controlling the navigation of farm vehicles. On the basis of GIS a decision support system could be developed for operational application of precision agriculture at farm level [6, 8].

Remote sensing technologies are being used more and more often in agriculture providing data for monitoring within and between-field. In parallel with development of spatial, temporal and spectral resolution in the last decade the quantity and quality of data is constantly increasing as well. Results of research in the field from all over the world have provided a fundamental information relating spectral properties of soils and crops to their agronomic and biophysical characteristics. This knowledge has facilitated the development and use of various remote sensing methods to detect spatially and temporally varied environmental stresses which limit crop productivity [1, 2, 10]. This can make significant contribution in optimizing crop management as sowing, irrigation, fertilization and harvest. However, gathering, accessing, and processing of remote sensing images from different satellites require high technical skills and agricultural knowledge as well. Besides expertise, a computer (software and hardware) background is also required. Processing large amounts of data can be time consuming. The lack of comprehensive software platforms to extract useful spatially and temporally varied information from remote sensing and other sources, and the lack of knowledge can hindered the wide application of technology to support precision farming.

II. DATA GATHERING

The introduction of precision technologies in agriculture has been motivated by the high degree of variability of agro-ecological conditions within fields. One of the criterion for introducing precision agricultural technologies is the development of an up-to-date arable crop information system that provides information on soils, crop land cultivation, plant status, etc. [1, 5, 11, 12]. This information can be used as starting data for cultivation and predicting yield estimate. In order to set up such an information system, it is essential to use modern data gathering and analysis technologies. Remote sensing is the most effective tool for surveying the Earth's surface and tracking its changes.

With increased use of precision agriculture techniques, information on crop yield variability within-field is becoming increasingly important for effective crop management. The yield map integrates the effects of various spatial variables so that it provide also information on soil properties, topography, plant population, nutrient replacement practices and applied agrotechnology. A yield map can therefore been indispensable input for site-specific operations either by itself or in combination with other spatial data. Yield data can be obtained at harvest by harvester-mounted yield monitors. The first yield

measuring devices were applied in the early '80s, since that they have started to become standard equipment on combines. With technological advances of harvester-mounted yield monitors and Global Position Systems (GPSs) farmers are able to collect intensive and accurate yield data during harvest. Yield maps can be generated immediately following data collection to show yield patterns within fields [3, 13]. The result of analysis can be used for after-season management. The yield monitor accuracy depending on the type and brand of yield monitor, calibration regime, flow rate and conditions at harvest. Yield monitor calibration plays a key role in obtaining the best possible accuracy from the yield monitor [3].

Despite the commercial availability of yield monitors, many crop harvesters are not equipped with them. Furthermore, additional information is needed for effective analysis of the map e.g. information on plant stress during the growing season. Yield monitor data cannot be used to detect problems and generate maps within season.

Within season estimates of relative yield variation and stress detection can more useful address by remote sensing. Satellite imagery obtained during the growing season can be used to generate yield maps for both within season and after season management (Figure 1.).

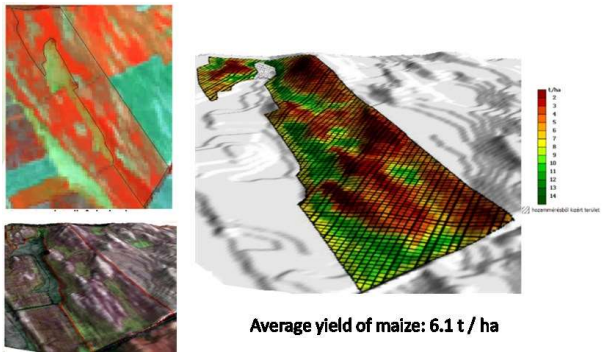

Figure1. Cell yield of maize created from Sentinel data: input data and output). Source: [13]

III. VEGETATION INDECISES

By measuring the reflectance of the plants at various wavelengths, it is possible to collect a lot of information about the status of the plants. The reflectance of light spectra from plants depends on plant type, water content within tissues, and other intrinsic factors [4]. The reflectance of vegetation is low in the blue and red regions of the visible spectrum, due to absorption by chlorophyll for photosynthesis. It has a peak at the green region which gives rise to the green colour of vegetation. In the near infrared (NIR) region, the reflectance is much higher than that in the visible band due to the cellular structure in the leaves. In the mid infrared there are more water absorption regions (Figure 2.) [14].

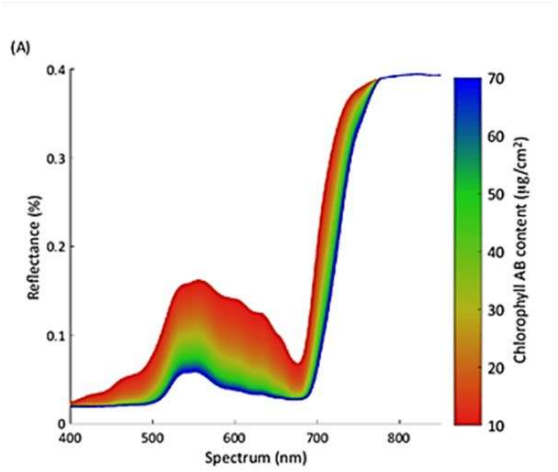

Figure2. Reflectance pattern of a typical crop as a function of the chlorophyll AB content Source: [16]

During the quantitative interpretation of remote sensing information from vegetation can be created by extracting vegetation information using individual light spectra bands or a group of single bands for data analysis. The construction of VI algorithms are effective tools to measure vegetation status. Vegetation information from remote sensed images is mainly interpreted by differences and changes of the green leaves from plants and canopy spectral characteristics. The data from near infrared (0.7–1.1 m) and red (0.6–0.7 m) or other bands are combined in different ways according to their specific objectives [4]. From previous research, there are known relationships between the indices using those two regions of the spectrum and the amount of vegetation. Different indices have been developed to better model the actual amount of vegetation on the ground. A lot of research has been done to derive relationships between a vegetation index of a crop, measured at a particular time, and the final crop yield. Low index values usually indicate little healthy vegetation while high values indicate much healthy vegetation [11, 12].

IV. DATA ANALYSIS BY UNSUPERVISED CLASSIFICATION

There are various approaches and quantitative methods for using remote sensing data to discriminate different types of habitat cover. In this study pixel-based and object-based approaches were applied for mapping spatial variability within a field.

In an unsupervised classification, the analyst does not predefine the land cover or habitat types. The image processing software divides the image into a certain number of classes, based entirely on the spectral data and with no knowledge of what cover types are present in the image. The user can define limits to the number of output classes and spectral variance within each class. The resulting classes are identified by different numbers, and the analyst must then assign names to these classes with the support of field knowledge and an understanding of how different habitats should appear in these images. There are several mathematical strategies to represent the clusters of data in spectral space. For example: IsoData

Clustering (Iterative Self Organising Data Analysis Techniques). It repeatedly performs an entire classification and recalculates the statistics. The procedure begins with a set of arbitrarily defined cluster means, usually located evenly through the spectral space. After each iteration new means are calculated and the process is repeated until there is some difference between iterations. This method produces good result for the data that are not normally distributed and is also not biased by any section of the image. The other one is Sequential Clustering. In this method the pixels are analysed one at a time pixel by pixel and line by line. The spectral distance between each analysed pixel and previously defined cluster means are calculated. If the distance is greater than some threshold value, the pixel begins a new cluster otherwise it contributes to the nearest existing clusters in which case cluster mean is recalculated. Clusters are merged if too many of them are formed by adjusting the threshold value of the cluster means.

In this study to delineate classes the IDRISI software was used. So called 'CLUSTER' algorithm was used for classification. It provides an unsupervised classification of input images using a histogram peak technique. CLUSTER uses a histogram peak technique of cluster analysis. This is equivalent to looking for the peaks in a one-dimensional histogram, where a peak is defined as a value with a greater frequency than its neighbors on either side. Once the peaks have been identified, all possible values are assigned to the nearest peak and the divisions between classes fall at the midpoints between peaks. Here a one to seven-dimensional histogram is used to find the peaks. A peak is thus a class where the frequency is higher than all of its cardinal neighbors. The diagonal neighbors are omitted because of the correlation between bands.

CLUSTER does not use the histogram from the original images to define peaks. Instead, it stretches each input image into a given number of grey levels before calculating their histograms. There are three stages involved in this process:

1. The histogram of each input image is obtained by going through the original input image's digital numbers. From this histogram, the numeric cumulative proportion at each grey level is found by adding up the frequency of each grey level from low to high frequencies. The cutoff points are then determined according to the saturation percentage specified. For example, to saturate an image by 5% in each tail, the 5% and 95% cumulative proportion cutoff points are determined by checking the accumulative proportion from the histogram. To derive the histogram for each input image, the gray levels of the input images are linearly stretched into 256 levels, ranging from 0 – 255.
2. Each image is linearly stretched into the given grey levels by applying the cut off points. In the stretch process, a pixel's new value is evaluated using the following procedure:

Assuming $DN_{original}$ is the original value in the input image, the two cutoff points obtained in the previous stage are $Cutoff_{left}$ and $Cutoff_{right}$, the number of grey levels specified is GreyLevel, the new value of each pixel Val_{new} is evaluated using the following logic:

If $DN_{original} <= Cutoff_{left}$ then $Val_{new} = 0$;
Else
If $DN_{original} >= Cutoff_{right}$ then $Val_{new} =$ GreyLevel-1;
Else
$Val_{new} = (DN_{original}-Cutoff_{left})/(Cutoff_{right}-Cutoff_{left})*(GreyLevel-1)$

3. Finally, histograms are developed from each newly stretched image. The histograms derived from the newly stretched images are used to find peaks to perform the cluster analysis [15].

The Figure 3 presents the work flow of mapping spatial variability by unsupervised classification methods and the results of classification.

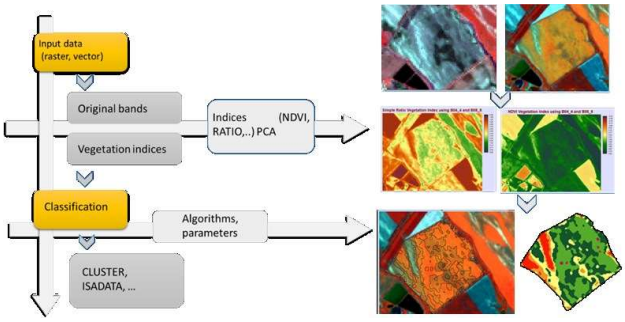

Figure3. Work flow of mapping spatial variability by unsupervised classification methods.

V. CONCLUSION

Remote sensing data can be useful as data sources for estimating and mapping within field crop yield variability for precision agriculture. Imagery taken during the growing season can be used to monitor crop growing conditions and identify potential problems that could be addressed within the growing season. The multitemporal imagery can also be used to generate yield maps to record the spatial variation in yield. Vegetation index is a useful tool in crop monitoring and crop estimation: identification of problems (lack of sowing, cultivation problems, pests, ..), mapping stressed plants, mapping variable requirements for irrigation within a field, identifying fertilization and pesticide requirements, and mapping potential management zones within fields [6, 7, 11]. However, the analysis should take into account that the reliability of such surveys depend on more factors like as the type of index, the time of data gathering and the stage of plant. In this article, one of the way of performing clustering was discussed. The results of the study show that method of unsupervised classification is suitable for mapping differences within a field. This type of research cannot be considered complete as more and more satellite and airborne imagery are becoming available, more research is needed to develop right data analysis techniques for yield estimation and other precision agriculture applications.

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[15] https://clarklabs.org/wp-content/uploads/2016/10/IDRISI-Selva-Spanish-Manual.pdf

SLAM in Simulation and Test Environment

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***Abstract*— Smart manufacturing encompasses a wide range of specializations. One of the most important areas is intralogistics, which besides being part of the supply chain, is a safety critical field as well. Industry has an emerging need for automated solutions thus there is a trend to use more and more automated guided vehicles (AGV). This study introduces a simulation and test environment for simultaneous localization and mapping (SLAM) methods.**

Keywords—SLAM, autonomous robotics, mobile robotics, localization, mapping, ROS

I. Introduction

The SLAM problem is simple, but very important for an autonomous mobile robot [1]–[4]; starting from an unknown starting position in an unknown environment, creating a map of the place (mapping) incrementally, and using this map to determine its current position (localization) [5]–[7].

The task was defined by the research community back in 1986, and they began experimenting with probabilistic methods in robotics. The work started successfully; it has been shown that landmarks are highly correlated, and this correlation increases with increasing number of observations. The first attempts to apply the Kalman filter were also made that time. However, later solutions split the problem of positioning and mapping. This was a consequence of the generally accepted opinion that the estimated errors of the map do not converge, but rather resemble a random motion within an infinitely increasing margin of error. The researchers focused on one or the other sub-problem, trying to provide approximate solutions. This involved minimizing or neglecting the correlation between landmarks.

The breakthrough came in 1995 when they realized that the combined mapping and positioning problem was, in fact, convergent in terms of a single estimator, and also recognized that landmark correlation, which many researchers had sought to minimize, was critical to solving the problem; the stronger the correlation the better the solution. Since then, interest in the area has increased; they primarily seek to reduce the computational complexity of the algorithms, and further refine data association and loop closure.

II. Problem Description

Fig. 1 shows a typical SLAM task. The mobile robot travels through an unknown area of which he has no prior knowledge. As the robot moves, it uses a built-in sensor (relative to its current position) to make relative observations of landmarks along the way.

As the robot odometry responsible for navigation often proves to be inaccurate, we cannot rely solely on odometry information. We can use the results of the built-in sensor to take measurements of the environment for more accurate data. We can do this by identifying certain landmarks of the environment and observing them again and again as we move. When the odometry changes as a result of robot movement, the uncertainty about the new position of the robot changes (odometric update). The landmarks are then identified in the new position of the robot. The robot attempts to connect the newly discovered landmarks to previous measurements (re-observation). The re-observed landmarks serve to update the robot's position.

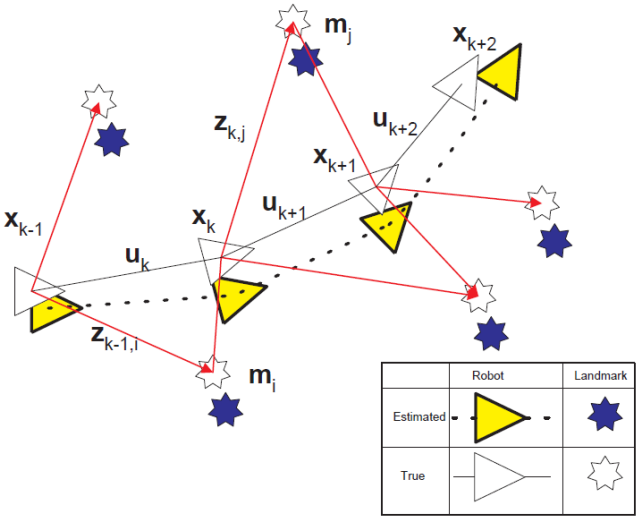

Fig. 1: SLAM problem [8], [9]

The most commonly used methods for solving a SLAM problem is the extended Kalman filter (EKF), the Fast Slam [10] and the Graph SLAM [11]. There are newer solutions and improved versions of these basic methods for which we can find comparison in the literature [12]–[14]. A list of the most common SLAM methods:

- Lidar SLAM methods
  - GMapping [15]
  - Hector SLAM [15]
  - Cartographer
- Monocular SLAM methods [16]
  - Parallel Tracking and Mapping (PTAM)
  - Semi-direct Visual Odometry (SVO)
  - Dense Piecewise Parallel Tracking and Mapping (DPPTAM)
  - Large Scale Direct monocular SLAM (LSD SLAM) [17]
  - ORB SLAM (mono) [17]
  - Direct Sparse Odometry (DSO)
- Stereo SLAM methods [16]
  - ZEDfu
  - Real-Time Appearance-Based Mapping (RTAB map)
  - ORB SLAM (stereo) [17]
  - Stereo Parallel Tracking and Mapping (S-PTAM)

The focus of this paper is the lidar based SLAM methods as these are the most common solutions in AGV navigation. 2D lidar sensors provide range and bearing data of the obstacles around the robot (see Fig. 2). The SLAM methods are based on these measurements and the odometry of the mobile platform [18], [19].

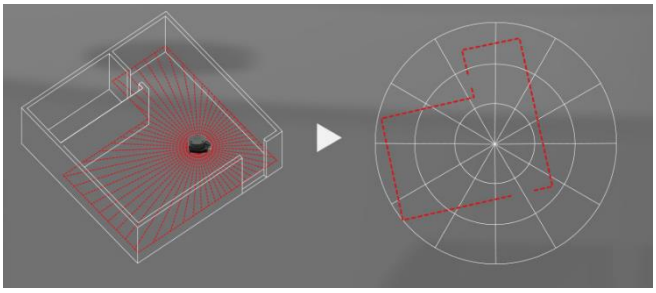

Fig. 2: Lidar measurement [20]

EKF is usually used for state estimation assuming an ideal map is provided. Thus, the procedure is missing the map update required by the SLAM algorithm. In contrast to the EKF used for state estimation, the matrices used in the SLAM-EKF change. Most of the SLAM-EKF procedure follows the classic EKF after the matrices are correctly formed.

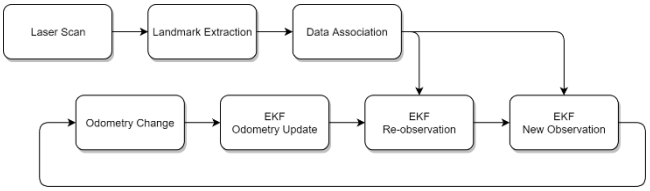

Fig. 3: EKF SLAM method

The Kalman filter and the EKF represent the probability distributions with a parameterized model. Particle filters [21], on the other hand, represent distributions with a finite set of sample states called particles. High probability regions have denser particles, while lower probability regions have few or no particles. For a sufficient number of samples, this non-parametric representation can be used to estimate arbitrarily complex multidimensional distributions. If the number of samples goes to infinity, the true distribution can be accurately reconstructed. Fast SLAM, based on the particle filters, takes advantage of the conditional independence that results from the structure of the SLAM problem.

The third common approach to the SLAM problem is Graph SLAM. Graph SLAM divides the problem into two parts: front end and back end, which are connected by the pose graph of Fig. 4.

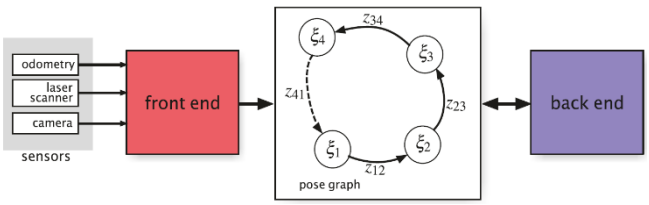

Fig. 4: Graph SLAM method [22]

The path of the robot is considered as a series of discrete positions, and the task is to estimate these positions. The constraints between unknown positions are based on measurements of various sensors, including odometry, laser scanners and cameras. The problem is formulated as a directed graph.

III. Simulation Environment

As simulation environment V-REP software (see Fig. 5) was chosen. V-REP is capable of performing most robotics-related simulation tasks, and what is important in our study it is compatible with Robot Operating System (ROS). ROS is a flexible robotic software framework that incorporates a number of toolkits to integrate some of the aforementioned SLAM algorithms and also facilitates building of industry 4.0 systems [23]–[27].

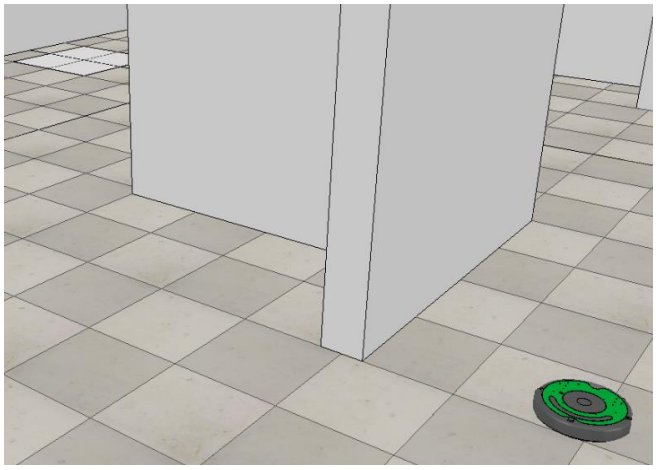

Fig. 5: V-REP simulation environment

In addition to the 3D rendering, V-REP also has various physical motors that allow real-time motion modeling. Sensors can also be simulated, allowing the simulation of real Lidar measurements. Fig. 5 shows the mobile robot platform moving towards the white target in the upper left corner.

IV. Experimental setup

The real environment is two adjacent halls of a robotics center between which mobile robots are traveling (see Fig. 6 and Fig. 7).

Fig. 6: ABB-KUKA robot laboratory

Fig. 7: Fanuc-UR robot laboratory

The robotic center is equipped with Fanuc, Universal Robots, ABB and KUKA robot arms. From the viewpoint of the SLAM environment the most important features of the laboratories are the tiled floor and the several legs of the tables and chairs. The previous one might deteriorate the measurements of the mobile robot platform by influencing the orientation. Several legs might be hard to detect and associate during the SLAM algorithm.

The mobile robot platforms are based on the iRobot Roomba 605, which is commercially available, cost effective, easy to repair and has an open communication protocol for its controller that provides access to its actuators and sensors, and its battery accessible. We built three versions on this platform:

- Lidar (see Fig. 8), which can be used to test laser scanning based algorithms.
- Kinect (see Fig. 9), which can be used to test image-based algorithms.
- Mobile manipulator, where the mobile platform is equipped with a small robot arm (not relevant for this paper)

Fig. 8: Lidar mobile robot platform

Fig. 9: Kinect mobile robot platform

The connection between the components was solved with Raspberry Pi (see Fig. 10). The Raspberry Pi and the sensors are powered by the mobile robot's battery, where a highly reliable circuit is needed [28]–[30]. As the battery voltage of the mobile robot platform is too high for the elements built up on it, a buck converter was needed to transform the DC voltage to the suitable level. Communication with the mobile robot, such as moving the wheels, is done by Raspberry Pi. The raw data of the sensors (IMU, Lidar, Kinect) is received by Raspberry Pi and then transmitted to an external PC into ROS environment, which performs data processing requiring high computing capacity. This PC is also responsible for performing tasks of industry 4.0 like ERP system connectivity [31] or Big Data [32].

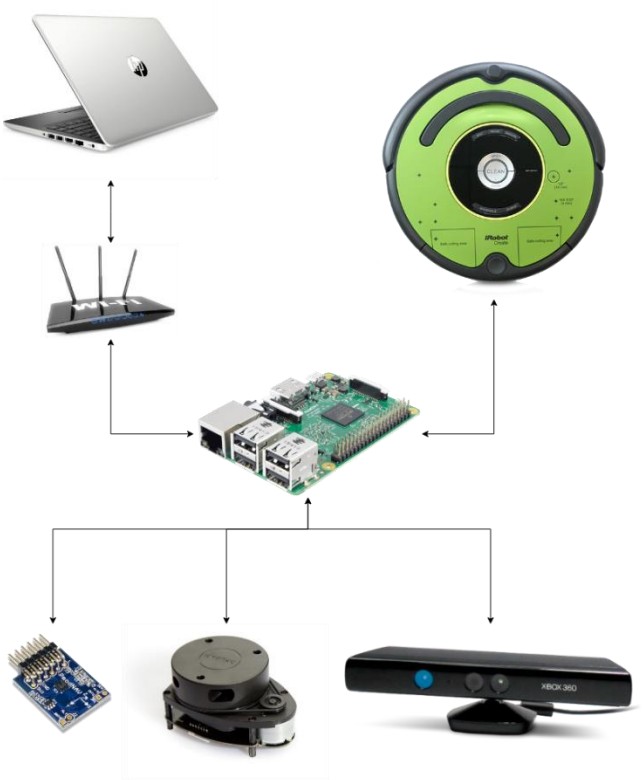

Fig. 10: Hardware architecture

V. Conclusion

This article introduces a simulation and test environment for testing SLAM algorithms. The presented environment is built up of cost-effective, easily accessible elements, but it also allows testing most SLAM methods in both software and hardware environments. The equipment has also proven to be a good basis for research, development and education purposes of SLAM and industry 4.0 components.

VI. Acknowledgement

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VLC technology data transfer based on microcontroller STM32

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***Abstract*—The paper proposes a data transmission system using white LEDs. This technology uses a microcontroller series STM-32. The transmission uses digital pulse-frequency modulation to encode the binary system. The modulation is implemented using the digital output of the microcontroller. The proposed scheme has allowed to transfer character data with a frequency of 10-3 s. In the period of the improvement of the proposed scheme, the data transmission speed can be increased significantly and to communicate to the CPU clock.**

Keywords—microcontroller, LED, modulation, VLC, generator, comparator, photo detector

I. INTRODUCTION

Today, VLC systems are considering by American developers led by Professor Thomas Little as a very valuable future generation of wireless communication systems that will surpass data systems in terms of data transfer speed, such as Wi-Fi connections, which today reach the 600 Mbps standard IEEE 802 [1]. The coding of data using VLC technology is carried out due to the quick, not perceptible to the human eye, turning off / on (blinking) a light source, which simultaneously performs the function of a lighting device. Visible light sources such as incandescent and fluorescent lamps cannot be switching quickly enough to provide high-speed transmission.

Scientists in many countries are beginning to develop data networks that use not radio waves, but visible light - and the most common LED bulbs [1-8].

Flickering of light, occurring with a high frequency, will allow you to transmit information without noticeable changes in the level of illumination of the room. "Imagine that your computer, iPhone, TV, radio and air conditioning can interact with each other and with you, anywhere in the room. To do this, just turn on the light - and not a single wire is needed," explains Thomas Little.

VLC - optical wireless communication technology, which suppose the use of LEDs, promises high bandwidth [2]. From the works of Thomas Little you can see that at a maximum distance of 5 m, it is possible to organize a communication channel at a speed of 500 Mbit / s, protected from data interception and exposure to electromagnetic interference.

VLC systems use specific modulation schemes. To provide additional opportunities for modulation and signal determination in the VLC system, lamps equipped with multi-color LEDs can be used.

VLC can provide simultaneous access to the network to many users, as it is a sheer rock-band wireless technology. VLC technology can be implemented optical spatial multiple access scheme (Space Division Multiple Access, SDMA), when using angular diversity transmitters. Compared to time division optical multiple access (TDMA), SDMA can achieve a tenfold increase in throughput in a VLC network. Using OFDM provides a simpler multiple access method, i.e. orthogonal frequency division multiple access (OFDMA), in which users are served and shared by multiple orthogonal subcarriers.

VLC network performance can be improved by using NOMA non-orthogonal multiple access. Different from conventional OFDMA technologies, NOMA can serve an increased number of users through the allocation of non-orthogonal frequency resources.

Possible modulation types for VLC technology are presented in Fig. 1[3].

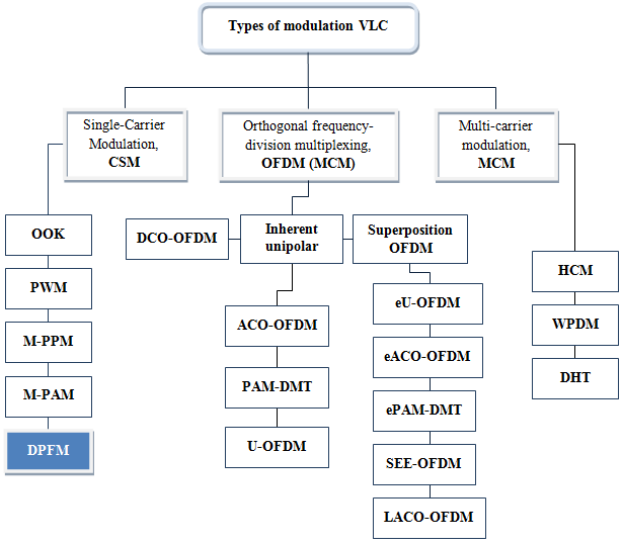

Fig. 1. Classification of VLC modulation methods

When modulating a single carrier (Single-Carrier Modulation, SCM) commonly used circuits include amplitude manipulation (On-Off Keying, OOK), pulse phase modulation (Pulse Position Modulation, PPM) and pulse

frequency modulation (Pulse Frequency Modulation, PFM) pulse amplitude modulation (Pulse-Amplitude Modulation, PAM).

OOK is one of the simple modulation schemes, and provides a compromise between system performance and implementation complexity. OOK transmits data by sequentially turning the LED on and off, the circuit can provide support for reducing light intensity (dimming). Dimming by adjusting the levels of on and off of the LED can maintain the same data rate, however, the range and reliability of communication decrease with a low level of light intensity. And at the same time, dimming by means of symbol compensation can be achieved by inserting additional on and off pulses, whose duration is determined by the desired level of light intensity reduction. Since the maximum data transfer rate is achieved at a level of decrease in light intensity by 50%, assuming an equal number of ones and zeros on average, an increase or decrease in the brightness of LEDs

In this work, we used DPFM modulation, a type of pulse modulation in which the average value of the output parameter is controlled by changing the pulse repetition rate with a constant duration [11].

II. DEVELOPMENT OF THE TRANSMITTING AND RECEIVING PART OF THE SYSTEM

The information signal enters the VLC transmitting module via power lines (power lines) through a PLC modem, which extracts the information signal from the supply voltage. The transmitting module, in turn, includes a matching device, a modulator, an LED control device and an LED light source (Fig. 2)

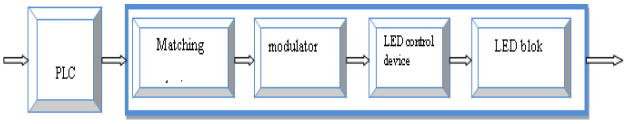

Fig. 2. VLC technology transmitter module circuit

The matching device brings the parameters of the signal from the modem output in accordance with the parameters required for controlling the LED modulator (comparing the parameters of the input signal with the parameters of the LED control device). The modulated signal is fed to the LED control device, which is a board containing a microcontroller, which controls the brightness, flicker frequency and the selection of the necessary LEDs from the unit.

Development of the receiving part of the system. The VLC technology receiving module is a small unit based on a photodetector (Fig. 3).

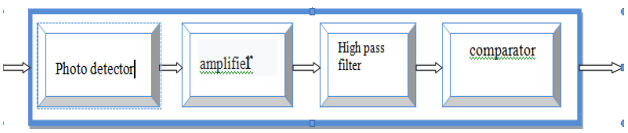

Fig. 3. VLC technology receiving module circuit

From the photodetector output, the detected signal goes to a low-noise amplifier and a filter to minimize noise. As a rule, the noise in a VLC receiver is similar to the noise of a conventional optical receiver from a communication line. This may be thermal noise from the load resistor and photodiode, excess noise from the amplifier, shot noise, as well as any other light sources in the room.[12]

The processed signal is fed to the input of a comparator, which converts the received analog signal into a digital sequence. The developed structure implements simplex mode. To implement duplex mode, the circuit is supplemented by a symmetrical channel.

Fig. 4 shows the transmitting part of the modulator, which includes a clock, counter, multiplexer, LED panel, STM 32 microcontroller and the receiving part of the device.

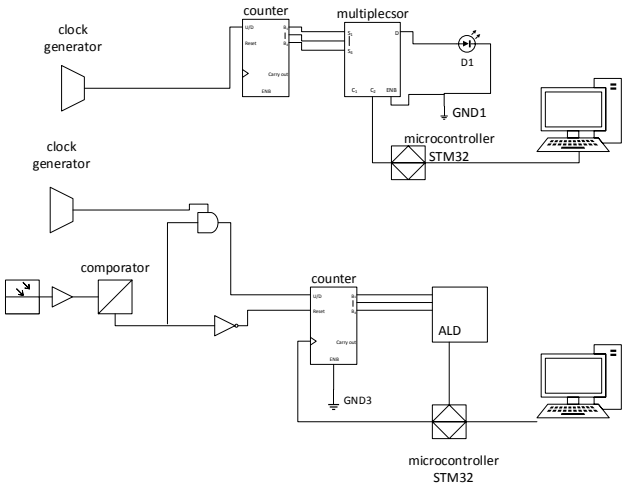

Fig. 4. Scheme experimental setup

A solar panel is installed at the reception, the signal received from the solar panel to the amplifier is transmitted to the comparator where the elements are compared and fed to the counter through the inverter and through the "AND" element are sent back to the counter of the receiving device. From the counter, the signal passes to an arithmetic - logic device, in which the variables are compared according to this algorithm: if $0 \leq X \leq 3$, then 0, if $3 \leq X \leq 6$, then 1, if $6 \leq X \leq 10$, then 2, if $10 \leq X \leq 18$, then 3.

III. FIELD STUDY RESULTS

The appearance of the experimental layout is shown in Fig. 5.

1-PC, 2,3- microcontroller STM32, 4-solar battery,5-led, 6-front panel screenshot, 7 – screenshot from the transmission panel

Fig. 5. Appearance of the experimental layout

The program for implementing data transfer using white LEDs is written in the Python programming language. Fig. 6 shows a block diagram of a program.

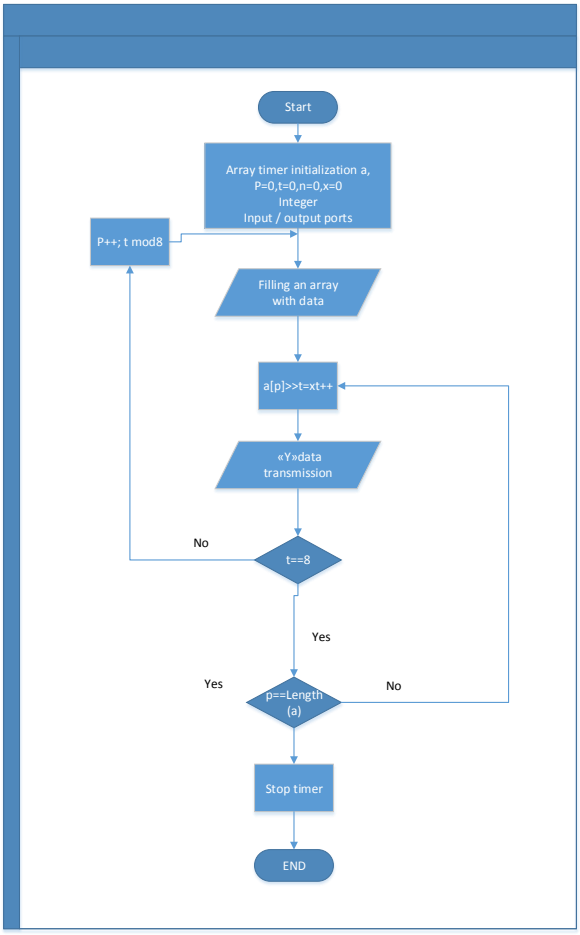

Fig. 6. Block diagram of the program

When the application starts, the following actions occur:

1. Initializing a timer, array a, P=0,t=0,n=0,x=0,

Input / output ports.

2. Filling the array with the data to be transmitted

3. Starting a timer to call the Send function.

The program exits either after the message arrives, or during the execution of the Send functions, which are responsible for the operation of the modulator.

The project file is called Pasha. Python is a light stream data transfer application. It initializes, processes events, calls the "Send" functions.

1) transmitted bit of the array a = a[p]>>t

2) number of steps (k+1)2=i

3) Describing the While loop N<i

X=(n//(k+1))

The resulting x value is sent to the LED

4)

if (t>=7)

{

if (p>= (array length a)-1)

{END}

Otherwise {p=p+1;}

}

Otherwise{t++;}

According to this algorithm, symbol data is transmitted.

Conclusion

As a result of the operation of the data transmission system using lighting LEDs, symbol variables were transmitted. At the same time, the proposed modulated light technique allows increasing the data transfer rate up to 5 Mbit per second using the STM-32 microcontroller. The proposed data transmission system can be used to monitor and control various technological processes.

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Efficient Monitoring and Control of Solar Energy Consumption by LED Lighting Devices with Embedded Microcontroller

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Abstract—**The paper deals with the effective monitoring and control of solar energy consumption by LED lighting devices with embedded microcontroller. The low-voltage power supply system and the operation method of the control system for LEDs serviceability in LED matrices were developed.**

Theoretical information revealing the basics of LED lighting system control were considered in this article.

The block diagram of the control system and described the principle of its operation are presented. The program algorithm presented in the form of a flowchart.

Keywords— energy saving, solar panel, energy consumption, alternative energy sources, microcontroller, control system

I. INTRODUCTION

One of the most important global problems of the 21st century is the modernization of the planet energy complex aimed at reducing the greenhouse gas emissions, reducing and even abandoning the use of all type of fossil fuels, slowing the global warming. The world community has clearly decided that without the transition to renewable energy sources (RES), the most scientists' pessimistic forecasts can become a reality. In our modern world and particularly in Kazakhstan, great importance is given to improving the energy efficiency of power supply systems allowing the release of a significant amount of energy, which in turn will reduce greenhouse gas emissions or use the released energy in new industrial projects. Improving the energy efficiency of the economy is important for business and society as a whole.

A. Political Energy Efficiency Efforts

In Paris, in December 2015, a climate agreement was worked out in the form of a commitment signed by the countries to decarbonize energy by replacing the use of fossil fuels with RES. This agreement has been approved by 195 countries that allowed to call it a historic one. It replaced the then-current Kyoto Protocol of 1997 that set greenhouse gas emission quotas for only a few of developed countries. Start between 2050 and 2100 to limit the emission of greenhouse gases from human industrial activity to levels that trees, soil and the oceans can naturally process. Review the contribution of each individual country to reduce harmful emissions to the atmosphere every five years. Developed countries should allocate funds to a special climate Fund to help poorer countries deal with the effects of climate change – such as natural disasters or rising ocean levels – and the transition to renewable energy.

The Agreement purpose is to prevent the temperature on the planet from increasing by more than 2 degrees Celsius. Increasing the RES share in the global energy system will affect both exporters and importers of fuel. For fossil fuel importers the transition to a higher share of RES will have potentially beneficial effects by shifting the positive factors from trade to the economy. Also, such a transition will mean higher energy security that is ensured by greater use of local resources. [1]

B. Energy Saving Technologies

Energy saving is the efficient use of energy resources through the use of innovative solutions that are technically feasible, economically justified, acceptable from environmental and social points of view and do not change the usual life way. This definition has been formulated at the UN International energy conference (IEC). [2]

The main aim is the energy saving in all areas by reducing useless energy losses. Analysis of losses in the field of production, distribution and consumption of electricity shows that most of the losses – up to 90% – are in the energy consumption field, while losses in the electricity transmission are only 9-10%.

Therefore the main efforts on energy saving are concentrated in the electricity consumption sphere. The main role in increasing the efficiency of energy use belongs to modern energy-saving technologies. Energy-saving technology – a new or improved technological process characterized by a higher efficiency of fuel and energy resources (FER). Introduction of energy saving technologies into the economic activity as businesses and individuals at the household level is an important step in solving many environmental problems – climate change, pollution (e.g., emissions from HES), exhaustion of fossil resources, etc.

The people used to live their modern lifestyle by using an amount of electronic and electrical devices. However, the increase in the use of electronic and electrical appliances has

negatively affected the unprecedented increase in energy consumption. Subsequently, due to the gap between supply and demand, the fees paid by the end user increase annually. As a result, there is a serious need to optimize the energy consumption and to develop more energy-efficient technologies and electronic systems. This need has LED to the development of new fundamental and applied research in the field of energy conservation. [2, 3]

C. *The Alternative Energy Sources*

Energy saving mode is especially relevant for mechanisms that work in a part of the time with a reduced load, for example, conveyors, pumps, fans, etc. There are many devices, which could reduce losses during the operation of electrical equipment, the main of them are capacitor banks and variable frequency drives. Variable frequency drives with built-in power optimization functions flexibly change the speed depending on the actual load, which allows to save up to 30 50% of the electricity consumed. At the same time, it is often not necessary to replace the standard electric motor, which is especially important by modernizing production. Such energy-saving electric drives and automation tools can be implemented in most industrial enterprises and in the field of housing and communal services: from elevators and ventilation systems to enterprise automation. [4]

II. DEVELOPMENT AND DESIGN OF AUTOMATED LED LIGHTING CONTROL SYSTEM

During the development and design of the automated LED lighting control system with LED serviceability control, the following tasks were completed:

- the structure of LED lighting system with LEDs serviceability control was substantiated;
- the system features were defined;
- the block diagram of the control system was designed;
- the block diagram of the algorithm was developed.

One of the most important parameters of the LED lighting system – that needs to monitor – is the LEDs serviceability. The most modern systems offer a light level control and an automatic on/off switching function for LEDs. The LED health control system proposed by us consists of the following parts (Figure 3): power supply; current sensor; relay; LED matrix; microcontroller; personal computer.

A. *The Principle of the System Operation*

The LED matrix consists of 4 LED strips, each of them includes 8 LEDs connected in series. Power to the LED matrix can be supplied from the power supply or from the solar panel. Since each LED strip located in the matrix is rated at 24V, so we have the ability to use a solar panel as a power source, which saves from the electricity consumption.

In order to calculate the required power for our solar panel it is necessary to know the monthly electricity consumption. To determine the required amount of electricity consumed in kilowatts in hours, you can look at the electric meter. So, if the monthly used energy was, for example, 200 kWh, the solar battery should produce about 7 kWh of electricity per day.

The calculation should take into consideration that solar panels generate electricity only in the daytime, and their performance depends on the angle of the Sun above the horizon, and also on the weather conditions. On average, up to 70% of the total amount of energy is generated from 9 am to 16 PM and in the presence of even a small cloud or haze, the power of the panels falls by up to 2-3 times. If the sky is covered with continuous clouds, then at the best can be get 5-7% of the maximum capabilities of the solar system. (Figure 1)

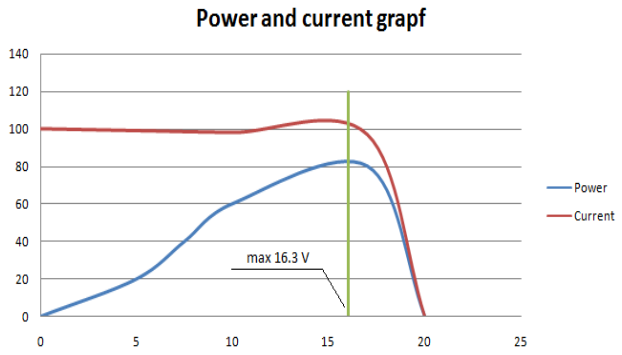

Fig. 1. .The graphics of the power and current of the sunlight at 80W in the inclining fire

B. *Calculation of the Power Supply System's Features*

Given all of the above, it can be calculated that to obtain 7 kWh of energy under ideal conditions, you will need an array of panels with a capacity of at least 1 kW. If we take into account the decrease in performance associated with changes in the angle of incidence of rays, weather factors, as well as losses in batteries and energy converters, this figure should be increased by at least 50-70 percent. If we take into account the upper figure, then for this example we will need a solar panel with a capacity of 1.7 kW.

Further calculation depends on which photocells will be used. To dial an array of solar cells with an output voltage of 12 V and a current equal to 1 700 W / 12 V = 141 A you will need to connect 24 elements in a row (serial connection allows you to summarize the voltage) and use 141 A/ 3 A = 47 such rows (1 128 plates).

The area of the battery with the most dense laying will be 1 128 x 0.0046 = 5.2 sq. m. for the accumulation of electricity, batteries with a voltage of 12 V, 24 V or 48 V are used, and their capacity should be enough to store the 7 kWh of energy. (Figure 2)

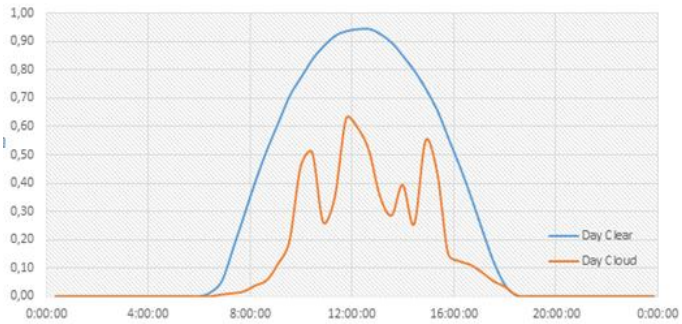

Fig. 2. .Graphics of fireworks of solar energy.

C. *Design of the Control System*

A sensor connected to the power supply block to detect the current level of energy consumption of the LED matrix panel. The measured value of the current level is sent to the microcontroller. After that, the microcontroller compares the received data with the set value (a certain constant).

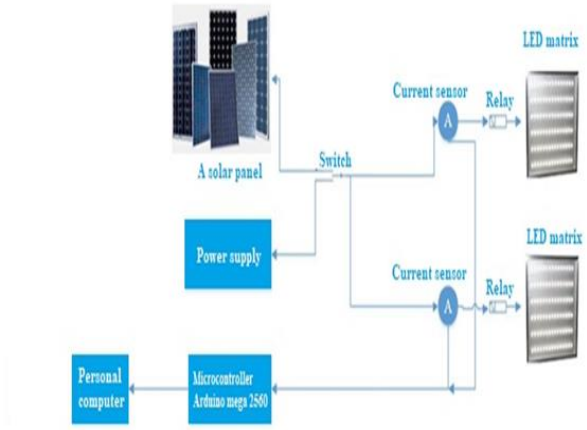

Fig. 3. A block diagram of the LEDs serviceability control system

(a solar panel, a switch, current sensor, relay, LED matrix, power supply, personal computer, microcontroller)

If the data obtained is less than this value, the personal computer will display information about the failure of the number of LED strips in the corresponding matrix.

There may be another case – if the value of the obtained value is greater than the specified value. This means that there has been a short circuit in the system. In this case, first of all, the power supply will burn, if it does not have short circuit protection, all LED matrices will also go out, in addition, there is a high probability of fire. Therefore we suggest installing a solid state relay on the LED matrix and connecting it to the microcontroller.

The microcontroller will control the LED matrix via relay. This will allow us to de-energize the LED matrix in the event of a short circuit, which ensures the safety of the system. System features – for LED power supply, low voltage 24V power supply will be used. In ordinary office buildings, 4×18W fluorescent lamps are used, their light output is 4000K.

LED matrices with such light output will have a power twice less than 32 W. In this regard, for lighting the corridor of the University, we can save half as much power. Using a low-voltage lighting system allows to include alternative energy sources (in our example, solar energy) in the lighting system. The possibility of using such solar energy will increase the energy efficiency of the system.

D. *The Program of Control System*

The block diagram of the program's algorithm illustrated on the Figure 4.

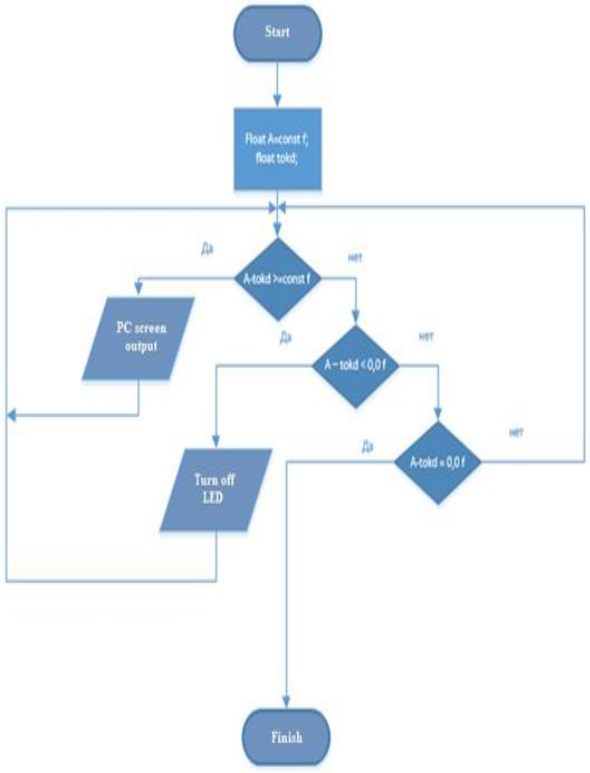

Fig. 4. . Block diagram of the program algorithm

Start of the program. Set a value A, which will be a constant necessary for further work. Declare a *tokd* variable. This *tokd* value will show the value received from the current sensor. After that, we subtract the value obtained from the current sensor from the constant. Then the first condition is checked:

$$A\text{-}tokd >= const\ f \qquad (1)$$

If this condition is met, then the PC screen will display the information that the LED strip of the corresponding LED matrix "burned out" and the cycle repeats again until we eliminate the LED malfunction.

Next, if the condition A-tokd>=const f is not satisfied, the following condition is checked:

$$A - tokd < 0{,}0\ f \qquad (2)$$

If the condition is satisfied, then a short circuit has occurred, in which case the LED matrix is switched off and the comparison is performed again. After the condition A – tokd <0,0 f is not met, the last condition is checked

$$A - tokd = 0{,}0\ f \qquad (3)$$

If the condition is met, then all LED strips are serviceable. If the specified condition is not satisfied, the cycle will return to the first comparison and will repeat until the system problems are resolved.

CONCLUSION

The proposed control system of LEDs serviceability provides a unique opportunity to save energy in the safe operation of the entire system.

At this stage, we have given theoretical information that reveals the basics of LED lighting system control. The block diagram of the control system and the principle of its operation have been presented and described. We have developed a program algorithm, which is presented in the form of a flowchart. His description has been given.

In the future, it is planned to develop the program code in the C language, the Arduino MEGA 2560 microcontroller will be used for control, and a PC application will be developed in the Visual studio 2015 software environment.

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Depth Cameras and their Usefulness in Social Places

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***Abstract*—Nowadays the Kinect sensor and its analogs can be said very important innovations in creation of smart places, because they combine the 2D video image and the depth data to 3D and with time parameter to 4D information. These inspired the development a lot of applications at first in the field of game industry and entertainment, later in the field of medicine, health care and finally in the industry. In this paper a review is given of the pros and cons of this type of sensor and focuses onto the usage of it in social places. Some proposals are provided to use it in these places to become smarter.**

I. INTRODUCTION

After 2000 an extraordinary innovation raised up in the field of depths sensing complex cameras. The development was primarily inspired by the entertainments and game industry. The result is products with affordable price and enough robust market demand to produce and use these devices in large volume.

The sensing technology of depth cameras mainly based on two principles. One of them is the analogue of human depth sensing by comparing the two different pictures of two RGB cameras makes possible to compute the depth information. The other strategy use infrared (IR) sensors for supplement the 2D information of the RGB cameras video stream to gain 3D information and with the time parameter finally 4D information. In this paper the focus is on the IR based depth sensing cameras and mainly on Kinect sensors, because the experiments were taken with these devices (Fig 1).

Several examples of such types of devices are: Kinect for Xbox 360, Kinect v2, Intel SR300, Intel SR305 Intel R200, Orbbec Astra, Orbbec Persee.

However these cameras were primarily developed for entertainments, they implicated the scientific applications and connected researches and further the industrial applications [2]. Depth sensing is used for medical[3],

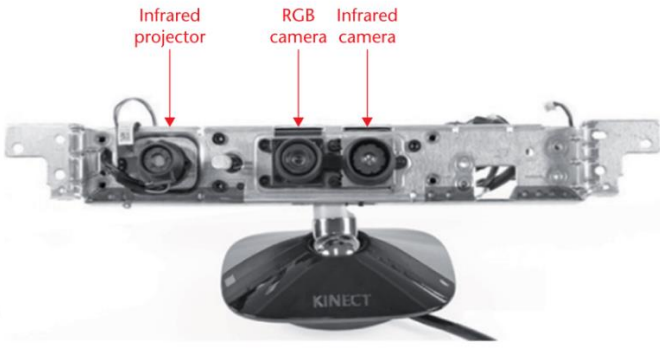

Figure 1Kinect sensor XBOX 360 [1]

rehabilitation and elderly care systems [4], even more in industrial usage is a target of important R&D [3]. Now the game industry is giving up this field, because the accuracy and speed of these devices do not give appropriate user experience but the scientific applications and the number of the connected publications is growing by exponential trend (Fig 2).

First Kinect version was launched on 4 November 2010. On 1 February 2012, and more than one year later Microsoft released the Kinect Software Development Kit (SDK) for Windows, which helps the software development.

The Kinect sensor contains several advanced sensing hardware. Most notably, it contains a depth sensor, an RGB camera, and a four-microphone array. These provide full-body 3D motion capture, facial recognition, and voice recognition capabilities [1]. Microsoft and its Kinect systems have been among the earliest affordable depth sensors that use different technologies for the respective iterations. The first version had a comparatively low resolution of only 320 × 240, whereas the next edition updated this to 512 × 424, amongst other improvements in RGB camera resolution and microphone arrays[5].

Table 1 Comparison of different depth cameras

	RGB camera resolution	Depth Camera resolution	Frame rate	Min. depth	Max. depth	Angle
Kinect 360 [6]	640x480	320x240	30fps	0.85	4m	58,44
Kinect v2 [6][7]	1920x1080	512x424	30fps	0.85	4,5	70.6,60
Intel SR 300[8]	1920x1080	640x480	60fps	0.2m	1.2m	71,55,88
Orbbec Persee [9]	1280x720	640x480	30fps	0.6m	8m	60,49,73

Intel has developed its RealSense technology for several years later. The cameras are demonstration sets for a desired future integration in end-user devices, such as note-books, smart phones, or tablets. The two presented systems are the back-facing R200 system, for installation at the back of a device, and the SR300 system for installation in the front of a device. Both cameras are capable of a depth resolution of 640 × 480 at high frame rates.

Orbbec is a company founded by one of the main developers of the OpenNI SDK and provides depth cameras using structured light technology. The main advantage of the Persee device is the integrated processing that enables the creation of depth maps and point clouds that can be directly sent over network. The comparison of these complex cameras in table 1 shows that by hardware solutions the Kinect camera is not an outstanding one.

Sensing of depth information can be based on two concepts. One possibility is to use the structured light (SL)

concept, where the infrared laser light is passed over a diffraction grating, which sprinkles the light and creates a special pattern of infrared dots. This pattern is reflected on the surface and is changed. This pattern is sensed and used for the calculation of the depth information [1]. This is the working strategy of Kinect XBOX 360 sensor system. The Kinect v2 uses the TOF technology for sensing. In this concept the time difference is measured between the IR light emission and the reflected light sensing. If we know the speed of the light, we can calculate the depth information. Later investigations proved that that TOF method can produce more accurate results [1]. There is a quasi-compliance between experts that the Kinect cameras by hardware features are not outstanding in the market competitors, but more the marketing strength and mainly their software, the Microsoft Kinect SDK is really excellent. It is able to detect and follow in real time the human skeleton with many joints parallel for six persons, which makes possible to develop a lot of applications to this device. The other SDKs (OpenNI) later reached similar results [10].

In this paper we will focus on the human gesture and behaviour detection in social places. In this point of view the basis of the Kinect sensing is that the visual information supplemented with depth information is more effectively used for human body posture and movement detection than the only visual information [11]. This was proved in the literature and showed by Table 2.

Table 2 Accuracy of foreground recognition technics [10]

	True positive	False positive
Depth information	96.7%	0%
RGB information	45.3%	2.3%

Now the Kinect XBOX 360 creates depth maps with accuracy (0...40mm) and (0...18mm) in the newer version. Their accuracy depends on the temperature, light, and distance which are important parameters in application development [7][12][2].

Now the number of publications is growing dynamically respected to simple human gesture detection, which accuracy's improvement is an important research field up to now and the complex behaviour recognition research which will be the basis of the future applications (Figure 2).

Connected to this research several database developments were executed for the valid testing of different algorithms. Mainly the aim was the behavior and gesture type identification, and video and/or depth stream databases were collected in relation to different human activities [13]. These contain basic movements (sitting, standing, walking, lying), sport activities and later home activities etc. [13]. It was described that the adult and child motions are different, so there were databases for these activities as well. These databases were used not only for research purposes but moreover the film industry in animations [14]. Based on these databases, the movement identification methods become evaluable. Now the identification of the most simple postures, movements can be of near 90% accuracy and the more complex home activities (phone call, eating, clothing) can be detected with near 80% accuracy [13].

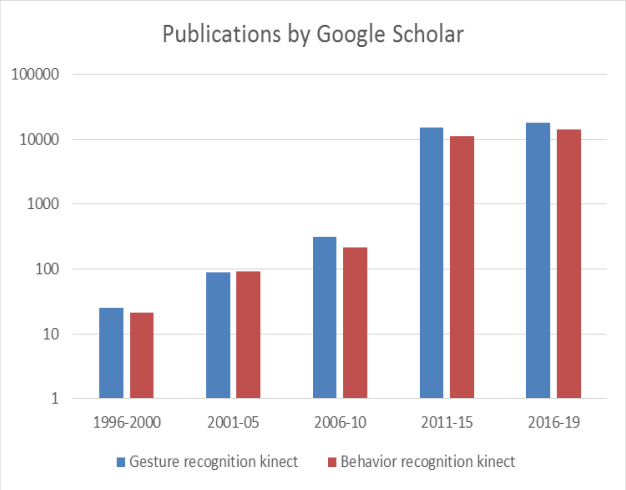

Figure 2 Number of Kinect related publications in the field of gesture and behavior recognition.

Now the applications of Kinect cameras are frequently limited by the sensors. There are strict limitations in depth and the number of identified persons. By the references the best method to place the camera to 3m height to the ceiling and it results 8,25m^2 valid sensed area/camera. [5]. Generally it can be summarized that the high accuracy sensing and gesture detection work now mostly in artificial laboratories, but the effects of a real environment (color patterns, different light) disturb these applications which are not used widespread yet[5].

In this paper we are focusing on the effective usage of depth sensing complex cameras in real applications. A database development is demonstrated, which aim is to help the effective storage, processing and querying of skeleton stream information. Furthermore we are discussing what type of developments is needed for this revolution mainly in the field of the human gesture and behavior detection in social places.

II. METHODS

A User Interface program and a database were developed for the storage of the skeleton data. The software is a simple .NET Framework WPF App, which offers a form for the user and collects and stores skeleton data into a database. Kinect handling which uses the Kinect SDK and data stream storage is executed in asynchrony thread.

In this project Kinect XBOX360 camera and its Microsoft Kinect SDK kit were used.

Now the UI collects data of one Kinect camera and stores them into a MongoDB database or can list onto the screen or avataring on the screen (Fig 4). Now the SDK can follow two persons and 20 joints of each person with the help of the Infrared sensor. The structure of the database is shown on figure 3. The 3D coordinates of each joints with a timestamp are stored to reach 4D data storage. The database contains the activity string, which is the ID of the current activity.

Each joint contains the x, y, z, timestamp data, the sensing frequency is 30 fps and storage frequency is the same. In the user interface the activity code can be typed till a good

database will gathered for the valid classification of human activities.
The tests were made on a typical PC (Intel i7, 2GHz, (8GB RAM 64 bit Microsoft Windows 10 Operating System)
The MongoDB database was stored at the official site and used the free, minimal storage capacity.

```
{
   "id": "string",
   "activity": "string",
   "skeletonData": [{
      "jointsData1": {
         "jointType": "number",
         "x": "number",
         "y": "number",
         "z": "number"
      },
      "timestamp": "date"
   },{
      "jointsData2": {
         "jointType": "number",
         "x": "number",
         "y": "number",
         "z": "number"
      },
      "timestamp": "date"
   }
      ...
   }, ...]
}
```

Figure 3 Database structure

III. RESULTS

The developed database and the connected UI was tested in a typical environment. The question is that a given PC with MongoDB database can execute real time data processing and storage. It was proved that it is inside the normal operational range. The storage capacity of the stream is 1MB/minute. In the later development the storage capacity can be reduced until 350KB/minute (10 Byte/joint*20joints*30fps*60second) without any calculated compression algorithm and to 100KB with compression. However it is important to focus on the computing capacity to the most important calculations, namely to the real time activity classification, which can be used for labeling the skeleton data. This label will make possible the later semantic querying of the database which makes possible the proposed application and research.

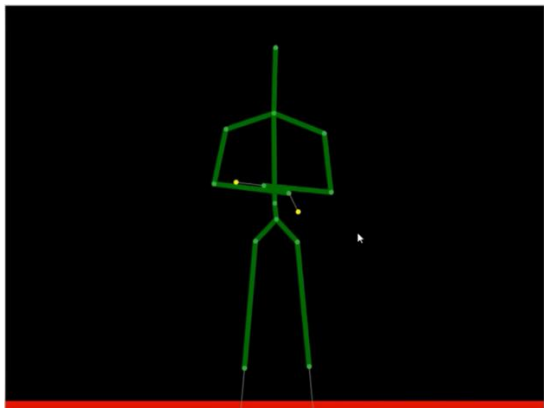

Figure 4 Skeleton picture by the detected 20 joints of a person

IV. PROPOSALS

Our proposal and aim to research is how could be used depth sensor based complex cameras in the investigation of human population and people's activities in social places. It would be very interesting for the quantitative psychology and in practically it could be useful in safety services.

The advantages of these devices in safety that could be expected to detect, store and query data of human activities without the violation of human rights. The later developments will make possible the semantic querying of the database (a human is running, phoning, faints etc.).

The disadvantages of this concept are the restricted spatial scope of these devices, and the other difficulty is the restricted number of the followed human skeleton streams.

The safety services will be possible if these two restrictions will be defended. Now there are signs to this trend. The first sensors could handle 1-2 persons but the newer Kinect v2 can increase it to six and may be increased in the near future depending on the software developments. The scope of the Orbbec Persee has already reached the 8 m and later may will further increase to the scope of RGB cameras.

Nowadays the Kinect sensing is more accurate in optimal light conditions, the human detection algorithms make possible some improvements in this field in the near future (see Fig 5) [10]. The light will not effect it, so it can be used in dark places (cinemas, theatres etc.), furthermore the flashing light also will not limit the device, so it can be used in pop concerts and other night entertainment places.

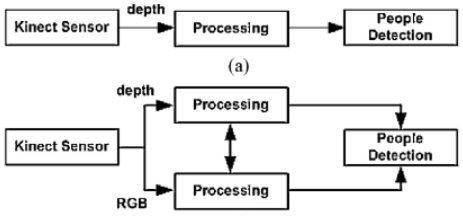

Figure 5 The schemes that Kinect use for human detection
source: J. Han, L. Shao, D. Xu, and J. Shotton, "Enhanced computer vision with Microsoft Kinect sensor: A review," *IEEE Trans. Cybern.*, vol. 43, no. 5, pp. 1318–1334, 2013.

In person identification it can be successfully used when the basis of the identification are biometric features, so it can be used if the face of the person is not visible and with some restrictions if the person wears special clothes which makes the identification harder (chador, cloak etc.).

There are references of the investigations of person identification by anthropometric and motion identical features [15]. Present results show that the identification of anthropometric features can be made with 80-90% accuracy and the identification by the movement is a bit lower. These results are the consequences of the limited spatial scope and the depth sensing accuracy of the device. For example if the scope of the camera is 4m and the person is walking or running, he/she can do only 3-4 steps in the scope of the device which may not be enough to analyse the identical features [15].

If the spatial scope and the depth sensing accuracy can be increased, this causes the increase of person identification. The identical feature selection of the human motions is an interesting research area, much younger than the anthropometric identification and there are possibilities to reach remarkable development in it.

V. CONCLUSION

In this paper a summary was collected about the investigations with depth sensing complex cameras. The point of view was from our research question that with the present devices can be placed cameras in social areas and detect the human behaviour. It was clear that such research has importance in safety and in psychology. However the present hardware and software solutions make possible this type of applications with some limitations. Smaller areas, for example medical places, smaller educational places, bank vestibules and limited population can be monitored. Monitoring of larger areas and higher population needs further developments. Based on the literature we really can expect remarkable development in this field.

In this paper the development and testing of a real time NOSQL (MongoDb) database was presented, which will be applicable for the semantic querying. This is a missing link between the human gesture, activity detection, storage and quantitative behaviour analysis.

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The new algorithm for handwritten characters recognition based on the digital image conversion into planar graph

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***Abstract*—The paper presents the new algorithm for handwritten characters recognition. The algorithm is based on the procedure for converting an image into a planar graph, where the lines in the image correspond to paths in a flat graph, that is, a sequence of graph vertices connected by edges. A special function is used to determine the shape of a simple smooth curve without self-intersections. This function is invariant with respect to such transformations of the plane as rotation and scaling, which makes it very convenient for recognizing handwritten characters. The mathematical construction of the function of the angular characteristics of the curve can easily be transferred to simple broken lines. The window vector Fourier transform coefficients are used as feature vectors to identify polylines corresponding to paths in a flat graph.**

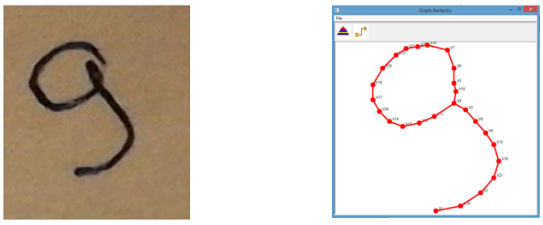
Keywords— line thin, line segment, gradient, image analysis, handwritten characters recognition, planar graph

INTRODUCTION

At present, the theory of computer vision is a rapidly developing interdisciplinary field of research. The high practical relevance of research in this area is primarily associated with its applications to robotics and the problems of automation of production. At the same time, solving problems in this area find important applications in other areas of human activity, in particular in medicine and education. Character recognition is one of the most important tasks of the theory of computer vision, for many years attracting specialists in the field of applied mathematics, artificial intelligence and computer science. The general task of character recognition is usually divided into the task of recognizing printed and handwritten characters. Due to the great practical importance (primarily for the automation of office work) and comparative simplicity, the recognition of printed characters has been well studied, while the recognition of handwritten characters has been considered one of the most interesting and complex image analysis tasks in recent years [1-5]. For the recognition of handwritten characters, as well as for solving the more complex and general task of handwriting recognition, various authors have proposed many methods (a fairly complete review of the literature on this subject can be found in [1-5]), but it is recognized that so far none of the proposed methods can not be compared either in reliability or in the speed of recognition with a human.

RESULTS AND DISCUSSION

Purposed method of handwritten symbols recognition is based on digital image to planar graph conversion procedure. According to the definition of a planar graph, there is a one-to-one mapping of the set of vertices of the graph to the set of points on the plane. Accordingly, each graph edge corresponds to a line segment in the plane, and the segments corresponding to different edges can intersect only at the end points. Each path in the graph corresponds to a simple polyline on the image plane. Suppose we have a digital photo of handwritten symbols drawn with thin lines (for example, written in pen on paper). After applying the conversion procedure to this image, each isolated symbol will correspond to a connected component of the resulting planar graph. The curves forming the images of the symbol will be approximated bypolylines (simple or closed) corresponding to the paths and cycles in the graph (see Fig.1). We have developed two algorithms for converting a raster image to a planar graph. We developed software that implements these algorithms and used it for experiments with character recognition of decimal digits on real photos. Immediately, we note that the input data for character recognition procedures, including the feature extraction procedure, are the connected components of the planar graph. Thus, the planar graph obtained as a result of applying the conversion procedure contains all the necessary information for recognition, and after converting the image into a planar graph, the original image is not used in the recognition procedures.



a b

Fig. 1. A fragment of a digital photo (a) and a screenshot of the "GraphRedactor" window (b) with the image of the planar graph of the digit symbol "9" obtained when converting an image into a graph.

Another key idea of the proposed handwriting recognition method is the use of a special function to identify the shape of a simple smooth curve without self-intersections. We called this function the "curve angular characteristic function." This characteristic is invariant with respect to such transformations of the plane as rotation and zooming, which makes it very convenient for use in recognizing handwritten characters. The mathematical construction of the function of the angular characteristics of the curve is easily transferred to simple broken lines. We use the vector coefficients of the window Fourier transform as a feature vector for identifying the polylines corresponding to the paths in the planar graph. The concept of the function of the angular characteristic of a curve is discussed in detail in the section “Function of the angular characteristic of a curve”. Purposed optical handwritten symbol recognition method is divided into five phases which are digital image preprocessing, image to planar graph conversion, graph analysis, feature extraction and classification (see Fig. 2). In this paper, we will focus primarily on the feature extraction procedure, which includes the analysis of a planar graph

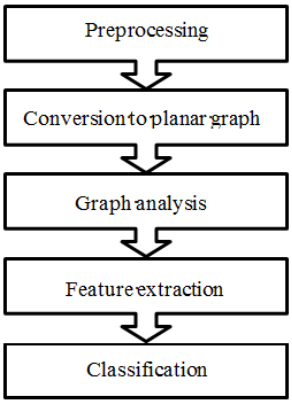


Fig. 2. Block Diagram of handwritten symbol recognition.

A. *Graph analysis. Main concepts*

There are two types of geometric primitives that we can directly classify using the methods proposed in this paper, namely, curves without self-intersections with two ends and closed curves without self-intersections. (Note that the first of these types of objects is topologically equivalent (homeomorphic) to the D^1 , and the second type is homeomorphic to S^1.). In the planar graph of the symbol, the objects of the first type correspond to the paths between the vertices of the graph, and the objects of the second type correspond to the cycles of the graph. Some symbols of decimal digits (for a specific spelling) are objects of the first group (for example, numbers 1 2 3 5), and their planar graphs are trees with two leaves. Obviously, if the planar graph is a tree whose vertices v_1 and v_2 are leaves and the graph has no other leaves, then a broken line corresponding to the path in the graph connecting the vertices v_1 and v_2 will be the most suitable object for classifying. But even if the connected component of a planar graph is a tree, then in more complex cases, the choice of paths between the vertices to classify this component becomes a task that allows for many solutions. For example, planar graphs of decimal digits 4 and 7 (in some cases of spelling) are a ‘cross’, i.e. a tree with 4 leaves, only one vertex of which A has a degree greater than 2 (more precisely $deg(A) = 4$) (see Fig. 3). In any case, it is necessary to apply some combinatorial procedures to select a classification scheme for such objects. For example, we can choose two unordered pairs from the set of the leaves of this tree, and use paths between pairs of vertices (B, D) and (E, C) for recognition. But it is clear that even if these paths are recognized as elements of the digit "4", this does not at all mean that we can classify this planar graph as the symbol of the digit "4". It is necessary to carry out additional procedures, based on the results of the first stage of classification, namely, to classify paths between the vertices (B, E) and (D, C).

Thus, the results of the graph analysis stage determine the rules by which the classification procedure will be conducted. Graph analysis can be called a topological analysis of a planar graph. In some cases, the information obtained as a result of this analysis in combination with the results of the classification of geometric primitives may not be sufficient to classify a symbol as a whole.

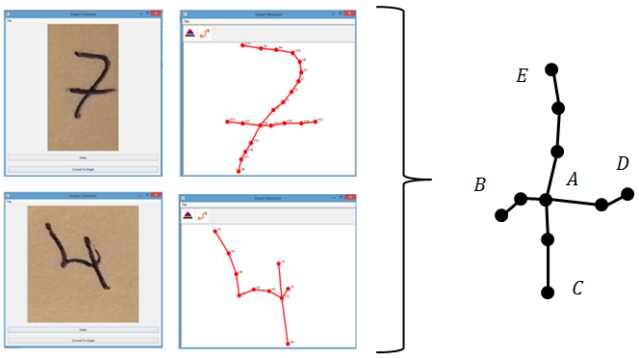


Fig. 3. Symbols of decimal digits ‘7’ and ‘4’ has same planar graph topology

In such cases, the application of ‘metric’ algorithms of computational geometry, such as calculating areas of polygons, calculating the angles between lines, etc., are required. But in most cases (when recognizing digit characters), the role of such methods of computational geometry is insignificant, compared to the value of graph analysis methods and the recognition of geometric primitives. Thus, the fundamental role of the graph analysis procedure is to choose the recognition scheme for the connected component of the planar graph. But during the analysis of the graph, the procedures for eliminating artifacts that arise when converting an image into a planar graph are also performed. As mentioned above, we assume that each symbol corresponds to a connected component of a planar graph. Of course, the first stage of image graph analysis is to find the connected components of this graph, and further graph analysis procedures are applied to each component. Below we describe the procedures for constructing the spanning tree of the connected component of the graph and generating cycles. In the course of these procedures, the elimination of artifacts is carried out and it is determined whether the component is a tree, or a graph having cycles. Below we describe the procedures for constructing the spanning tree of the connected component of the graph and generating cycles. These procedures are the first stage of analyzing a connected component of a planar graph. During these procedures, the elimination of artifacts is carried out and it is determined whether the component is a tree, or a graph that has cycles. Further graph analysis procedures related to the choice of a scheme for recognizing the corresponding connected component are rather complicated

and require a lot of space for their detailed description. At the same time, the development of these procedures can be considered a technical task, since quite elementary and well-known methods are used to solve it. In this regard, we do not consider it appropriate to describe these procedures in this article

II. ANGULAR CHARACTERISTIC FUNCTION

A. *Angular characteristic function:introduction*

The function of the angular characteristics of the curve completely determines the geometric shape of this curve. More precisely, this function can be viewed as a mapping of the set of regular curves to the functional space $D \subset L^2$ of functions defined on the interval $I = [0,1]$. As shown in the "Properties of angular characteristics function" section, this mapping is invariant with to plane similarity transformations. The concept of the function of the angular characteristics is easily transferred to broken lines. The functions of the angular characteristics of a broken line can be put in accordance with the feature vector (the procedure for extracting features is described in detail in the "feature extraction" section), which allows to classify it. As mentioned above, the paths in the planar graph correspond to broken lines on the plane, which explains the key role of the concept of the function of the angular characteristics in the proposed method of recognizing handwritten characters.

B. *Definitions*

We will denote the set of vectors of unit length by E, so $E = \{\vec{e} \in \mathbb{R}^2 | \, |\vec{e}| = 1\}$ .The oriented area of the parallelogram spanned by vectors $\vec{a}, \vec{b} \in \mathbb{R}^2$, we will denote by $S(\vec{a}, \vec{b})$. For an arbitrary Cartesian system on the plane, mapping $S: \mathbb{R}^2 \times \mathbb{R}^2 \to \mathbb{R}$can be determined analytically by the formula (1)

$$S(\vec{a}, \vec{b}) = a_x \cdot b_y - a_y \cdot b_x \tag{1}$$

, where $\vec{a} = (a_x, a_y)$,$\vec{b} = (b_x, b_y)$. If $\vec{e}_1, \vec{e}_2 \in E$, then

$$S(\vec{e}_1, \vec{e}_2) = \sin(\varphi) \tag{2}$$

, where φ is the angle to turn the vector $\vec{e}_1$ counterclockwise so that it coincides with the vector $\vec{e}_2$. We will denote mapping $E \to \left[-\frac{\pi}{2}, \frac{\pi}{2}\right]$, defined by (3) as$\angle(\vec{e}_1, \vec{e}_2)$.

$$\angle(\vec{e}_1, \vec{e}_2) = arcsin\big(S(\vec{e}_1, \vec{e}_2)\big) \tag{3}$$

In view of the equality $\sin(\alpha) = \sin(\pi - \alpha)$, it would be incorrect in the general case to consider $\angle(\vec{e}_1, \vec{e}_2)$ as the angle between the vectors $\vec{e}_1$and $\vec{e}_2$.Below we provide the exact definition of the concept of 'angle between vectors' used in this article.For two nonzero vectors $\vec{a}, \vec{b} \in \mathbb{R}^2$ we determine the value δ by formula (4)

$$\delta = arccos(\vec{e}_a * \vec{e}_b) \tag{4}$$

where $\vec{e}_a$ is normalized vector $\vec{a}$ (i.e. $\vec{e}_a = \frac{\vec{a}}{|\vec{a}|}$) and $\vec{e}_b$ is normalized vector $\vec{b}$ (i.e. $\vec{e}_b = \frac{\vec{b}}{|\vec{a}|}$). Then we define the function Ang as (5)

$$Ang(\vec{a}, \vec{b}) = \begin{cases} \delta, if S(\vec{a}, \vec{b}) \geq 0 \\ -\delta, if S(\vec{a}, \vec{b}) < 0 \end{cases} \tag{5}$$

C. *Function of the angular characteristic of a smooth regular curve.*

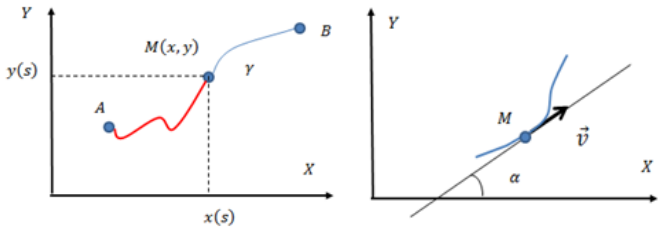
Let γ be a regular curve with end points A and B. If we choose one of the end points (for example, A), then we can parameterize γ as follows: For an arbitrary point $M \in \gamma$, we define the corresponding value of the parameter s as the length of the curve segment AM. Thus, we define the mapping $[0, L] \to \gamma$, where L is the total length of the curve γ. For a given Cartesian coordinate system, this mapping defines two functions $x(s)$and $y(s)$. In the case of a smooth regular curve under consideration, both functions $x(s)$and $y(s)$ are differentiable. Let the mapping $[0, L] \to \mathbb{R}^2$ be given by formula (6)

$$\vec{v}(s_0) = \left(\left(\frac{dx}{ds}\right)_{s=s_0}, \left(\frac{dy}{ds}\right)_{s=s_0}\right) \tag{6}$$

As is known,for arbitrary $s \in [0, L]$ vector $\vec{v}(s) \in E$ is a tangent vector of the curve γ. It should be noted that the vector $\vec{v}(s)$ can be represented as (7)

$$\vec{v}(s) = (\cos(\alpha), \sin(\alpha)) \tag{7}$$

where α is the angle between the tangent line and the X axis (see Fig. 4).



a b

Fig. 4. Natural parameterization of regular curve. Parameter s is a length of the segment AM(left image), and tangent line (right image).

For an arbitrary point $M(s_0) \in \gamma$, we define $k(s_0)$ as (8):

$$k(s_0) = lim_{\Delta s \to 0} \frac{\angle(\vec{e}(s_0 + \Delta s), \vec{e}(s_0))}{\Delta s} \tag{8}$$

It should be noted that $|k(s_0)| = \frac{1}{R}$, where R is the radius of the tangent circle, is the curvature of the curve γat point $M(s_0)$. We define the function $\alpha(s)$ by the formula (9):

$$\alpha(s) = \int_0^s k(\tau)\, d\tau \quad (9)$$

Assuming some uncertainty, we can give the following clear geometric definition of the function $\alpha(s)$:Let $\vec{v}_0 = \vec{v}(0)$ be a tangent vector to γat endpoint A. Then $\alpha(s)$ is the angle between the vectors $\vec{v}_0$ and $\vec{v}(s)$ (see Fig.2).The function $\alpha(s)$is defined on the interval$[0, L]$, where L is the length of the curveγ. We define on the interval $I = [0,1]$ the function $\theta(x)$:

$$\theta(x) = \alpha(x \cdot L) \quad (10)$$

We will call $\theta(x)$ the function of the angular characteristic of the curve γ (or simply the angular characteristic of γ). As will be shown below, this function has properties that allow it to be effectively used in symbol recognition tasks.

D. Properties of an angular characteristic function.

1) Invariance to similarity transformations of the plane.

The most important property of the function of angular characteristics is its invariance to similarity transformations of the plane. Below we provide the necessary explanations: A similarity is a transformation of Euclidean plane which maps lines to lines and preserves the sizes of angels. The set of all similarities is the similarity group $S(2)$. Each similarity transformation can be viewed as a composition of translation, rotation, and uniform scaling. Let γ be a regular curve with endpoints A and B. Applying an arbitrary transformation $f \in S(2)$ to the plane transforms γ into a regular curve γ' with endpoints $f(A)$and $f(B)$. Thus, if θ_1 is the function of the angular characteristic of γ, then it corresponds to the function of the angular characteristic θ_2 of the curve γ'. The statement about the invariance of the function of the angular characteristic to similarity transformations means that equality (11) holds.

$$\forall x \in [0,1]\theta_1(x) = \theta_2(x) \quad (11)$$

2) If the curve γ is a line segment, then its function of the angular characteristic $\theta$of the γ is defined by (12)

$$\forall x \in [0,1]\theta(x) = 0 \quad (12)$$

3) If the curve is an arc of a circle cut off by an angle φ, then regardless of the radius of the circle, the function of the angular characteristics of this curve will be a linear function (13):

$$\theta(x) = \varphi \cdot x \quad (13)$$

It should be noted that the curves forming the symbol in the image can be approximated by curves made up of segments and arcs of a circle. The last two properties of the angular characteristics function make it easy to imagine the angular characteristics of these curves. In addition, the idea of approximating curves by joints of segments and arcs suggests an idea of using segmentation methods to recognize curves.

E. Function of angular characteristic of broken line.

We denote a broken line by a sequence of vertices $\{A_0, A_1, \dots, A_n\}$. Let (x_i, y_i) denote Cartesian coordinates of the i -th vertex. Then the broken line corresponds to a sequence of n vectors $\{\vec{v}_1, \vec{v}_2, \dots, \vec{v}_n\}$ given by equalities (14).

$$\vec{v}_i = (x_i - x_{i-1}, y_i - y_{i-1}) \quad (14)$$

We define the sequences $\{l_1, l_2, \dots, l_n\}$ and $\{\varphi_1, \varphi_2, \dots, \varphi_n\}$. by equalities (15) - (16).

$$l_i = |\vec{v}_i| \quad (15)$$

$$\varphi_i = \begin{cases} 0, if\ i = 1 \\ Ang(\vec{v}_i, \vec{v}_{i-1}), if\ i \neq 0 \end{cases} \quad (16)$$

Let $x_0, x_1, \dots, x_n$be a sequence of points on the X axis given by the equations (17)

$$x_i = \begin{cases} 0, if\ i = 0 \\ \sum_{k=1}^{i} l_k\,, if\ i \neq 0 \end{cases} \quad (17)$$

So, the interval $[0, L]$, where $L = \sum_{i=1}^{n} l_i$ is the length of broken line $\{A_0, A_1, \dots, A_n\}$, contains all points $x_0, x_1, \dots, x_n$. Now we define on the interval $[0, L]$ the step function α by (18)

$$\alpha(x) = \sum_{i=1}^{n} \varphi_i \cdot \chi_{D_i}(x) \quad (18)$$

,where $\chi_{D_i}(x)$ is the indicator function of interval D_i (19),and sequence of intervals $\{D_1, D_2, \dots, D_n\}$ is defined by equations (20).

$$\chi_{D_i}(x) = \begin{cases} 1\ if\ x \in D_i \\ 0\ if\ x \notin D_i \end{cases} \quad (19)$$

$$D_i = \begin{cases} [x_{i-1}, x_i)\ if\ 1 \leq i < n \\ (x_{i-1}, x_i] if\ i = n \end{cases} \quad (20)$$

The function of the angular characteristic θ of a broken line will be determined (as for a regular smooth curve, see (10)) by equation $\theta(x) = \alpha(x \cdot L)$.An example of a broken line (strictly speaking, a planar graph representing a tree with two leaves) and the corresponding function of the angular characteristic is shown below (see Fig. 5)

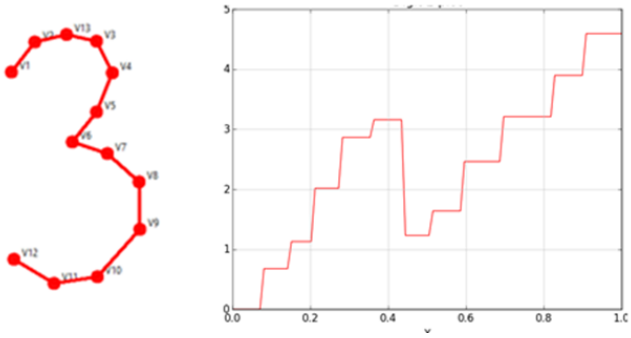


Fig. 5. Broken line (planar graph of real image) and plot of its angular characteristic function.

As Ψ is a piecewise continuous bounded function it is possible to define its absolute value $\|\Psi\|$ by (22)

$$\|\Psi\| = \sqrt{\int_{-1}^{1} \Psi^2(x)\,dx} \tag{22}$$

Let $\Omega = L^2([-1,1])$be a L^2 space of functions, defined on interval $[-1,1]$. Then ,$\Psi \in \Omega$, due to the fact that the norm $\|\Psi\| < \infty$ is defined by (2). As Ω is a L^2 space, $\Omega$is a Hilbert space, where inner product of $f_1, f_2 \in \Omega$ is defined by (23):

$$\langle f_1, f_2 \rangle = \int_{-1}^{1} f_1(x) \cdot f_2(x)dx \tag{23}$$

Each even function $g \in \Omega$ can be represented as a Fourier series in form (24)

$$g(x) = \sum_{i=1}^{\infty} c_i \cdot \varphi_i(x) \tag{24}$$

where functions φ_i is defined by equations (25)

$$\varphi_i(x) = \begin{cases} \frac{1}{\sqrt{2}} \; if \; i = 1 \\ \cos(\pi \cdot i \cdot x) \; if \; 1 < i \end{cases} \tag{25}$$

The system of functions (25) is orthonormal, which means that (26) holds true.

$$\forall i, j \; \langle \varphi_i, \varphi_j \rangle = \delta_{ij} \tag{26}$$

The coefficients c_1, c_2 ... of Fourier series expansion (24) are defined as the projections (27) of the vector $g \in \Omega$ onto the vectors of the orthonormal basisφ_1, φ_2 ...:

$$c_i = \langle g, \varphi_i \rangle = \int_{-1}^{1} g(x) \cdot \varphi_i(x)dx \tag{27}$$

F. Feature extraction.

An arbitrary function$f$ defined on an interval$[a, b]$ can be considered as a periodic function $\forall x \in \mathbb{R}\, f(x + T) = f(x)$with a period $T = b - a$.By definition, the function of the angular characteristics θ of arbitrary broken line is defined on the unit interval $I = [0,1]$and $\theta(0) = 0$, but in the general case $\theta(1) \neq \theta(0)$ .Consequently, a periodic function θ in the general case will have jump discontinuities. Due to Gibbs phenomenon, the partial sum of the Fourier series will be poorly approximated to the original function θ .To solve this problem, we use the following method: For a given function of angular characteristic θ, we define an even function Ψ defined on the interval $[-1,1]$ by equation (21)

$$\Psi(x) = \theta(1 - |x|) \tag{21}$$

For a given N, the N-th partial sum of the Fourier series (28) will approximate the original function.

$$g(x) \approx \sum_{i=1}^{N} c_i \cdot \varphi_i(x) \tag{28}$$

We will consider the real numbers $c_1, c_2 \ldots c_N$, as components of the vector $\vec{g} \in \mathbb{R}^N$,so in some orthonormal basis of $\mathbb{R}^N \vec{g} = (c_1, c_2 \ldots c_N)$. Let designate by $g \to \vec{g}$ correspondence between even function $g \in \Omega$ and vector $\vec{g} \in \mathbb{R}^N$ of Fourier series coefficients. Then, for arbitrary even functions $f_1, f_2 \in \Omega$ approximations (29)-(30) holds true.

$$\langle f_1, f_2 \rangle \approx \vec{f}_1 * \vec{f}_2(\tag{29}$$

$$\|f - g\| \approx \left|\vec{f} - \vec{g}\right| \tag{30}$$

Both Hilbert space and Euclidean space are metric spaces. A metric in space (a set of points D) may be defined by the distance function d, defined for all pairs of points $A, B \in D$, which satisfies four conditions:

1) $\forall A, B \in D \;\; d(A, B) = d(B, A)$
2) $\forall A, B \in D \;\; d(A, B) \geq 0$
3) $\forall A \in D \;\; d(A, A) = 0$
4) $\forall A, B, C \in D \;\; \rho(AB) \leq \rho(AC) + \rho(CB)$

As is known, in the Euclidean space $\mathbb{R}^N$, distance d between $\vec{A}, \vec{B} \in \mathbb{R}^N$ is defined as $d(\vec{A}, \vec{B}) = \left|\vec{A} - \vec{B}\right|$. Similarly, for a Hilbert space L^2 metric d^* is defined by equation (31), where $f_1, f_2 \in L^2$

$$d^*(f_1, f_2) = \|f_1 - f_2\| \tag{31}$$

It is proved that conditions 1) –4) are satisfied for the metric d^*. Suppose that for a given function of the angular characteristic θ, the function Ψ is determined by the ratio (21) and $\Psi \to \vec{\Psi}$. If we consider the vector $\vec{\Psi}$ as a featurevector of the Euclidean feature space, then based on

the above considerations, it can be argued that such a method of feature extraction will be good suitable for curve classification tasks. But in practice we need to classify the step characteristic functions of broken lines, containing discontinuous jumps. It is highly desirable to smooth out such functions. To do this, we apply the operation described below to the vector $\vec{\Psi}$of the Fourier expansion coefficients of the function Ψ. Let denote by $g(x)$ Gaussian function, defined as,

$$g(x) = \frac{1}{\sqrt{2\cdot\pi}\cdot\sigma}\cdot e^{-\frac{x^2}{2\cdot\sigma^2}} \tag{32}$$

where $\int_{-\infty}^{\infty} g(x)\,dx = 1$,i.e. $g(x)$ is normalized. As g is an even function, equations (33)-(34), for arbitrary $\omega \in \mathbb{R}$ holds true.

$$\int_{-\infty}^{\infty} g(x)\cdot\cos(\omega\cdot x)\,dx = \int_{-\infty}^{\infty} g(x)\cdot e^{-i\omega x}dx \tag{33}$$

$$\int_{-\infty}^{\infty} g(x)\cdot cos(\omega\cdot x)\,dx = e^{-\frac{\sigma^2\cdot\omega^2}{2}} \tag{34}$$

For the values of the parameter σ, satisfying the non-equality$\sigma < \frac{2}{3}$, we can assume that$g(x) \approx x\ if\ x \notin [-1,1]$. Then the values g_k^* defined by (35) can be considered as the Fourier expansion coefficients of the function g^*, approximating the Gaussian function $g(x)$.

$$g_k^* = \begin{cases} 1 & if\ k = 0 \\ e^{-\frac{\sigma^2\cdot(k-1)^2}{2}} & if\ k > 1 \end{cases} \tag{35}$$

Let $\vec{\Psi} = (\varphi_1, \varphi_2, \dots, \varphi_N)$ be the vector of the Fourier coefficients of the function Ψ, and $\vec{g}^* = (g_1^*, g_2^*, \dots, g_N^*)$the vector of the Fourier coefficients of the functiong^*. We define the vector $\vec{\Psi}_s = (\varphi_{s1}, \varphi_{s2}, \dots, \varphi_{sN})$ by equalities (16).

$$\varphi_{sk} = \varphi_k \cdot g_k^* \tag{36}$$

According to the convolution theorem for Fourier series, we can consider the components of the vector $\vec{\Psi}_s$ as the Fourier expansion coefficients of the function $\Psi_s(x)$, which is a result of application of a filter with Gaussian kernel g^* to the function Ψ (37)

The choice of the number *n* and the values of the parameter *t* strongly affect the quality of recognition.

$$\Psi_s(x) = \int_{x-1}^{x+1} \Psi(t)\cdot g^*(t)\,dt \tag{37}$$

The most interesting result of this study is a practical confirmation of the applicability of the angular characteristic function for handwriting symbol recognition. Unfortunately, the limitations of this paper's volume did not allow including the discussion of a number of issues that arose during the research. In particular, this paper does not include a description of methods for eliminating artifacts that occur when converting an image into a planar graph, and methods for identifying symbols whose planar graphs contain loops. The authors are currently working on the angular characteristic function applying, particularly on segmentation of curves obtained by smoothing the step functions of the angular characteristic broken. Such segmentation will allow us to represent the curve as a sequence of geometric patterns - primitives (circular arcs, line segments, etc.). The recognition algorithm can be improved using segmentation methods, as well as applied to the recognition of a wider class of objects.

III. CONCLUSION

In our opinion, the most interesting result of the work is a practical confirmation of the applicability of the angular characteristic function for handwriting symbol recognition. Unfortunately, the limitations of the work volume did not allow us to include in it a discussion of a number of issues that arose during the work on the project. In particular, this work does not include a description of methods for eliminating artifacts that occur when converting an image into a planar graph, and methods for identifying symbols whose planar graphs contain loops. We are currently working on the father development of the idea of using the angular characteristic function, namely, we are trying to segment the curves obtained by smoothing the step functions of the angular characteristic broken. Such segmentation will allow us to represent the curve as a sequence of geometric patterns - primitives (circular arcs, line segments, etc.). We hope that our recognition algorithm can be significantly improved (in particular, using segmentation methods), as well as apply it to recognition of a wider class of objects.

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An Exploration of Constraints Faced by Bangladeshi Start-up Companies and Proposed Recommendations

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***Abstract*—The 4th industrial revolution is knocking at the door. The high-end technology, machine learning, industrial Internet of Things (IOT), cyber security, big data & analytics and artificial intelligence are in finger tips of this young generation. The concepts of Start-up come up with a revolution of technology across the world in recent years. Especially, the enthusiasm of the youth of developing countries likes Bangladesh that context very effectively. Establishing start-up is becoming a new trends and opportunity to them. Both the developed and developing economics are witnessing lot of new start-up in recent year. But the growth and success rate are relatively low due to many constraints. Globally the failure rate of start-up is high. Around half of companies are failed during their first five years' operation. This paper is intent to explore the challenges faced by the start-up companies of Bangladesh so that future start-ups can avoid those pitfalls. The researchers interviewed 38 start-up companies' top executives, managers to achieve the objectives. This study is conducted in qualitative way to get depth knowledge. The findings from the interviews shows that lack of awareness, education among customers, inadequate trust on online marketplace, price sensitivity, logistical and infrastructural problems etc. are main challenges start-up's facing right now. Finally, this paper suggests some recommendations to solve those problems and develop the scenario.**

Keywords— Start-up, Entrepreneurship, Challenges, Bangladesh

I. INTRODUCTION

Although Bangladesh is a tiny south Asian country but she has lot of possibilities. Yet with a vast population its consistent growth of GDP and development surprises the world which influences the economic experts to consider her as "An emerging new Asian tiger". Bangladesh envisions being a major global digital economy by the year 2021 (A.T. Kearney, 2017). It is a mobile-first nation, with more than 150 million mobile subscribers and over 25 percent Internet penetration. With 70 percent of the population under 35, media consumption is increasingly skewed towards digital (Mehedi, 2016).To achieve the vision stated earlier, the development of digital entrepreneurship is considered as a fuel. Last several years with the collaborative assistance government, private-public partnership (PPP), policy makers, angel investors, and conglomerates are trying to develop an organized and structured entrepreneurial ecosystem through mentorship and accelerator support. As a result it has seen that a huge number of start-up's are launching and some are doing exceptionally well. About 200 digital start-ups each year enter into the local business landscape in Bangladesh and about 1,000 were by the end of 2016 (A.T Kearney, 2017). Majority of the companies offer the e-commerce, e-travel, e transport, e-healthcare, e-payment services (Table 1).This positivity provokes the graduates to choose entrepreneurship as a career path. They are less likely to depends on parents or traditional jobs or universities or wait for opportunities. But challenges are available all over the place and business organizations like Start-up's specifically are no exemption to these challenges they confront today. The researchers are optimistic that the outcomes from this study will make conscious potential entrepreneurs to tackle those challenges.

II. LITERATURE REVIEW

A. Definition of Start-up:

A start-up company or start-up is an entrepreneurial venture or a new business in the form of a company, a partnership or temporary organization designed to search for a scalable business model (Kandasamy, 2015). Paul Graham (n,d) says that "A start-up is a company designed for rapid growth." There have some misconception about start-up. It is not mandatory to be a newly born company or technology based company or receives venture funding, or has some sort of "exit". The only vital thing is growth.

According to DIPP (2018), "Start-up means an entity, incorporated or registered in India which is operated up to a period of seven years from the date of incorporation/registration or up to ten years in case of Start-ups in Biotechnology sector and with an annual turnover not exceeding Rs. 25 core for any of the financial years since incorporation/registration".

Start-up guru Steve Blank (2017) provides a definition as a start-up is a "temporary organization designed to search for a repeatable and scalable business model", while the small business runs according to the fixed business model. Steve categorizes start-up companies into six types. Lifestyle Start-ups, small Business Start-ups, scalable Start-ups, buyable Start-ups, large Company Start-ups, social Start-ups.

B. Previous researches:

Building a new business is very difficult and involve high risk of failure (Reynolds & Miller 1992;Van De Ven 1992). Many start-ups fail in the very early stages and less than one-third of them turn into companies- "higher failure rate" (Vesper, 1990). Bhide, A. (2000) found in US that only 10% of start-up's offered novel product or services, rest all offer nothing authentic or new to the market. To find out the barriers and cause of failure there had numerous researches were conducted previously. In the Republic of Srpska (RS), one of two B&H entities, where we have conducted empirical research, in addition to the lack of available alternative external sources of financing for start-ups and existing SMEs, such as angel investors, venture capital funds, factoring, mezzanine financing, crowd funding, etc., there are a number of other factors, which could cause increasing failure rate of companies (Hisrich et al., 2016). The most crucial challenges, faced by 4,928 young businesses in the US were slow or lost sales 36% and unpredictable business conditions 28 % (Robb and Farhat, 2013).

Furthermore, Kennickell et al.(2015) added the financial crisis and the Great Recession, including facing limited credit constraints as major problems. Ahmad and Seet (2009) pointed out on management skills as the new small firm transits from the founding entrepreneurial stage to higher growth rate stages. Temtime and Pansiri (2004) found that insufficient market research, ineffective demand forecasting and analysis, poor customer service, and lack of training for sales staff are the most significant factors leading to the failure of new business. Omid Sharifi et al (2015) added the Imperfect education System and conservative Lifestyle, lack of Support Networks and Entrepreneurship Ecosystem, lacks of enough angel investors to fund start-ups, culture differences. In Pakistan for 81.8% of the businesses failed because of insufficient capital, poor business model, lack of staffs and perfect partners (Hyder et al, 2016).

C. Kandasamy (2015) has claimed that wrong market timing ,weak management team, ran out of cash, fail to develop a product that meets the market need are also responsible for start-up failure and lack of strategic planning, wrong marketing investments or inefficient resource allocation (Ashok ,2018). The Bamboo Report (2017) stated operational inefficiencies, product/market misfit, poor market understanding, poor product development, competition, misevaluation, and lack of finance, team management problems, lack of enough business knowledge, technology lag(Núñez, 2007), human resource management issues , lack of attention to environmental elements, such as the existing trends, limitations in the markets, legal issues (Salamzadeh, 2015).From a survey by A.T. Kearney (2017) on 62 start-ups of Bangladesh and has presented limited access to investors, funding ,limited availability of digital information ,limited availability of supporting networks, limited availability and quality of IT specialists, limited access to corporate business, Inefficient regulatory framework, undeveloped fixed broadband infrastructure and undeveloped mobile infrastructure as prime market barriers of entrepreneurs.

Table1: Bangladeshi Start-up's Customer segment focus your paper size.

Digital segment		Total number of start-ups	Number of product companies	Portion of work dedicated to local projects (%)
Services	E-commerce and delivery	42	42	93%
	E-transportation	10	10	100%
	E-health	9	6	89%
	E-learning	17	6	76%
	E-finance	5	5	80%
	E-travel	6	1	83%
	Classifiers	9	9	89%
	Communication & social platforms	5	5	100%
	Content (video, music, games)	13	11	54%
	SaaS and IaaS	2	0	50%
	Other (software-related)	35	4	69%
Transaction platforms	Payment platforms	2	1	100%
	Advertising and big data	11	0	82%
	Marketplaces (many-to-many)	19	19	84%
Internet of Things	Smart homes	0	0	0%
	Smart industry	5	2	60%
	Total	190	121	81%

Source: A.T. Kearney

C. Objectives:

1. To find out the challenges faced by the start-ups of Bangladesh
2. To provide suitable suggestions for improving the scenario of start-ups of Bangladesh.

III. Methodology

Primary data are the data directly collected from the respondents by using any structured methodology. For the literature lot of websites, journals, articles, reports, newspapers, books, magazines etc. were reviewed as secondary data source. Polkinghorne (2005) described that the most widely used technique in the production of qualitative data is interviews with participants. The researcher collected primary data using a structured interview of top management executives of 38 Bangladeshi start-ups. Most of the selected companies are from the Capital city Dhaka as it's the main focal point of all business activities and head offices are situated so. Interviews were taken place in the office of start-ups and normally 30-40 minutes lasted long each.

A. Data Presentation

Company	Challenges
1. **Rowza Pure Foods** (finest organic products)	- Uncertainty about the growth -Forceful obstrucles from the syndicate of the giant conglomerates
2. **BDjobs.com (**job portal)	- Reaching out to this segment of the users involves significant product and marketing challenges.

	- Away from the access to internet.
3.**Styline** (online hijab lifestyle start-up)	- Maintaining timely delivery - Customer education
4. Field Buzz (software system)	- Lot of resistance or difficulty to adapt to the new system -Uncertainty about the monthly salary - Like investing a lot of time and effort into a prospective client, including building demo applications for a project which never happens, - Making really hard decisions about employees
5. **Pathao (** a motor-bike hailing service)	-Lack of guidance
6. **Doctorola** (the health-Tech start-up)	-Lack of customer awareness -Balancing between cost and time -Expenses of communicating tools like ATL
7.Light of Hope (education for children and renewable energy)	-Lack of basic communication and marketing skills, - Inadequate financial literacy to run a business. - Lack of professionalism and commitment among young entrepreneurs.
8.**Bhalo Thakun** (well-being service provider)	- Keeping a low headcount - Technical aspects, developments, designing and redesigning the right product and managing the right resource within a constrained budget. -Customers perception about online shopping - Resource constraint
9. **HandyMama**(On-demand ride-hailing, on-demand grocery, on-demand services to on-demand travel assistance)	-Building capacity to handle challenging services, -Ensuring timely and best possible service quality
10. **GEEKY Social** (digital marketing agencies)	-Establishing new processes, structures, and systems, -Managing growth
11. **Bagdoom.com (online shop)**	-Awareness about E-commerce - The infrastructure problem. Timely delivery service to urban, semi-urban area -Trust on online payment -Finding good talent -Hard to find a local example to learn from. - Gender
12.**Raise IT Solutions** (Technology service provider)	-Previous bitter experience
13. **Chalda**l (ecommerce)	-Government policies. Excessive time for documentation, licencing, TIN -Keeping focus
14. PriyoShop.com (ecommerce)	-Customer retention

15.**Goponjinish** (online undergarment retailer)	- A steady growth -Lower margin for sourcing products from suppliers - The wide gap between male and female internet users in the country - Payment mode - Sourcing quality products
16. **Sindabad.com (**online B2B ecommerce platform)	- Absence of a structured supplier-base. -Marketing, making customers and organizations understand the benefits of taking a more efficient system.
17.**AjkerDeal** (eCommerce marketplace)	- To make model commercially viable, need more time and investments. -Investment - Size of the market and attaining a certain scale. lot of cost.
18. **Dnet (Online Health care service)**	-Finding the right person for the right job -Commitment -Depending on donor money and conducting experiments and fail -The absence of healthy competition. Copy products.
19.Bloodman	- Social pressures - Sustainable financial model - Keeping employees motivated
20. **Foodpeon** (Homemade food delivery start-up)	- Logistics. - Extreme traffic jam makes delay delivery -Increasing the number of suppliers
21.**Harriken** (online Food supply platform)	- Change in consumer behaviour, -Credibility is an issue -The unwillingness of breaking the status quo from the customer's side
22. **Khaas Food**	- Price sensitivity of customer
23. **Shadmart** (cross-border e-commerce company)	-Troubled with inevitable legal issues -Taking too much time for paperwork and inspection
24.Flight Expert (OTA)	-Investment and finance - Attract good talents
25.**Dude Style** (online men's fashion retailer)	-Lack of knowledge -Undeceived products and fake customers -Logistics -Rampant complaints about defects. Limited collection and slow delivery
26.24bazaar.com (home appliances)	-Social stigma and perception -Unsupportive family and friends, relatives -The growing competition
27.**Wreetu** (girl's health start-up)	-Developing critical partnerships that would enable us to scale.
28.**Frndz Lifestyle** (online man's cloth platform)	-Finding the right logistics partner. -Digital marketing -Advice and guidance.

29. Caretutors.com (an online tutor matching platform)	-Lack of knowledge about how to go about the implementation -Doing it all yourself -Not being tech savvy
30. **Eshosikhi.com** (an Edtech start-up)	-Creating market awareness and convincing people to pay for online education - Making quality content is an expensive chore.
31. Pickaboo (e-commerce marketplace with a concentration in electronics and related products)	-Convince investors to invest into this venture, -Go through legal issues, -Finding good people is a huge challenge - the expansion of our operations and making small groups more efficient
32.Planeter Limited (hardware, robotics and internet of things (IoT)	- The size of the local market - Access to information
33. Maya (A messaging platform with on-demand expert advice in areas like health, psychology, social problems and legal aspects.)	- Build the vetted expert network which is about scaling our on-demand model.
34. **CMED** (a cloud-based preventive health care start-up)	-Scaling our services while also ensuring the best quality customer service.
35.Bikroy (Online classified marketplace for both C2C and B2C users.)	-Customer awareness to use app, websites
36. **HungryNaki** (Online food delivery start-up)	-Turning from a scrappy start-up to a structured, process-oriented organization and instilling that mentality into the team. - Difficult to monitor other cities
37.**Seba (**An on-demand service marketplace)	- Hard to convince people that you can avail services from an online platform -Educating customers and maintaining the service quality
38. Prosiddho (Online destination for famous and prominent food products of Bangladesh.)	-Achieving trust of our customers -The main challenge for us now is ensuring on time delivery

IV. RECOMMENDATIONS:

A. Marketing, Promotion & CSR

- Creating awareness through marketing and branding is important. Need to ensure quality service and affordability.

- Run targeted campaigns, community engagement, CSR.

1) Pricing

-Customers are price-sensitive is Bangladesh just like in any other market. So, start-ups need to offer lower prices online than offline. From that point of view, an ecosystem needs to be built.

2) Operational

- Advance payment or at least partial advance payment can be implemented for paying the courier fair at least. This is a necessity because the e-commerce businesses have become matured and now many businesses are selling outside Dhaka in large quantities and most of them have the same complaints of un-received products.

-Build a strong Quality Control team and every product that you offer to your customers goes through QC for multiple times.

-Excellent after sell service. Even then, if you sell a defect product by any chance, replace the product within 2 days without hassle.

-Enrich by huge collection of categories. Build collaboration with multiple logistics partner that allows you to ensure timely delivery to your customers and flexibility in times of logistical obstacles.

- Need to invest in analytics and data so that you can make better decisions and design better strategy

B. Resource Related

1) Team

- Having a perfect match cofounder helpful. At least you can share with one other person. And of course, close family and friends are very important too, but in a different way. They help to give you a sense of perspective that life is about more than just your start-up.

2) Products/Service Related

-Have to find out a real, serious problem that you know and understand, try to solve it, and then try to build a company around solving that problem.

- Developed a few “niches” sometimes called “last-mile distribution”.

- Building an enriched database, and delivering the best possible experience

- You have to introduce new process, structure if needed, follow-up on it, and make adjustments based on practical applications. These are big undertakings.

- Highlight USP (Unique selling point) so that people would realize the severity of fraudulent activities and that they should prioritize local ad agencies over the foreign ones.

3) Family Support

-Understanding with your family, particularly with husband is important for female entrepreneurs. If the understanding is good, you would not face a lot of problem from your family. If you have firm determination, if you can work things out with your family, I think there is nothing that you could not outperform.

4) Soft skill Development

- Listen to others. It is a must for personal and organizational development and helps in fostering an environment of mutual respect. You need to learn every day from everyone.

- Interpersonal relationships in the office should be emphasized. If a superior pays attention to what his subordinates need, the subordinate will do the same and this is how an organization prospers.

-Try to understand your customers and their problems, including spending a lot of time "in the field" in rural areas, and change product and business model radically during first few months in response to what we're hearing from customers and experiencing in the field.

-One should never hide failures.

-It is also very important to remain positive and acknowledge others' successes, especially in a society like ours where we focus first on our weakness and try to demoralize.

-Maintaining a strong relationship with customers/ patients.

5) Functional Skills Development

-Being aware of the financial management of the company is also very important. Hire accounts if require.

- To build a long-lasting something, effective and timely succession planning is very crucial.

-Honesty, integrity, and focus. There are people who pursue too many things at once. That's a dangerous habit. You have to be determined and focused; you can't do many things at once.

6) Strategically Approach

-Probably for initial growth can follow the "lean start-up" approach, and it worked really well for some start-ups.

-Go out there into the real world and test a prototype with some real customers.

-Build a "minimum viable product", test it, measure, learn, and iterate until you find the winning formula. Then the business plan will write itself, the investors will come to you and the media will promote you.

- Go as lean as possible. To optimize at the maximum level, doing most with the limited resources that you have.

V. CONCLUSION:

In this 21st century each economy requires to special attention on entrepreneurship especially digital start-up companies. New technologies like internet of things (IOT), wearable devices, autonomous vehicles, 3D printing, and 5G mobile networks, together with advances in virtual reality, artificial intelligence, and robotics will transform the existing markets. So, to capitalize those facilities, opportunities government, and businessman's, financial institutions, policy makers, scholars, universities and entrepreneurs need to work in collaborative way. This research gives some insights and future research can be possible by widening contexts like sample size, research area, location and methodology. Every start-up should develop their core strategies that strengthen the work environment and increase the employee satisfaction, marketing, service to enhance performance and productivity, which ultimately results in high profits, customer satisfaction as well as customer retention.

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Examining Students' Creativity with the Torrance Creativity Test in Vocational High School

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***Abstract*— The rapid development of the industry requires workers to acquire new competences and improve existing ones. One of the main tasks of vocational education and training in the coming years is to develop the competences necessary for employment and occupation. Changes in working conditions are most likely to require the development of creativity. The purpose of this study is to demonstrate what students currently have in creativity and how their development is influenced by vocational training. For the study, the Torrance Creativity Test was completed with a series of questions including professional questions. The research focuses on justifying the presence of hypothesized creativity components and demonstrating whether there is a distinction between professional and general creativity in VET students. The research analyses whether there is a difference in creativity between apprentices and non-vocational students. The main hypothesis is that there is a noticeable difference in the creativity fluency between VET and high school students because VET participants apply their professional knowledge. The hypotheses were tested by analysing the fluency of student responses. The research was carried out among 11th grade students in vocational education and in upper secondary and art education. The 13th grade adults, who are now in vocational training and already have work experience, were also involved. Based on the results of the research, it was confirmed that the supposed creativity components are present. It can be stated that the students' creativity fluency is very poor and they tend to elaborate an idea as much as possible. There is no detectable difference between the 11th grade students and the adults now enrolled in VET, both in terms of general and professional fluency. However, it has not been clearly confirmed whether general and professional creativity can be distinguished.**

I. INTRODUCTION

As a result of the development of industrial technologies, some professions are being terminated, transformed or new ones are being created, with the result that different types of knowledge and, above all, different skills are needed. Employers have been questioned about the 10 competencies employers expect employees to have. In 2015, complex problem solving was the number one priority and is projected to remain the key employee competency by 2020. Creativity was ranked as the 10th most important competency in 2015, but ref. [32] expects it to grow in importance. According to the report, creativity will be ranked third in 2020, ref. [33] says that by 2022, it will be the second (projected first in Australia) most sought-after and needed competency in the labour market [33].

II. THEORETICAL BACKGROUND OF THE RESEARCH - CREATIVITY

A. *The concept of creativity*

Researchers have tried to interpret creativity in many forms and contexts, so there has been no uniform definition. Some researchers opted for a solution that was not clearly defined, but simply limited [10]. There are different theories for approaching creativity, which can be grouped around each factor of creativity. Several researchers have focused on defining the personality traits that characterize creative people [24] [13] [27] [18]. Other definitions focus on environmental factors, especially those investigating creativity and the potential for the development of SEN students in the school environment [1] [8] [17] [21] [12] [4] [5]. According to some researchers, creativity should be understood as a process [31] [22] [20]. According to the fourth widespread concept, creativity is nothing but unusual thinking [15] [29] [9] with the focus on professional problem solving, the definition of creativity is worth approaching from the psychometric and cognitive lines.

B. *Measuring Creativity*

The unusual use test developed by Guilford [16] to quantify creativity was the first to measure divergent thinking. The test measured the fluency and originality of the subjects [13]. The only inaccuracy of the test is that the measurement of originality depends on the fluency, since the more answers the test filler gives the higher will be the score given to the originality [19]. Originality is measured more precisely by the Barkóczi - Klein method [3]. The Unusual Usage Test is still used today because of the ease of data acquisition and evaluation, yet it reliably measures. The psychometric approach to measuring creativity has been criticized. Criticism is that creativity measured by tests does not correspond to real creativity, and that divergent thinking is also dependent on the test used [14].

Guilford's test was born almost simultaneously with the Torrance Test of Creative Thinking [25] [26]. The test consists of verbal and non-verbal tasks, which include the unusual use test applied by Guilford, subject optimization suggestions, a question-and-guess question, and a variety of options. The most well-known of the figurative tasks is the circle test, but it also contains a drawing supplement and an image editing task. The Torrance test measures flexibility, fluency, originality, and elaboration. A similar test was carried out by Hungarian researchers in 1965, featuring unusual usage, consistency testing, sentence

completion, and remote association tasks [2] [3]. The task set consisted of verbal tasks only. During the same period, the Wallach - Kogan Creativity Test was completed, which also included only verbal tasks. Such tasks include list of examples, unusual use test, similarity task, and interpretation of pattern and lines [30].

C. *Relationship of creativity to problem solving*

The development of creativity begins in early childhood, but the rate of development decreases with entry into school. Traditional teaching methods and the school environment do not support the development of creativity. Traditional forms of education focus on criterion-oriented output. Creativity is neither included in the content of VET curricula, nor in the competencies to be developed. So it is an often unrealized educational goal, although those in the construction and surveying sector need to solve life-long professional problems requiring some level of training. - mini c - small c [5] - creativity. Developing creative thinking is the best way for students to be prepared for a dynamically changing work environment [15] [28].

Creativity cannot be sharply separated from other mental-psychic activities and problem-solving. Creativity can also be seen as a tool for complex professional problem solving. Problem solving, in this line of thought, is a creative process that builds on existing professional knowledge and experience, but is the result of rearranging existing knowledge to solve a specific problem. The end result is the development of strategies for solving a given problem, that is, the creative product. The usability and novelty of the end results depends on the individual's level of creativity. The beginner's problem-solving creativity level is expected to be low, on the Beghetto-Kaufmann scale it is at mini c level, so problem-solving management and continuous feedbacks are required. The professional creativity of students entering VET is at this level. The creativity of experienced problem solvers reaches low c, in which case control is replaced by constructive exchange of experience. This is the level students can reach at the end of their professional training. By gaining work experience and expanding experience, the problem solver reaches the Pro c level, which, however, no longer takes place within school settings.

III. PURPOSE OF THE RESEARCH

A. *Hypothesis*

The present study is aimed at understanding divergent thinking among high school students. Previous research has shown that it takes time for creativity to develop. Some researchers estimate that this period lasts 10 years, when the individual translates that knowledge into practice to become a productive creator over time [6] [14] [11]. However, there is no information about research examining how professional training influences an individual's creative thinking. Whether the individual's creativity is complemented by the fluency, flexibility, or originality of the practitioner's professional knowledge, or does vocational training not affect the individual's creativity. The main question is whether professional creativity exists and, if so, to what extent does it influence the individual's overall creativity.

The aim of the research is to determine whether there is professional creativity in vocational training: professional knowledge pervades creativity even in areas that require solving a general problem independent of the profession. A further aim of the research is to reveal the level of creativity of students currently in sectoral vocational training, to determine if and to what extent the creativity of students is influenced by vocational training during the learning period. Which segment of creativity is the strongest among VET students? In the case of adult learners entering VET, is work experience already influenced by creativity?

The hypotheses of the research:

- Creativity can be divided into distinct components.
- There are detectable relationships between the components of creativity, one component inferring the presence and quality of another.
- Generic and professional creativity can be significantly differentiated.
- There is a noticeable difference in the creativity fluency between apprentices and non-VET learners because VET participants' responses are influenced by the learned profession.
- Vocational training has an impact on creativity, and responses to the learned profession also appear.
- The fluency of problem solving is influenced by the design of a strategy.
- Fluency can be used to identify homogeneous groups of learners.

B. *Research Participants*

The research was carried out among students in 11th grade vocational and secondary education and 13th grade vocational training in adult education.

TABLE 1
DISTRIBUTION OF STUDENTS IN RESEARCH

Type of group	Grade	Sector	Number of students
study group	11	road construction	13
study group	11	land surveying	11
study group	13	road construction	9
study group	13	railroad construction	17
control group	11	civil engineering	24
control group	11	grammar school	20
control group	11	artistic training	21

In the study groups, subjects were overwhelmingly male, due to the nature of the sectors studied, so it is not relevant to examine the gender gap in creativity. Differences in age have not been analysed either, as the age of adult learners varies widely and 68% of those involved in adult education research are only a few years older than full-time students.

C. Methods used

The participants completed a set of tasks based on the creativity tests developed by Guilford and Torrance. The exercises consisted of verbal and figurative tasks of the following types:

- inventing a strategy - verbal
- Graphic supplementation, pictorial creative thinking - figurative
- Visual similarity - figural-verbal
- Conceptual similarity - verbal
- Problem solving - verbal

Taking into account the above listed types of questions, participants in general and artistic training have been given tasks that include objects, drawings, etc. that occur in everyday life. Vocational training participants were also given further occupation-specific questions. The data collection was conducted in April 2019 for students of vocational secondary schools and in June 2019 for students of high school and arts education. The students completed the tests under standard classroom conditions, so differences due to different classroom climates do not affect the results of the research.

Data were analysed using descriptive and mathematical statistical methods. The correlations were explored by calculating correlation coefficients and by the analysis of variance to detect differences. The correlations and differences can be considered justified with the 95% probability level of pedagogical research. The appearance of the two components of creativity was investigated by cluster analysis.

IV. Results

A. Verification of the components of creativity

In my research, I used several versions of the assignment, depending on whether students in the construction or surveying sectors were in vocational or high school education. Therefore, reliability was examined for each set of tasks, and tasks were measured prior to testing to determine which responses may be related to the particular profession of the learners but are not considered to be effects of the learned profession, given by the students who do not receive vocational training. The reliability of the tests used is confirmed by Cronbach's value, which is presented in Table 2, broken down by test series. It is clear from the reliability metrics that the tests measure reliably.

In the preparation of the tasks, we defined five types of tasks, which were defined in general and professional aspects. When examining the tasks, we also examined the set of tasks, including professional questions, because the participants of the grammar school completed only the part related to general creativity.

TABLE 2
RELIABILITY OF USED TASKS

Type of group	Grade	Sector	Cronbach α
study group	11	road construction	0,800
study group	11	Land surveying	0,769
study group	13	road and railroad construction	0,800
control group	11	civil engineering	0,626
control group	11	grammar school	0,767
control group	11	artistic training	0,814

The hypothesized creativity components were verified by cluster analysis, in which all fluence variables were included. Based on the analysis, strategy-making, visual creative thinking, visual similarity, conceptual and visual similarity, and elaboration of problem-solving ideas can be considered as components of creativity and should be examined separately.

B. Fluency analysis

In the case of fluency, I investigated students' ability to gather ideas for five minutes performing association assignment, strategy development, and problem solving. An integral part of the research is to determine whether the learned or practiced profession has an impact on students' creativity, and how many of the responses to each task can be attributed to the occupant's learned profession. According to this, students' answers can be divided into two groups: general and professional response types.

Descriptive statistics are shown in Table 3. The members of the survey team have the highest fluence; in terms of professional fluency, the rail construction group achieved better results. Grade 11 road builders and 13th grade road builders show similar results, with professional fluency appearing in almost the same proportion of responses. The fluency of 11th-grade students in the construction industry is much lower than expected, especially regarding professional fluency. As this control group, surveyor and road construction study groups have been conducting professional studies for the same amount of time, similar values were expected. The fluency of non-VET students is lower than that of VET students, which can also be explained by the development of the student's creative thinking through VET professional tasks.

TABLE 3
AVERAGE FLUENCY VALUES FOR TESTED GROUPS

Group	All answers	General answers	Professional answers
Land surveying	56,36	45,09	11,27
Road construction	35,09	27,82	7,27
Civil engineering	21,91	19,64	2,27
Road construction	29,87	23,89	6,22
Railroad construction	36,0	23,00	13,00
artistic training	not relevant	4,58	not relevant
Grammar school	not relevant	3,69	not relevant

Vocational education and training students also find professional answers to general questions, but on a very small scale. This means that the students 'creative thinking is already embedded in the students' professional knowledge, but it is not applied automatically unless they are confronted with a question about the profession they are learning. The same considerations apply when looking at the average number of students' responses to a task.

When analysing the components of creativity separately, it can be concluded that each professional training group performed best in conceptual similarity tasks by analysing the answers to all general and professional questions. Non-vocational students achieved the greatest fluency in developing problem-solving ideas. It was the second place for vocational training participants. The fluency of visual similarity is the weakest in both the examined and the control groups, which is quite surprising for the vocational training participants, since the special form of communication of the technical profession is the preparation and interpretation of diagrams and technical drawings.

Because the response rate to professional questions is lower than to general questions, the fluency of the three components of professional creativity is lower than that of average creativity. Fluency values for non-vocational and construction students are nearly the same. Compared to the groups studied, students in the construction sector, in arts and high school, did poorly in general and professional fluency compared to the other groups. Professional fluency is the highest in railway construction (35.65% on average), and the lowest in the construction control group (11.21%). The question is whether statements based on descriptive data can be justified by mathematical statistical procedures, and whether differences between groups can be detected.

In mathematical statistical analysis, there is a close relationship between general and professional fluency at a 99% probability level (r = 0.322). Taking into account all the answers of high school students, there is a close relationship between 99% probability of finding a strategy, visual and conceptual similarity, and problem solving. At the 95% probability level, there is a loose relationship between visual creativity, strategy inventiveness and problem solving. There is neither connection between visual and conceptual similarity nor between visual similarity and visual creativity. Examining general fluency by including the responses of non-vocational students, it can be concluded that only correlation between visual creativity and visual similarity cannot be demonstrated (r = 0.155). When examining purely professional responses, there is only a relationship between problem solving and conceptual similarity at a 99% probability level (r = 0.343). It can also be inferred from this that students usually use analogical thinking instead of creative thinking to solve professional problems. From a professional point of view, there is a negative relationship between inventing a strategy and visual creativity, so the better the learner's elaboration the more difficult it is to develop strategies. Developing the strategy has a 95% probability level of close association with visual similarity (r = 0.257) and problem solving (r = 0.261).

I examined whether homogeneous groups can be formed among students in terms of the fluency of creativity using significantly detectable relationships. Applying the relationships in all combinations and involving all students, although they may distinguish homogeneous groups of students based on their answers to general questions, these groups contain a mixed number of individuals from each of the studied and control groups. The groups thus formed are not the same as the groups of students who have the same profession or grade. I analysed whether homogeneous groups can be created within a student group. In this case, it is possible to form homogeneous study groups within the studied groups by examining the variables of all general questions together. The least homogeneous group is made up of students in the 11th grade construction sector, according to the cluster analysis, the 24 students in the group form 16 groups based on the proximity of their creativity, so this control group cannot be considered homogeneous. This predicts that similar results were obtained when examining the combinations of creativity components. The most homogeneous group consists of 13th grade road building students. In this group only two groups could be formed. Based on these, the surveyor and road construction survey groups can be considered homogeneous, because few groups can be formed in relation to the number of students. Sharp (1991) has already pointed out that engineering is nothing more than problem solving, therefore it is advisable to examine how creativity can be considered as having the same level of creativity on the basis of the components of problem solving, conceptual similarity and strategy development. On the basis of the analysis of the three components, only members of the construction and arts groups cannot be considered homogeneous. Survey students are outstanding: each member of the study group is a group, so the group itself can be considered homogeneous. The 11th grade road construction study group also shows similar homogeneity. Further investigation is needed to prove whether the homogeneity of group creativity in problem-solving and strategy-making can be caused by learning according to the problem-based learning high school model [7]. Based on the cluster analysis of the professional issues (in this case the examination of the students of the grammar school and the arts training is not relevant) the students of the construction industry do not

show a uniform picture here either. Surveyors are less uniform than the fluency of their answers to general questions, but there is much less distance between group members than among students in the construction industry. However, in the case of grade 11 road builders, the homogeneity of the group decreased, with four groups being formed.

When comparing the groups, it should also be examined whether there is a significant difference between them. The assessment was performed by analysis of variance. As a result of the analysis, for all variables belonging to the general question, the value between groups was greater than the value within the group, but on the basis of F test these differences are not considered significant, what means there is no detectable relationship between group creativity fluency. In vocational secondary school students, it is necessary to examine to what extent the answers to the general questions and the answers to the professional questions influence the development of the differences between the groups. In this case too, the value of the variance between the groups is much higher than the value of the intra-group variance for all creativity components, but the F test does not show if there is a significant difference between the examined groups. It was not demonstrated whether there was a detectable difference between general and occupational fluency of students, and only in the 11th grade road construction group could be pointed out that general and occupational fluency are significantly related (r = 0.746) at a 99% probability level.

V. SUMMARY

In the research we sought to find out whether there is professional creativity and how vocational training influences students' creativity fluency. This required proof of the supposed problem-solving components of creativity.

In the study of fluency, I came to the same conclusion as ref. [6] and ref. [11]: in the early stages of learning, the learned profession is not yet embedded in everyday creative thinking; it requires at least ten years professional experience to become an inside of the individual. This is also supported by the analysis of variance for all variables and for all students in VET. According to it there is no detectable relationship between the groups. It can be concluded that the students have not yet reached the stage of gaining professional experience, so they still show problem solving features of a beginner.

For all VET groups, based on a contextual analysis, there is a 95% probability that a connection can be found between students' professional problem-solving, conceptual similarity recognition and strategy development. There are more connections between components of 11th grade students' creativity than among adult learners. The question arises whether the creativity of adult learners is below that of 11th grade students.

Although the results presented in the study are limited to the groups studied, important relationships have been found with regard to vocational training, especially in terms of creativity components and problem solving. The descriptive analysis of the data shows that we can speak of professional and general creativity among the students of a profession. Professional creativity has not fully developed during the studies, so the difference between general and professional creativity is not yet apparent in the groups studied. To substantiate this by mathematical statistical methods, it would be necessary to involve groups who have practiced their profession for at least 10 years.

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Image Acquisition and Processing on Raspberry Pi in Matlab for 3D-Scanning

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***Abstract*—The paper presents the results of applying a special image processing method on the Raspberry Pi platform using Matlab. An image processing system has been developed using the necessary element base for quick image processing, including image transmission using a camera. A new algorithm for extracting lines on a recognizable image has been developed, which uses a gradient image processing technique. Images were obtained and this system was successfully tested on the Raspberry Pi 3. It is proposed to use this method for a robotic machine vision system, where the video camera is mounted on a robot manipulator that scans the surface**.

Keywords—image processing, machine vision system, 3D-scanning

I. Introduction

One of the traditional applications of machine vision is robotics. Since robots have been mainly used in industry and their working conditions have been determined, highly specialized solutions using expensive equipment, including optical and computer systems, turned out to be applicable for machine vision problems.

Currently, the most common are machine vision systems that use standard cameras and computers. The term “computer vision” is more suitable for such systems, although there is no clear separation of the concepts of machine vision and computer vision. However, different machine vision systems are equally important. The use of “non-standard” imaging acquisition methods, including the use of spectral ranges other than visible, coherent radiation, structured illumination, hyperspectral devices, time-of-flight, omnidirectional and high-speed cameras, telescopes and microscopes, etc., significantly expands the capabilities of machine vision systems [1].

While the capabilities of the algorithmic support of machine vision systems are significantly inferior to human vision, the capabilities of obtaining information about the observed objects significantly exceed it. Image acquisition issues constitute an independent field of research, and the methods for processing images obtained using various sensors are so diverse that their review is beyond the scope of this paper.

Kawasaki RS10LA robot manipulator has been used for plasma surface treatment in our research, as described in our papers [2–5]. The robot manipulator program was generated according to a given geometric model of the plasma-treated object. However, deviations of the shape of a real object from this model often lead to violation of the processing technological parameters. To solve this problem, it is necessary to obtain a 3D model of a product of complex shape as a result of its scanning and generate a robot program in order to realize the movement of the robot arm along a given 3D path. Thus, at first the 3D model of an object to be processed by plasma should be obtained. Since machine vision devices are one of the most expensive parts of robotic systems, we propose to develop and test an inexpensive and universal machine vision system on the Raspberry Pi platform using Matlab.

The goal of this study is to apply 3 Raspberry Pi platform combined with Matlab for developing machine vision system, followed by its application for robotic scanning objects.

II. Methods

Various methods of images acquisition and processing, as well as algorithms of objects transformations and recognition most often used in computer vision theory for robotics [6-9] have been considered. The selected methods are briefly described below for implementation on the RPi3 platform.

A. Edge Detection by Sobel operator

In simple terms, edge detection is the process of identifying points in a digital image where the brightness changes aggressively. Edges in images are areas with strong intensity contrasts a jump in intensity from one pixel to the next. Edge detection is mainly used for feature detection or feature extraction in various fields. Inideal circumstances, the outcome of applying an edge detector to an image may lead to a set of connected curves that indicate the borders of objects, the borders of surface markings as well as curves that correspond to discontinuities in surface orientation. Thus, applying an edge detection algorithm to an image may significantly reduce the amount of data to be processed and may therefore filter out information that may

be regarded as less relevant, while preserving the important structural properties of an image. Usually gradient operators,laplacian operators and zero-crossing operators are used for edge detection [6]. The gradient operators are divided into two categories (first and second order) depending on whether they approximate the first derivative (Prewitt, Sobel, etc.) or the second derivative (intersection of the Laplacian zero) of the input image.

The Sobel operator performs a 2-D spatial gradient measurement on an image and emphasizes regions of high spatial gradient that correspond to edges. Typically it is used to find the approximate absolute gradient magnitude at each point in an input greyscale image. Compared to other edge operator, Sobel has two main advantages:

1. Since the introduction of the average factor,it has some smoothing effect to the random noise of the image.

2. Because it is the differential of two rows or two columns,so the elements of the edge on both sides has been enhanced,so that the edge seems thick and bright [7].

B. Corner Detecion by Harris operator

A corner detection is the next qualitative level in an image understanding. All known corner detectors generally differ from edge detectors in stronger response in places where corner is present in comparison with places where only edge appears [8].

The simplest angle detector is the Moravian operator, summing up only eight differences between the center pixel and pixels in an 8-neighborhood. More sophisticated angle detectors are the Harris and Stevens algorithm, the Shea and Tomasi algorithm, and the Rosten and Drummond algorithm. We dismantled the Harris & Stephens corner detector. It is based on the autocorrelation function of a small fragment of the input image. The first step in the Harris algorithm is to compute the Harris matrix, a matrix containing all combinations of gradients in the horizontal and vertical directions. Angles are places in the image where gradients are significant in both horizontal and vertical directions at the same time [8].

C. Line Detecion by Hough operator

Each line passing through the image area, Hough Transformation associates the sum of the values of the pixels closest to this line. The Hough transform is used to detect straight-line objects or their various configurations in the image, for example, to detect road markings, search for document boundaries, color segmentation, computational tomography and others. In other words, the Hough transform is a method of detecting straight and curved lines in grayscale or color images.

The method allows you to specify the parameters of a family of curves and provides a search on the image of the set of curves of a given family. The paper [9] is devoted to the study of algorithms for calculating the fast Hough transform for two-dimensional and three-dimensional images. A method for calculating the fast Hough transform (BPH) for straight lines in a three-dimensional image is proposed. The BPH algorithms for approximation in two-dimensional and three-dimensional spaces are considered, the accuracy and completeness properties of the corresponding sets of dyadic patterns are investigated.

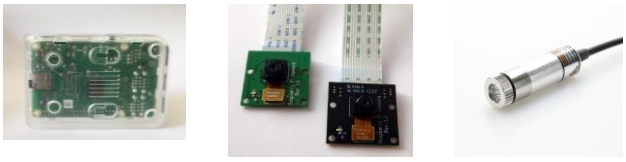
III. Experimental Results and Discussion

The experiment was carried out in the laboratory of the Obuda University, Szekesfehervar (Hungary). As a result of this experiment, the results were obtained, which are analyzed and summarized in this paper.

A. Equipment and Sofware

Raspberry Pi 3 (Fig. 1) is a single-board computer having a size as small as a credit card. Raspberry Pi uses powerful BCM2837 which offers 1.2 GHz quad-core ARM Cortex-A53 CPU, 1 GB RAM. built-in Wi-Fi 802.11n and Bluetooth 4.1. In addition, the processor has the ARMv53 architecture, which allows using the operating systems: Debian Wheezy, Ubuntu Mate, Fedora Remix, and even MS Windows 10 IoT.

The compact module with infrared camera for Raspberry Pi was used. The second version of the module is equipped with an eight-megapixel Sony IMX219 Exmor sensor. It allows you to capture, record and broadcast video in 1080p, 720p and VGA formats. The maximum resolution for photographs reaches 3280 × 2464 pixels.



a b c

Fig.1. a - Raspberry Pi 3, b- integrated camera, c - Line LASER

A power connector and an Ethernet cable were used for communication between the RPi3 and the PC. All the algorithms developed in Matlab were deployed in the ARM processor on RPi3 via an Ethernet cable.

The first step was to combine Matlab with raspberry pi. To do this, Matlab support installation was selected for the Raspberry Pi Home-Add-Ons-Get hardware support packages in the Raspberry Pi list, and the Matlab component was installed. After loading, the process started and the name was set for raspberry pi:

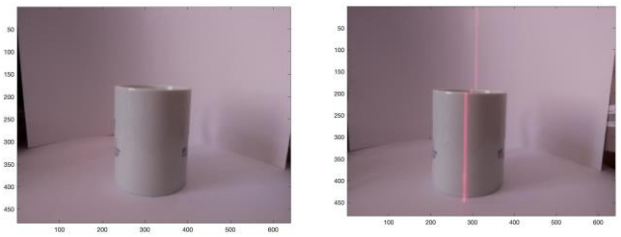
Mypi = raspi // The raspberry pi characteristic were received

mycam = cameraboard(mypi,'Resolution','1280x720') // The command was called to create a camera connection board.

The shooting modes: brightness, illumination and size were chosen. Two shots were taken - one shot with the Line LASER diode, which is also connected and controlled by the Raspberry Pi and one shot without a laser (see Fig. 2), while the pictures were saved manually.

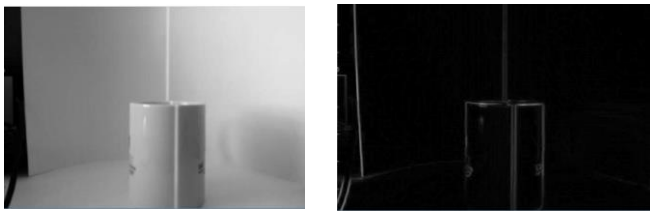
Since everything else in the camera's field of view remains unchanged, the difference between the two images should have given us all the points that lie on the Line LASER projected onto the object.

The received images (as shown in Fig. 2) have been saved for future use.



a b

Fig. 2. Images captured using the Raspberry Pi 3
a - without Line LASER diode, b - with Line LASER diode
.



a b

Fig. 3. Processed images
a - black and white digital image; b- magnitude of image gradient. Maximum value of gradient magnitude corresponds to maximum value of gray scale intensity.

B. Equations

Using the images taken on the Raspberry Pi3 platform through Matlab, the authors developed a new method for selecting lines. The algorithm uses a gradient technique of image processing. Therefore, below we give the used designations and the necessary explanations. The concept of a continuous image intensity function allows you to introduce into consideration an image function gradient $\vec{g}(x,y)$ (1), often referred to simply as an image gradient:

$$\vec{g}(x,y) = (g_x, g_y) = (\frac{\partial I}{\partial x}, \frac{\partial I}{\partial y}) \quad (1)$$

In practice, the image is discrete and the image derivatives ($\frac{\partial I}{\partial x}$ and $\frac{\partial I}{\partial y}$ functions) in the classical sense (as partial derivatives of the analytically given function) do not exist, therefore either their difference analogs are used or the image derivatives are calculated using some smooth approximation of discrete intensity function. There are many algorithms for calculating derived images and their software implementations. As well known, the gradient image processing technique is widely used for feature extraction [5-8]. Figuratively speaking, regions of an image containing features are characterized by high values of the gradient magnitude function $G(x,y)$ (1) (see Fig. 3):

$$G(x,y) = \left|\vec{g}\right| = \sqrt{g_x^2 + g_y^2} \quad (2)$$

Image gradient is a vector field. The two-dimensional vector field is defined by two vector fields (scalar functions of two variables) - $g_x(x,y)$ and $g_y(x,y)$. In software processing of the image, we calculated for each image pixel the e_x and e_y components of the gradient direction vector e $\vec{e} = (e_x, e_y)$ (3) and calculated for each grid point (i, j) the magnitude of the image gradient $G_{i,j} = G(i, j)$.

$$\vec{e}(x,y) = \frac{1}{G(x,y)} \cdot g(x,y) \quad (3)$$

Thus, the gradient field was defined by three 2 Darrays. In the description below of the algorithm for converting an image into a graph, we will call $\vec{k}$ a unit vector perpendicular to the gradient vector:

$$\vec{k} = (-e_x, e_y) \quad (4)$$

As is easy to see, vector $\vec{k}$ is just a result of 90° degree counterclockwise rotation of corresponding direction vector $\vec{e}$. Note also that the vector $\vec{k}(x_{0,}y_0)$ is a tangent vector to the isoline of the intensity function $I(x,y) = I_0$, where $I_0 = I\ (x_{0,}y_0)$.

The next important step of the algorithm is the shift of the vertices (and with them the segments - edges of the graph) in the direction of the gradient vector. Figuratively speaking, the purpose of the procedure is to move the vertex into the "middle point" of the laser strip. It is clear that the choice of the magnitude of the vertex displacement significantly affects the quality of the transformation procedure, so we give a detailed description below. Let us first define the restriction of the intensity function to the line: For a given point $M(x_{0,}y_0)$ and a normalized vector $\vec{e} = (e_x, e_y)$ we define the function $\varphi(S)$ by equation (5):

$$\varphi(S) = I(x_0 + e_x \cdot S, y_0 + e_y \cdot S) \quad (5)$$

Geometrically, the parameter *S* can be interpreted as the length of the path traversed from the point *M* in a straight line with the direction vector. We will assume that the function $\varphi(S)$ is defined on the ray $[0,\infty)-|$ and will call it the restriction of the function *I* to the ray with the vertex at the point *M* and the direction vector $\vec{e}$. For a given *S* and the number *N*, we can build a sequence of values $\{S_{1,}S_2,....,S_N\}$ evenly spaced on an interval $\prod 0,S$. Using a smooth approximation of the intensity function *I*, we can calculate the sequence $\{\varphi_{0,}\varphi_1,....,\varphi_{N-1}\}$ of the values of the function $\varphi\ \{\varphi_{k=,}\varphi(S_{k+1})\}$ and construct a piecewise linear approximation $\varphi^*(S)$ of the function φ, defined by(6).

$$\varphi^{\uparrow *}(S) = \varphi_{\downarrow}k + ((\varphi_{\downarrow}k+1) = \varphi_{\downarrow 0}k))/ \\ \tau \cdot (S - S_{\downarrow}k) if S \in [S_{\downarrow}k, S_{\downarrow}(k+1))-| \quad (6),$$

where $\tau = S/(N-1)$.

With a suitable choice of the value of *S*, the equation $\varphi^*(S) = \varphi_0$ has at least one solution (expect trivial solution *S=0*). Let's denote it by *S=L*, so $L \succ 0$ and $\varphi^*(L) = \varphi_0$

If there are *K* solutions $L_1, L_2, ..., L_K$, then $L = \min\{ L_1, L_2, ..., L_K \}$.

We will call the restriction of φ to the interval $[0, L]$ the profile of the laser strip (see Fig. 4).

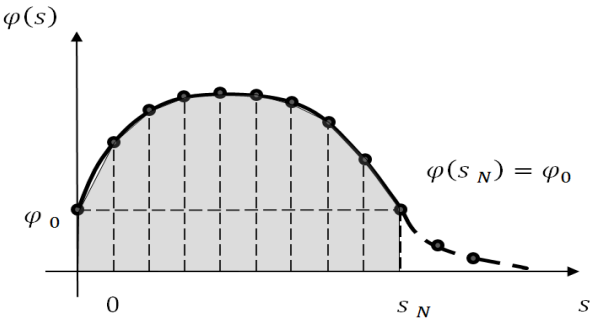


Fig.4. Schematic representation of the use of piecewise linear approximation to determine the displacement value

The main idea of calculating the amount of displacement in our proposed method is to calculate the center of gravity of the laser strip profile. Those, we calculate the value of displacement d according to formula (7).

$$d = \frac{1}{L}\int_0^L \varphi(S)dS \qquad (7)$$

The integral $\int_0^L \varphi(S)dS$ is calculated numerically, to find it we construct a new discretization of the function φ on the segment $[0, L]$. The procedure for building up the broken line representing the laser strip in the image is shown schematically in Fig. 5.

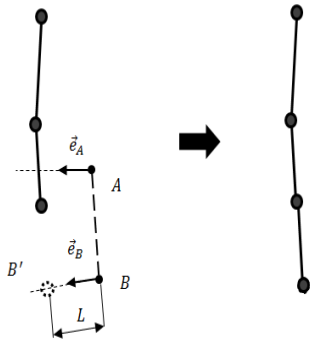


Fig. 5. Scheme of the procedure for constructing a broken line on the laser strip. AB is the region of gradient homogeneity transformed into a line segment. $\vec{e}_A$ and $\vec{e}_B$ are the direction vectors of the image gradient at the points A and B, respectively

This procedure is performed for each line segment obtained by converting the corresponding region of the gradient uniformity.

IV. Conclusion

The snapshots of images obtained on the Raspberry Pi platform were processed in Matlab using a new algorithm. The main feature of the proposed image processing algorithm is the detection of fragments of the curve, which can be approximated with sufficient accuracy by a straight line segment.

The proposed algorithm is adaptive and its application does not require a priori knowledge of the profile properties of the detected curves.

It has been established that the removal of the contour of the laser strip is the most important part of the three-dimensional measurement based on linear laser scanning, and its accuracy and reliability directly affect the performance of the system.

The results of the research are of significance for a wide range of researchers developing the image acquisition and processing algorithms.

Acknowledgment

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Aspects of Mission Planning for UAVs

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Abstract— **We can find several software applications for mission planning and execution of flight plans for UAVs (Unmanned Aerial Vehicles) on the market. Some of them are fully free or very cheap, others are working like services on monthly price basis and few of them have desktop versions with perpetual license. The main question is which software is useful for photogrammetric purposes and which are the most essential parts when planning a flight mission. The paper lists important photogrammetric aspects like flight height, ground resolution, image overlap, flight patterns, and expected measurement accuracy by following an example of a mission plan and execution carried out by the UgCS program.**

Keywords— **UAV, photogrammetry, mission planning, flight plan**

I. Introduction

In digital photogrammetry the Unmanned Aerial Vehicles (UAVs) are getting to play an important role thanks to their price, efficiency and sophisticated software applications and services. At the same time this rapid spread involves professionals form other disciplines and there is an increasing demand to get knowledge about the different solutions, possibilities and requirements to produce photogrammetric outputs and end products in good quality. The digital photogrammetric workstations (DPWs) face new challenges upon processing UAV imagery. This relatively new way of evaluation offers the possibility of automation of essential tasks of photogrammetry like interior and exterior orientation, digital terrain extraction and orthophoto production.

One of the most important problems is to plan and accurately accomplish flight missions with UAVs. During the mission planning we must consider several aspects, parameters and accuracy issues.

II. Important Aspects

If we decide to plan and carry out flight missions with UAVs, we need to consider several aspects including the following:

- Ground Sampling Distance (GSD)
- Contrast and measurability of points
- Height measurement accuracy (it depends on the base-height ratio)
- Accuracy of determination of ground control points
- Camera calibration accuracy
- Introduction of additional parameters

The GSD value can be calculated from the average photo scale and the pixel size. In order to calculate the average photo scale (S_{avg}), we must know the average flight height (H_{avg}) and the camera constant or focal length (c_k), see Eq. 1 and Fig. 1. [2]

$$S_{avg} = \frac{H_{avg}}{c_k} \tag{1}$$

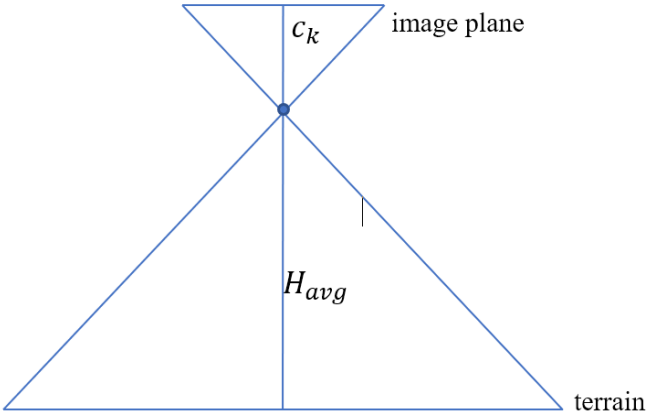

Figure 1. Projection of terrain to image plane

Based on the calculated S_{avg} and pixel size Δ_p, we can get the GSD value, in other words the ground resolution by the following equation:

$$GSD = S_{avg} \cdot \Delta_p \tag{2}$$

The GSD is an important parameter and usually this vlue is the starting point for planning the flight height and other mission parameters. Let's take an example. We intend to reach the GSD value as $5\,cm$. We know the focal length of our camera and its calibrated value is $3.7546\,mm$. The pixel size Δ_p equals $1.625\,\mu m$. Now our task is to plane the flight height. Substituting S_{avg} from Eq. 1. to Eq. 2. and expressing H_{avg}, we gain the following equation and result:

$$H_{avg} = GSD \cdot \frac{c_k}{\Delta_p} = 0.05 \frac{3.7546}{0.001625} = 115.5\ m$$

In UAV projects usually we use ground control points and these points are better being artificial signs. Besides the GSD, the size, form and colour of these signs will affect the measurability. Concerning the size, the main thumb rule is to use signs at least 10 times larger than GSD value. Which

means in our example of sign size of 50 cm. As you can see in Fig 2., the original sign even with a good contrast and suitable size can be hardly visible in photos. Therefore, it is a good strategy if we test several forms with different colours before we apply the signs in real projects.

Figure 2. Ground control point sign and its image

To keep in mind the GSD value is important from another aspect as well. The positional (horizontal) measurement accuracy can be estimated as 1/3 of GSD. Besides the GSD, the vertical measurement accuracy σ_Z also depends on the height-base ratio ($\frac{H_{avg}}{B}$) by the following equation:

$$\sigma_Z = \frac{GSD}{3} \cdot \frac{H_{avg}}{B} \quad (3)$$

The height-base ratio also affects the angle between the intersecting projection rays of stereo images and this angle affects the vertical measurement accuracy as well. As shown in Fig, 3, the same image coordinate uncertainties give different error ellipses around point P in object space [1].

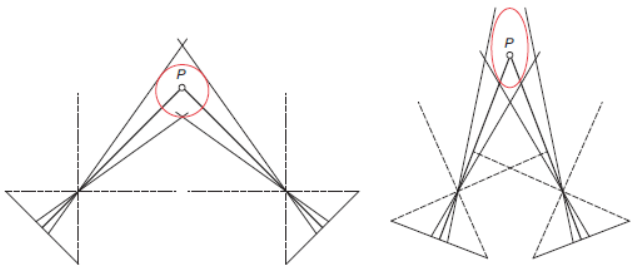

Figure 3. Intersection of projection rays

Based on these considerations, as an example, the maximum available vertical accuracy as a function of average flight altitude at 60% overlap and 1/3 base ratio equals 0.1 ‰. For example, at flight height of 115 m, the maximum attainable σ_Z=1.15 cm.

III. Some Examples

For the whole technological process when selecting a suitable UAV-serving application we should consider the following aspects to be fulfilled:

- Project Parameters (PP)
- Flight Plan (FP)
- Autonomous Aerial Survey (AAS)
- Data Quality Control (DQC)
- UAV Block Triangulation (UAV BT)
- DSM, Orthophoto, 3D Model (DO3D)

The software solutions dedicated for UAVs can be grouped into three categories:

- Programs for planning and execution of flight plans (PP, FP, AAS and sometimes DQC).
- Programs for evaluation of UAV imagery (UAV BT and DO3D).
- Programs for complete solution (mission planning, execution of flights and evaluation of images).

Let's see some example for these categories.

A. Litchi for DJI Mavic / Phantom / Inspire / Spark

The Litchi is very popular for its price and simplicity and it is ideal solution for mission planning and flight execution, but it is not designed primarily for photogrammetric purposes, although it is suitable for completing small projects [4].

Figure 4. Main screen of Litchi application

Among the operational types we can find useful functions as it is shown in Table I.

TABLE I.
FUNCTIONALITY OF LITCHI

Function/Mode	Useful for photogrammetry	Short description
FPV	No	It allows you to fly the aircraft manually using the joysticks.
Waypoint	Yes	It allows you to setup classic waypoint missions
Mission Hub	Yes	It lets you plan waypoint missions from a desktop or laptop PC
Follow	Not really	It causes the aircraft to follow the movements a subject.

Orbit	Yes	It causes the aircraft to circle around a point of interest while optionally having the gimbal keeping focus on it.
Focus	No	It allows you to easily keep a subject (Point of Interest or Mobile Device) in the video frame while flying the aircraft manually.
Panorama	Yes	It allows you to easily shoot horizontal, vertical and spherical panoramas.
Track	Only for special projects	It uses state of the art computer vision algorithms to track a selected object on the video preview and keep it in the frame.

B. Trimble Inpho UASMaster

It is a complete Photogrammetric Workstation for UAS and Terrestrial Close-Range Imagery based on well-known algorithms used in photogrammetry for 30 years (see Fig. 5.) The full orientation and evaluation procedure is based on photogrammetric concept and methodology. The software offers highly unified and automatic processes, but it also gives the user the possibility to setup the project parameters in flexible way relying on the photogrammetric engineering knowledge and know-how. With this application we can carry out the following tasks:

- Fully automatic geo-referencing, calibration, refinement and analysis.
- Creation of colorized dense point clouds, surface models and topographic terrain models.
- Creation of classical and true digital orthophotos.

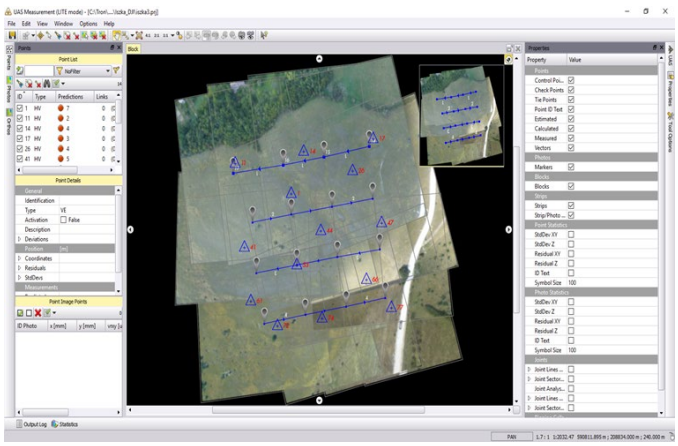

Figure 5. Measurement of tie and control points in Trimble UASMaster

C. Pix4D

Pix4D is a set of modules offering solutions not only for mission planning and flight control, but it also covers many end products and solutions (see Fig. 6.). Through the modular concept we can buy a software solution for the application areas of

- Surveying and Mapping
- Construction
- Agriculture
- Mining
- Public Safety

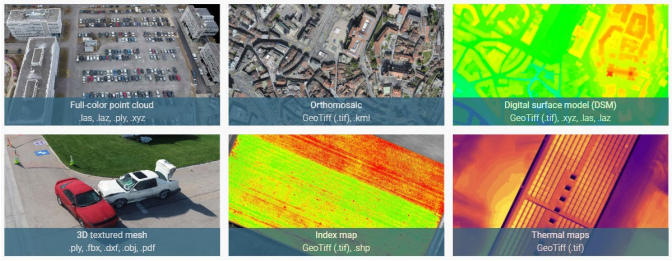

Figure 6. Possible export formats in Pix4Dmapper

In Table 2. we can see the different possible end products for each software module [3].

TABLE II.
PIX4D MODULES

Module	End products	Purpose
Pic4Dmapper	- Full-color point cloud - Orthomosaic - Digital surface model (DSM) - 3D textured mesh - Index map - Thermal map	Accurate 3D maps and models, purely from images
Pic4Dbim	- 3D point cloud - Classified point cloud - Orthomosaic - DSM - 3D textured mesh - Contour lines	3D mapping software for earthworks and construction management
Pic4Dfields	- Orthomosaic - DSM - Field boundaries - Vegetation index map - Zonation map - Prescription map	Advanced agriculture mapping software for aerial crop analysis and digital farming
Pix4Dreact	- 3D orthomosaic map - Markers and measurements - PDF report	2D fast-mapping for emergency response and public safety
Pix4Dmodel	- 3D mesh model - Fly-through video	Making 3D models from drone images

		has never been easier
Pix4Dcapture	Set of images captured by polygon, grid, double grid or circular trajectory plan	Free drone flight planning app for optimal 3D mapping and modelling

IV. Planning with UgCS

The UgCS (Universal Ground Control System) provides full functionality for planning and execution of UAV flight missions, The main functions of the program are

- Setup an UAV profile
- Camera setup
- Setup basic parameters
- Selecting the area
- Set flight and route formation
- Design of photogrammetric array of strips
- Flight simulation
- Upload flight plan to UAV
- Flight execution

Using this application, a project setup can be followed in this chapter.

A. Setup an UAV profile and the camera

UgCS recognizes many tapes of UAVs. The payloads as cameras can be selected for the given UAV. The UAV together with the selected camera can be saved as a profile and we can reuse it later referring to the saved profile (see Fig. 7.).

Figure 7. Building a profile form an UAV and a camera

For testing or for emulation we can select UAVs without connecting a real UAV to the application. This function is very useful for planning and flight simulation. Later on, we can change the UAV for a real one and we can execute a real flight with more safety.

B. Setup the basic parameters for the project

Before planning the detailed flight plan parameters like area, resolution and son on, we must setup first the basic project parameters which include the following (see also Fig. 8.):

- Project name
- Home location
- Maximum altitude
- Emergency return altitude
- Vehicle profile
- Altitude mode
- Trajectory type
- Action on emergency situation

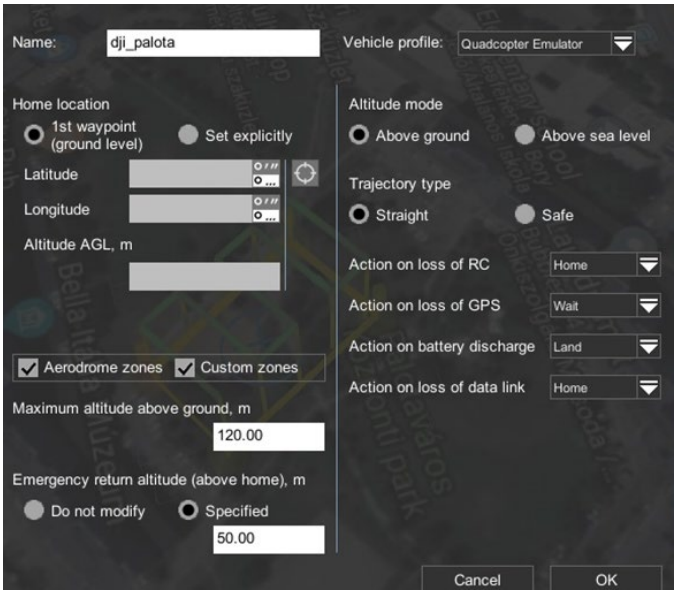

Figure 8. Setting up the basic project parameters

The home location is usually the first waypoint in our flight plan, but we can setup other location by geographic coordinates.

To setup all the other parameters is straightforward and logical.

C. Selecting the area and setup the photogrammetric array of strips

After setting up the basic project parameters we can start the planning of the photogrammetric flight plan choosing the photogrammetry tool. The first step is to pin the corners of the mapping area out. For this we can use the google Earth engine. Then we can setup the flight parameters including the desired GSD, the forward and side overlap, the flight speed, the turn type between the strips, direction angle of strips, altitude type (above ground level (AGL) or above mean see level (AMSL)) and many other parameters and options. In Fig. 9. we can see that the GSD is set to 3 cm and the forward and side overlaps

are 80%. These three parameters mainly determine the number of strips and the camera positions for shooting.

Figure 9. Setting up the photogrammetry tool parameters

The action in each planned waypoint is setup separately as it is shown in Fig. 10.

Figure 10. Setting up the camera action in each waypoint

After this the program calculate automatically the strips, the waypoints and shows it graphically in 3D. In Fig. 11. the lines indicating not only the strips but the flight direction as well. We can see the home position and the corners of the selected area. If we change the GSD or the overlap values, the program immediately changes the flight plan and we can decide which plan suits more our needs.

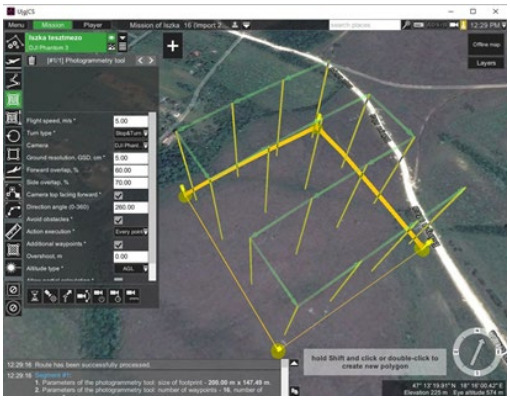

Figure 11. Photogrammetric block as a flight plan

D. Flight simulation and execution

We can simulate the flight and we can follow the elevation profile (see Fig. 12.) during the flight. If we are satisfied with flight result, then we must change the profile connecting a real UAV to the project. This connection is done automatically when switching on our UAV.

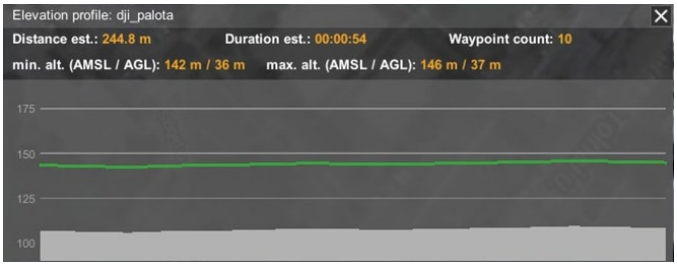

Figure 12. Elevation profile

After uploading the flight plan to the UAV, we can activate and start the real flight mission capturing all the necessary images for the photogrammetric evaluation.

V. Conclusions

As a summary we can say that a good mission planner software supports the autonomous flight in all steps. A wide selection of project parameters is a very important aspect and it helps to reach the maximum attainable accuracy during the aerial triangulation, the point cloud generation and the orthophoto map production. The UAS software market is developing very fast and hopefully it brings new, more sophisticated solution to the traditional aerial photogrammetry as well.

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Microcontroller Based Fuzzy Control System for Air Quality Controlling

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***Abstract*— Clean work environments and god air quality are essential for developing, manufacturing, constructing, maintaining products if the goal is that the employees work at high efficiency. Proper environmental parameters also can help a lot if the goal is to improve the effectiveness of the rest time. This paper is designed to control the parameters of enclosed airspace. By direct intervention in the measured parameters of the interior air and with the help of air exchange - if the parameters of the external atmosphere bring the parameters of the internal air space closer to the desired value - the internal airspace conditions can be optimized.**

Keywords — air quality, fuzzy control, fuzzy toolbox, s-function, embedded fuzzy controller, membership function, DS18B20, CO2 sensor, home automation, smart home

I. INTRODUCTION

Smart homes are all containing this feature, but smart homes are rear yet. Also nowadays a lot of houses and flats have got an air conditioning unit beside the controllable heating elements. Ventilation systems are less common, but it is easy to replace because of the low cost. Fig. 1. is showing a simple solution with a blower and an extractor ventilator. This cheap realization contains an easy to change air filter module. It is also possible to include a preheating element before the air filter, and a silencer element between the ventilators and the inner airspace.

The proposed solution primarily takes into account the temperature and humidity parameters of closed indoor airspace and the external airspace and measuring the carbon dioxide concentration of the internal airspace, which affects the control of the ventilation system.

II. SYSTEM DESCRIPTION

The measured parameter values are internal and external temperature, internal and external humidity, and internal carbon dioxide. The actuating elements are the heating element for increasing the temperature, the air-conditioning system for reducing the temperature - it also reduces the humidity. In addition to the above, the system also includes a humidifying element and an air exchange fan system.

A. System design

The system architecture can be seen in Fig. 2. The system has multiple inputs and multiple outputs (MIMO), the relationships between the parameters are non-linear, and there is an actuator whose activity also affects several input parameters, and the change of an input parameter also affects the output signals controlling several actuator elements. One way to solve these types of control tasks is to use Fuzzy controllers [1]. The controller was developed within the Matlab software package using the Fuzzy toolbox (Fig. 3).

Figure 1: Ventilation subsystem

B. Defining membership functions

The input membership functions were configured with trapezoidal functions, then formatted for type change(Fig. 4). This method is simple but appropriate because the proposed solution has got lot of simultaneously firing rules, and the control will be quite smooth. For the determination of the input membership functions, do not require a neural network.

Temperature limits were determined [2] based on the opinions of a small number of groups. For the determination of humidity, the optimal (for people) 40-60% range's boundaries were extended by ±10% due to the deviation of individual tolerance thresholds [3].

Values that were defining the membership functions of the internal temperature:

- • trapezoid – Cold: [-11 -11 5 20]
- • trapezoid – Ok: [10 20 25 30]
- • trapezoid – Hot: [23 40 51 51]
- • S gradual– Cold: [6.5 18.5]
- • Gauss – Ok: [6.158 22.25]
- • Z gradual– Hot: [24.7 38.3]

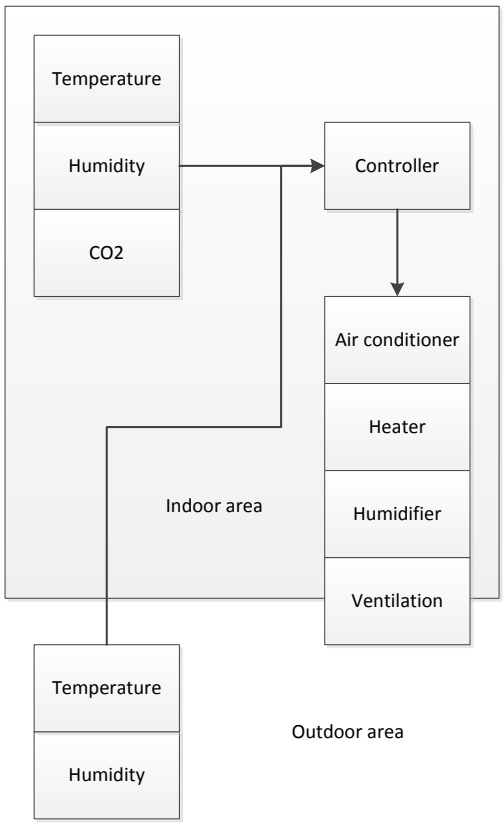

Figure 2: System architecure

The output membership functions are triangular [4], seen is Fig. 5. The output signals are generated at the fill factor of the actuator control PWM in the range from 0% to 100%.

C. *Creating rules*

It had been considered different groups when setting the rules [5] (see Fig. 6), as well as different weights had been given [6] for different rules:

- • It had been set the values of the heating and climate control output parameters based on the input internal temperature parameter (with lower weight)
- • It had been set the values of the climate and humidity control output parameters based on the input humidity parameter (with lower weight)
- • It had been set the values of the output parameters controlling the heating, climate, and ventilation based on the input external and internal temperature parameters
- • It had been set the values of humidity, climate, and ventilation control output parameters based on the input and internal humidity parameters
- • It had been set the values of humidity, climate, and heating control parameters based on the input temperature and humidity parameters

Based on the specified membership functions and rules [7], an illustration of the operation of the Fuzzy controller can be produced. Fig. 7 shows the output value for two input signals change, where the change within the allowed range (one output value can be displayed at one time). Also useful for checking the correctness of the regulation.

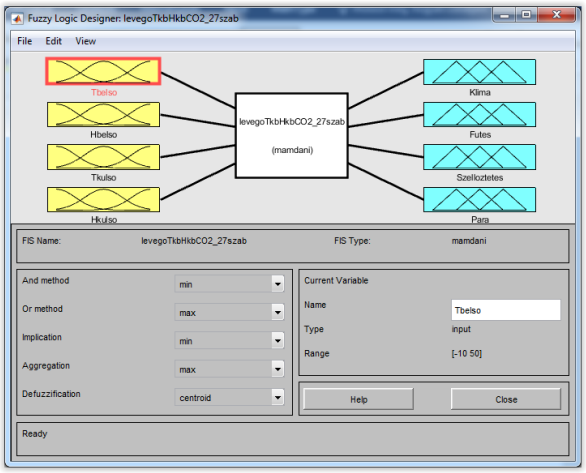

Figure 3: Fuzzy control toolbox

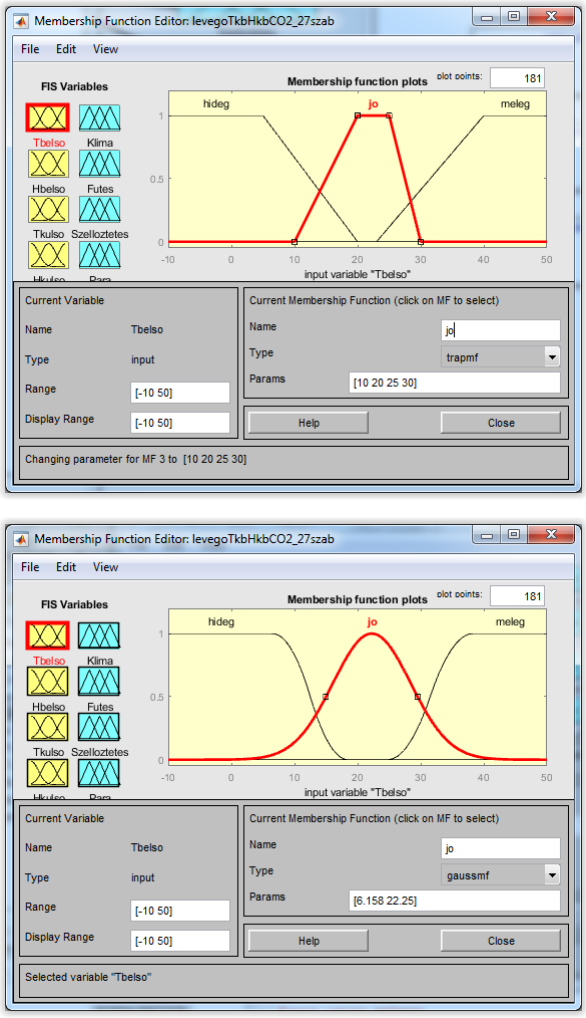

Figure 4: The internal temperature membership functions with trapezoidal and gradual transition

D. *Illustrating firing rules*

Based on the specified membership functions and rules, the operation of the Fuzzy controller can be emulated [8]. In the predefined range, firing rules can also be monitored for any level of inputs, and the output signals of their effect can be checked [9]. Fig. 8 show the output responses of the Fuzzy controller to various input parameters.

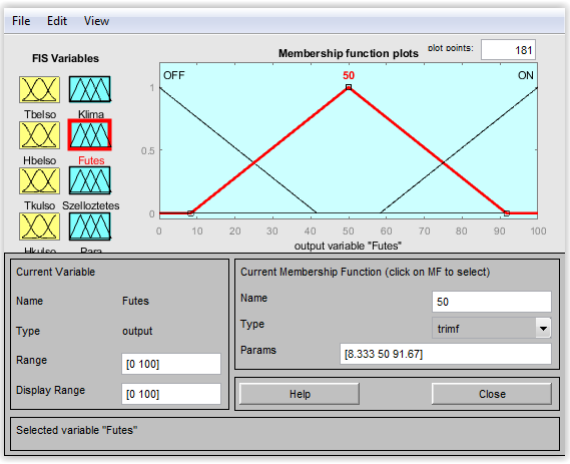

Figure 5: Example for the output membership function

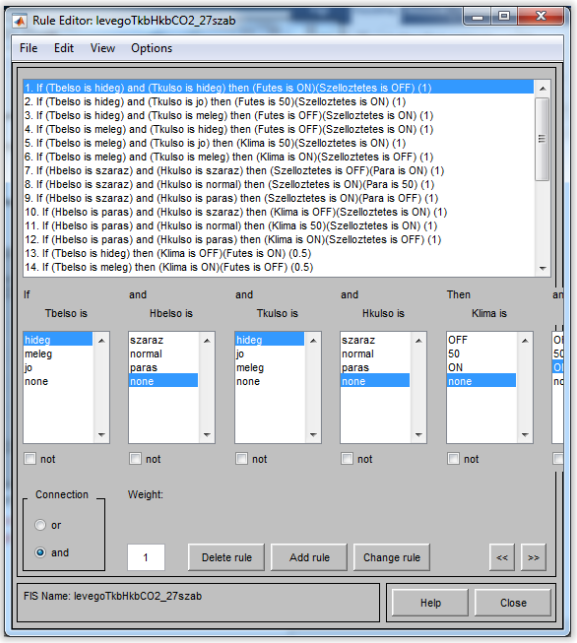

Figure 6: Illustration of the rules

III. Realisation

A. *Implementation in the development environment*

The system designed in Matlab Simulink is shown in Figure 9. In the left-hand side of the figure are the inputs; the inputs to the digital temperature sensors are on the upper part. Below are the pins used to measure analog humidity and CO2 concentration. The Fuzzy controller with multiplexed inputs and outputs is located in the center of the figure, and the PWM outputs used to control the actuators are on the right side of the figure.

The CO2 input influences the ventilation control's output through a feed-forward loop. Above a critical CO2 level, it activates the ventilation, and then deactivates it at a concentration below the critical level, creating hysteresis in the system.

B. *Realization with microcontroller*

Physical implementation was done using an AVR controller. Converting a Simulink-built model into a C / C ++ code was

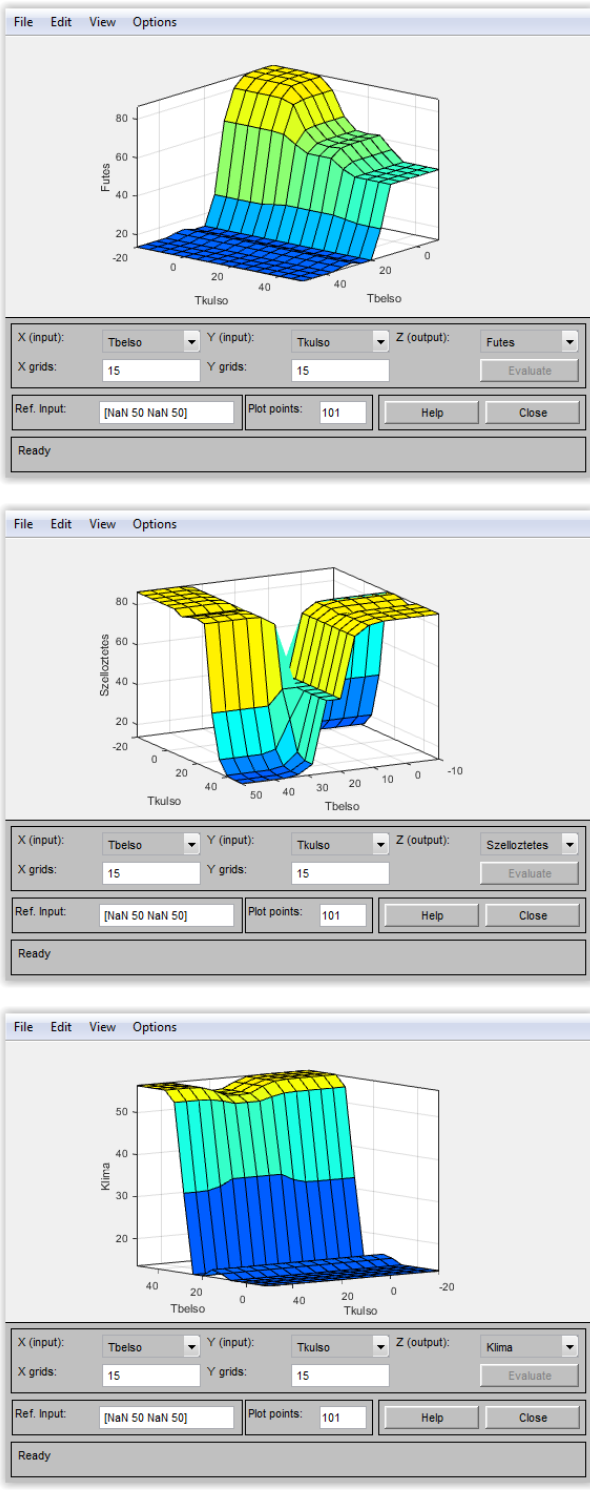

Figure 7: Changes in the values of Heating, Ventilation, and Climate Outputs as a function of internal and external temperatures

made using the Arduino toolbox that can be installed on the Matlab suite. The most critical parameters for translation and connection are the type of the development board / microcontroller and the communication channel parameters (see Figure 10). The applied controller must be memory sized appropriately to implement the generated code.

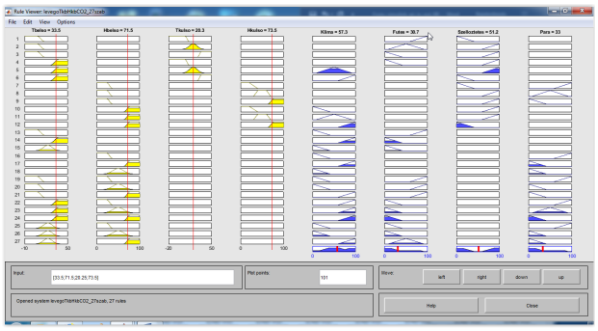

Figure 8: Illustration of firing rules and calculated outputs Beside high internal temperature and humidity under normal ambient temperatures, as well as higher internal than outer humidity

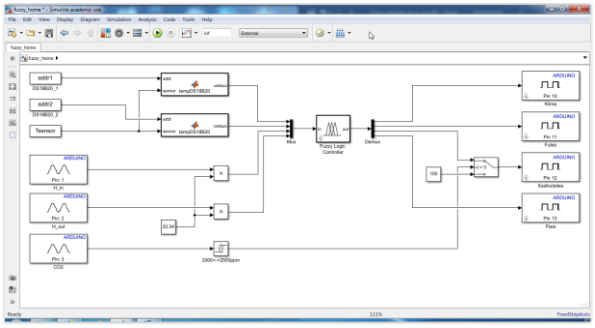

Figure 9: Realization in Simulink

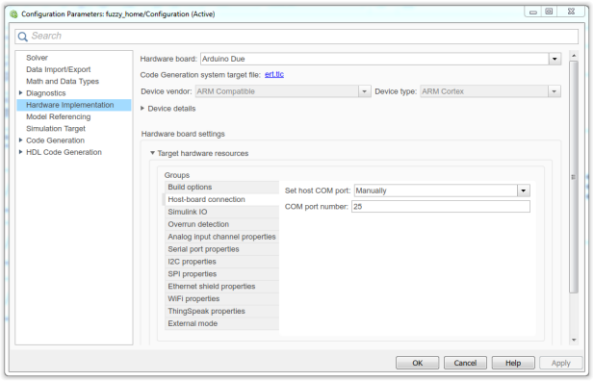

Figure 10: Realization in Simulink

IV. Sensors and Actuators

A. System-function

The protocol required to use the temperature sensor was implemented with the help of Matlab S-function. The value produced is in degrees of celsius, consistent with the input value range of the Fuzzy controller.

B. Temperature measurement

Measuring the temperature externally and indoors [10], a DS18B20 temperature meter integrated circuit was implemented. Block diagram is shown in Figure 11. The communication channel between the controller and the sensor is the 1-Wire Dallas bus, so the data cable must be connected to a digital leg. To ensure operation [11], the data bus must be equipped with a pull-up resistor. The measurement range is between -55 ° C and + 125 ° C, and the accuracy of the measurement is ± 0.5 ° C in the range of -10 ° C to + 85 ° C. Power supply voltage can be both of 3.3V and 5V voltage.

C. Humidity measurement

The humidity sensor [12] type AMT2001 (Fig. 13) has an analog output with a measurement range of 0% to 100%, with a range of output voltage between 0V and 3V. In the program - built in Simulink – the measured voltage is multiplied with a constant (33.34), to get the input range specified in the Fuzzy controller (0-100% RH). The accuracy of the measurement is ± 3%.

D. CO2 concentration measurement

The carbon dioxide sensor MG811 also has an analog output - see Fig. 14. The measurement range [13] is between 0ppm and 5000ppm, between 0V and 2V. Research shows that 3000ppm of CO2 concentration affects adversely mental and physical performance, so it must be ventilated above

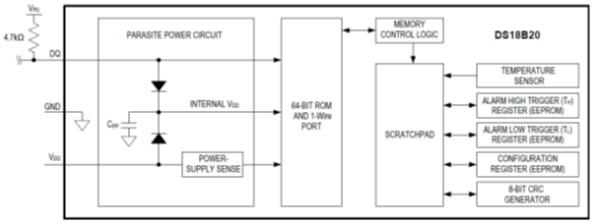

Figure 11: DS18B20 temperature sensor and internal block diagram

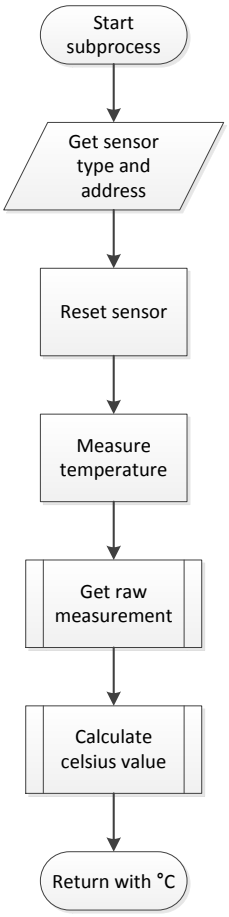

Figure 12: Matlab S-function flowchart

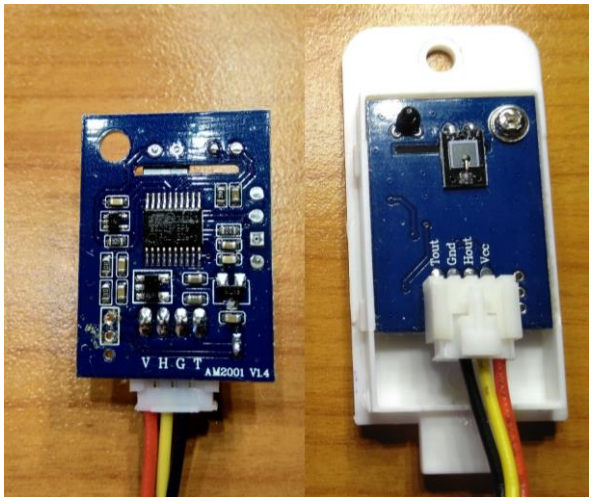

Figure 13: AMT2001 analog humidity sensor interior design

2500ppm. The corresponding analog voltage value is 1V. If the permissible reference level is exceeded [14], the output of the Fuzzy controller is shunted, and the ventilation is allowed at full speed. When the CO2 concentration is returned under 2000ppm, the control is given back to the fuzzy control system – to set a 500ppm hysteresis. [15] [16] [17] [18] [19] [20]

CONCLUSION

The controlling system made with relatively cheap electronic components and easy to implement software – if the user interface is well prepared –, therefore it is a cost-effective solution. It is a relatively low investment to expand the already existing actuators. The solution could also be useful if someone has a medical condition that requires them to keep the air clean in their homes. The proposed system architecture - as hoped by the author - could potentially be used for a variety of other applications.

ACKNOWLEDGMENT

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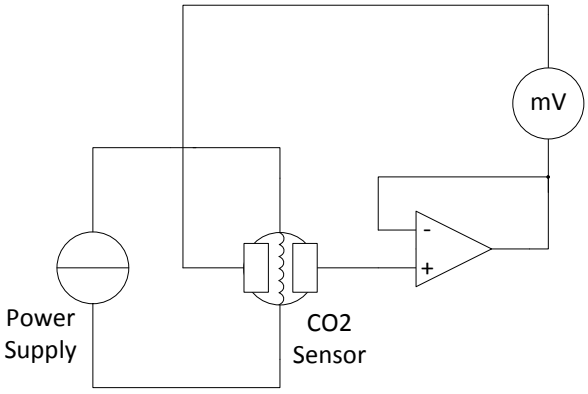

Figure 14: CO2 sensor and internal sensor structure

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Low-cost distance measuring methods and their investigation for BIM modeling

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***Abstract*— The purpose of the thesis is multifaceted. On one hand, I will investigate the feasibility of producing flat shapes that serve as the basis for different purpose BIM models, depending on reliability. On the other hand, I would like to examine separately the reliability of the various low-cost total stations nowadays, for such measurements. An earlier study dealt with the use of low-cost targets for laser scanning. In connection with this, an attempt was made to measure the extent to which the used styrofoam spheres available in decoration shops can be considered as perfect spherical shapes and whether they may have flatness.**

The purpose of the thesis is multifaceted. On one hand, we investigate the possibilities of producing flat profiles (flat surface, sphere), which are the basis of various BIM models, and their reliability. On the other hand, we would like to examine separately the various low-cost, so-called, low-cost the reliability of low-cost stations for such measurements.

Distance measuring was done with traditional total stations, laser scanner. Among the total stations, low-cost, conventional and mid-range total stations were tested. Of the low-cost, I used two of the same instruments to make sure they were free from any distance measuring errors.

The measurement of short distances at low-cost total stations was also investigated in the case of prismatic and prismatic measurement. In the former case, measurements were made on the wall, the styrofoam sphere, the styrofoam plane, the metal sphere, the signboard and the marble slab, while in the case of prismatic telemetry measurements were carried out at several angles on the mini Foif and Leica prisms.

An earlier study investigated the feasibility of using low-cost interfaces for laser scanning (4). In connection with this, there was an experimental measurement to determine whether the styrofoam spheres used as an interface point in decoration shops can be considered as a perfect spherical shape, and if there is any flatness. The result was a very noisy point cloud, which could not be examined by a smoothing sphere algorithm. The probable cause is the material of the sphere.

As a follow-up to the above-mentioned study, we studied the "behavior" of the spherical surface with distance measurement. The points on the spheres were measured from the four positions of a local network. The sphere is made of styrofoam and metal. For these two materials, two total stations, low-cost and mid-range, were measured. We used the equation sphere function calculated in Matlab to determine the fit of the points.

Low-cost instrument:

I. REMOTE MEASUREMENT ERRORS

Distance and angle measuring instruments were developed independently of each other. Their relationship has been and continues to evolve to this day. First, two separate structural units were involved in the measurements (stand-alone distance and angle measuring instruments), then telemeters mounted on the telescope or sub-telescope of the angle measuring instruments, finally the integration of the two structural units was technically resolved and electronic tachymeters were created, and later, with the help of the solution of field calculation and data recording, the measuring stations used today.

The additive constant is one of the most important errors in distance, which loads the same for all measurement results. The origin of the error is due to the construction of both the instrument and the prism.

$$t = t_m + c_m + c_p = t_m + c \quad ; \quad c = c_m + c_p$$

The instrument's constant depends on the frequency produced by the rangefinder, so this error is often referred to as frequency error. The cause of the error is that the instrument does not produce the fine measurement frequency that was designed, but a different value. Frequency determines the wavelength from the relation $\lambda = v / f$, ie. the wavelength of the measuring wave is not a multiple of the required international meter. The nature of the error is the same as when measuring with a tape measure if its length does not match its actual value in international meters.

II. TESTING THE ACCURACY OF RANGEFINDERS ON PRISMS

First of all, low-cost prisms were the first to be investigated; traditional; mid-range; with new mid-range stations at different distances, so that the circular prism is rotated in five degrees (0°, 5°, 10°, 15°, 20°) around its stationary axis. 0° represents the measurement arrangement where the direction is perpendicular to the surface of the prism. The prisms, located 1.5 meters, were measured three times in each degree in both telescope positions.

		0°		5°		10°		15°		20°	
		I.	II.	II.	I.	I.	II.	I.	II.	I.	II.
prism	1	1,590	1,500	1,499	1,545	1,588	1,598	1,588	1,579	1,498	1,498
	2	1,590	1,500	1,500	1,537	1,588	1,598	1,593	1,579	1,498	1,500
	3	1,590	1,500	1,498	1,535	1,589	1,598	1,588	1,578	1,499	1,498

Mid-range new instrument:

		0°		5°		10°		15°		20°	
		I.	II.	II.	I.	I.	II.	II.	I.	I.	II.
prism	1	1,499	1,501	1,500	1,499	1,499	1,500	1,499	1,499	1,499	1,499
	2	1,500	1,500	1,500	1,499	1,499	1,499	1,500	1,499	1,499	1,499
	3	1,499	1,499	1,499	1,499	1,499	1,500	1,500	1,499	1,499	1,499

Mid-range new instrument 2:

		0°		5°		10°		15°		20°	
		I.	II.	II.	I.	I.	II.	II.	I.	I.	II.
prism	1	1,499	1,499	1,499	1,499	1,499	1,499	1,499	1,499	1,499	1,499
	2	1,499	1,499	1,499	1,500	1,499	1,499	1,499	1,499	1,499	1,499
	3	1,499	1,499	1,500	1,499	1,499	1,499	1,499	1,499	1,499	1,499

It can be seen from the tables that for prism positions between 5° and 10°, the measurement is subject to a significant error of regularity, whereas it increases with the incidence angle and disappears.

For the low-cost instrument, it is striking that there was a large difference between measurements at one and a half meters. Therefore, we placed the III. five, six, eight and ten meters apart. The effect of the error decreased surprisingly as the distance traveled increased and then disappeared.

III. EXAMINATION OF PRISMATIC DISTANCE MEASUREMENT

The total station's distance meter was also tested on other surfaces after the prisms. First we measured the signboard, the flat styrofoam, and then the dark marble slab and wall. For these measurements we used a low-cost, traditional mid-range station.

The signal board was measured 1.5 and 30 meters from the low-cost total station. Similar to the prism measurement, it was measured by rotation in increments of 0° from 40° to 5° with ten repetitions and telemetry.

The results of the measurements obtained in tabular form are as follows:

		0°		5°		10°		15°		20°		25°		40°	
		I.	II.	II.	I.	I.	II.	II.	I.	I.	II.	II.	I.	I.	II.
geodetic target	1	1,517	1,517	1,521	1,523	1,527	1,529	1,535	1,535	1,541	1,538	1,543	1,546	1,556	1,570
	2	1,517	1,517	1,521	1,524	1,530	1,530	1,535	1,535	1,540	1,540	1,543	1,544	1,559	1,564
	3	1,517	1,517	1,521	1,523	1,529	1,530	1,535	1,535	1,539	1,537	1,543	1,545	1,557	1,566
	4	1,517	1,516	1,521	1,522	1,528	1,530	1,535	1,536	1,538	1,538	1,543	1,543	1,559	1,564
	5	1,517	1,517	1,521	1,522	1,529	1,530	1,535	1,535	1,538	1,538	1,543	1,543	1,559	1,564
	6	1,517	1,517	1,521	1,522	1,529	1,530	1,535	1,535	1,538	1,541	1,543	1,543	1,557	1,567
	7	1,517	1,517	1,521	1,521	1,529	1,531	1,535	1,536	1,538	1,541	1,543	1,544	1,557	1,564
	8	1,517	1,517	1,521	1,522	1,529	1,529	1,535	1,536	1,538	1,538	1,543	1,543	1,559	1,565
	9	1,517	1,517	1,521	1,522	1,529	1,530	1,534	1,536	1,538	1,538	1,543	1,544	1,557	1,566
	10	1,517	1,517	1,521	1,522	1,529	1,530	1,535	1,536	1,539	1,539	1,543	1,544	1,558	1,565

		0°		5°		10°		15°		20°		25°		40°	
		I.	II.	II.	I.	I.	II.	II.	I.	I.	II.	II.	I.	I.	II.
geodetic target	1	30,005	30,004	30,003	30,008	30,009	30,006	30,009	30,009	30,009	30,011	30,015	30,009	30,009	30,029
	2	30,005	30,004	30,003	30,008	30,009	30,006	30,009	30,009	30,009	30,011	30,015	30,009	30,009	30,029
	3	30,006	30,004	30,003	30,008	30,009	30,006	30,009	30,009	30,009	30,011	30,015	30,009	30,009	30,026
	4	30,006	30,004	30,003	30,008	30,009	30,006	30,009	30,009	30,009	30,011	30,015	30,009	30,009	30,026
	5	30,005	30,004	30,003	30,008	30,009	30,006	30,009	30,009	30,009	30,011	30,015	30,009	30,009	30,025
	6	30,005	30,004	30,003	30,008	30,009	30,006	30,009	30,009	30,009	30,011	30,015	30,009	30,009	30,025
	7	30,005	30,004	30,003	30,008	30,009	30,006	30,009	30,009	30,009	30,011	30,015	30,009	30,009	30,026
	8	30,005	30,004	30,003	30,008	30,009	30,006	30,009	30,009	30,009	30,011	30,015	30,009	30,009	30,026
	9	30,005	30,004	30,003	30,008	30,009	30,006	30,009	30,009	30,009	30,011	30,015	30,009	30,009	30,026
	10	30,005	30,004	30,004	30,008	30,009	30,006	30,009	30,009	30,009	30,012	30,014	30,009	30,009	30,026

With a mid-range total station for 1.5, 5, 30 meters:

		0°		25°		40°	
		I.	II.	II.	I.	I.	II.
geodetic target	1	1,505	1,505	1,509	1,509	1,509	1,509
	2	1,505	1,505	1,509	1,509	1,510	1,510
	3	1,505	1,505	1,509	1,510	1,511	1,510
	4	1,505	1,505	1,510	1,510	1,509	1,510
	5	1,505	1,506	1,510	1,509	1,509	1,510
	6	1,505	1,505	1,509	1,510	1,509	1,510
	7	1,505	1,506	1,510	1,510	1,510	1,509
	8	1,506	1,505	1,510	1,509	1,510	1,510
	9	1,505	1,505	1,510	1,510	1,510	1,510
	10	1,505	1,506	1,509	1,509	1,510	1,511

		0°		5°		10°		40°	
		I.	II.	II.	I.	I.	II.	II.	I.
geodetic target	1	5,001	5,001	5,002	5,002	5,004	5,004	5,005	5,005
	2	5,001	5,001	5,003	5,003	5,004	5,004	5,005	5,005
	3	5,001	5,001	5,003	5,003	5,004	5,004	5,005	5,005
	4	5,001	5,001	5,003	5,002	5,004	5,004	5,005	5,005
	5	5,002	5,001	5,003	5,003	5,004	5,004	5,005	5,006
	6	5,002	5,002	5,003	5,002	5,004	5,004	5,005	5,005
	7	5,001	5,001	5,003	5,002	5,004	5,004	5,005	5,006
	8	5,001	5,001	5,003	5,003	5,004	5,004	5,005	5,005
	9	5,001	5,001	5,002	5,003	5,004	5,004	5,005	5,005
	10	5,002	5,001	5,003	5,003	5,004	5,004	5,006	5,005

		0°		5°		10°		15°		20°		25°		40°	
		I.	II.	II.	I.	I.	II.	II.	I.	I.	II.	II.	I.	II.	I.
geodetic target	1	30,004	30,004	30,005	30,006	30,007	30,006	30,006	30,007	30,008	30,006	30,007	30,008	30,007	30,007
	2	30,004	30,004	30,004	30,005	30,006	30,005	30,006	30,007	30,007	30,006	30,007	30,008	30,007	30,007
	3	30,004	30,004	30,004	30,006	30,007	30,006	30,007	30,008	30,007	30,006	30,007	30,008	30,007	30,008
	4	30,004	30,004	30,005	30,006	30,007	30,006	30,007	30,007	30,007	30,007	30,007	30,008	30,008	30,008
	5	30,003	30,004	30,004	30,006	30,007	30,006	30,007	30,008	30,008	30,007	30,007	30,008	30,008	30,007
	6	30,004	30,004	30,005	30,006	30,007	30,006	30,007	30,008	30,008	30,006	30,007	30,008	30,008	30,008
	7	30,004	30,004	30,005	30,006	30,007	30,006	30,006	30,007	30,008	30,006	30,007	30,008	30,008	30,008
	8	30,004	30,004	30,005	30,006	30,007	30,006	30,007	30,007	30,008	30,007	30,007	30,008	30,007	30,008
	9	30,004	30,004	30,005	30,006	30,007	30,006	30,007	30,007	30,008	30,006	30,007	30,008	30,007	30,008
	10	30,004	30,004	30,004	30,005	30,007	30,005	30,007	30,007	30,008	30,007	30,007	30,008	30,007	30,008

It can be seen from the table that the difference in the distance between the two face and the angle of incidence is smaller than in the previous case.

With a conventional total station 1.5 meters:

		0°		5°		10°		15°		20°		25°		40°	
		I.	II.	II.	I.	I.	II.	II.	I.	I.	II.	II.	I.	I.	II.
geodetic target	1	1,504	1,503	1,506	1,507	1,507	1,508	1,510	1,509	1,510	1,511	1,511	1,513	1,514	1,514
	2	1,504	1,504	1,506	1,506	1,507	1,508	1,511	1,510	1,510	1,511	1,511	1,512	1,516	1,515
	3	1,503	1,503	1,506	1,506	1,506	1,507	1,511	1,509	1,510	1,510	1,511	1,512	1,515	1,514
	4	1,505	1,504	1,505	1,505	1,507	1,508	1,510	1,509	1,511	1,511	1,510	1,511	1,514	1,515
	5	1,504	1,504	1,505	1,505	1,507	1,507	1,510	1,509	1,510	1,510	1,511	1,511	1,515	1,514
	6	1,504	1,504	1,505	1,506	1,507	1,507	1,509	1,509	1,510	1,511	1,512	1,512	1,517	1,518
	7	1,504	1,504	1,505	1,506	1,507	1,507	1,509	1,509	1,511	1,510	1,511	1,512	1,515	1,514
	8	1,504	1,505	1,505	1,506	1,507	1,507	1,509	1,509	1,510	1,511	1,512	1,512	1,515	1,514
	9	1,504	1,505	1,505	1,505	1,508	1,507	1,509	1,509	1,510	1,510	1,512	1,511	1,517	1,516
	10	1,504	1,505	1,505	1,506	1,507	1,508	1,509	1,510	1,510	1,511	1,511	1,511	1,516	1,515

Dark marble surface 5, 10, 15, 20, 25, 30 meters I and II. telescope measurements were made with low cost and conventional total stations.

		II.	I.	I.	II.	II.	I.	I.	II.	II.	I.	II.	I.
marble	1	5,107	5,075	10,219	10,035	15,189	15,254	19,886	20,066	25,117	24,870	29,797	30,182
	2	5,108	5,075	10,219	10,035	15,189	15,154	19,885	20,066	25,117	27,870	29,797	30,182
	3	5,116	5,076	10,219	10,035	15,189	15,255	19,887	20,065	25,117	30,870	29,798	30,183
	4	5,109	5,078	10,219	10,036	15,189	15,255	19,886	20,065	25,117	33,870	29,796	30,183
	5	5,107	5,079	10,219	10,034	15,189	15,254	19,886	20,065	25,117	36,870	29,798	30,182
	6	5,109	5,076	10,219	10,034	15,189	15,254	19,886	20,065	25,117	39,870	29,797	30,182
	7	5,108	5,078	10,219	10,033	15,189	15,255	19,886	20,065	25,117	42,870	29,797	30,183
	8	5,109	5,079	10,219	10,034	15,189	15,255	19,886	20,065	25,117	45,870	29,797	30,183
	9	5,110	5,079	10,219	10,034	15,189	15,254	19,886	20,065	25,117	48,870	29,797	30,182
	10	5,110	5,077	10,219	10,034	15,189	15,254	19,886	20,065	25,117	51,870	29,797	30,182

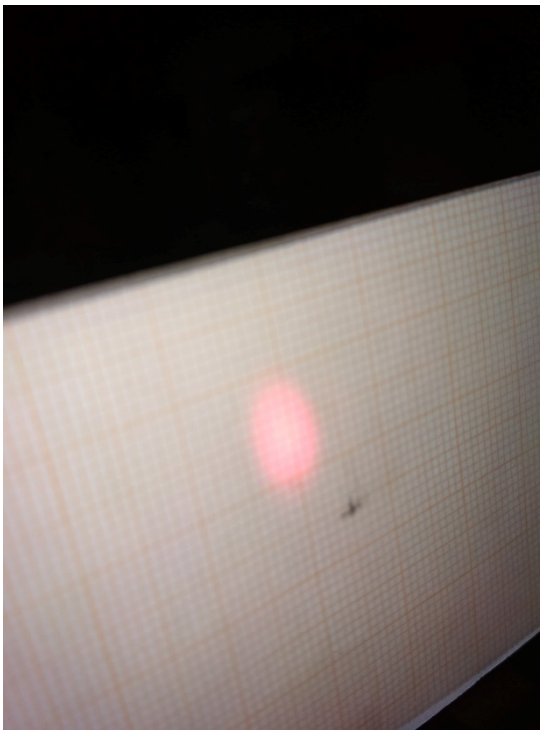
The wall surface was measured with a low cost and conventional measuring station at distances of about 4, 10, 15, 20, 25, 30 and 35 meters.

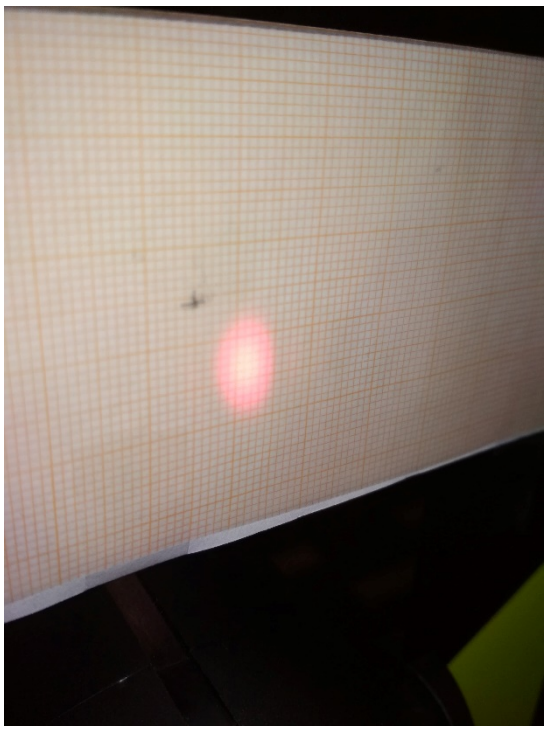
		I.	II.	II.	I.	I.	II.	I.	II.	II.	I.	I.	II.	II.	I.
wall	1	3.844	3.845	9.773	9.775	15.284	15.275	19.837	19.834	24.973	24.980	29.772	29.687	34.099	34.113
	2	3.844	3.843	9.773	9.780	15.285	15.275	19.837	19.835	24.974	24.974	29.698	29.689	34.085	34.111

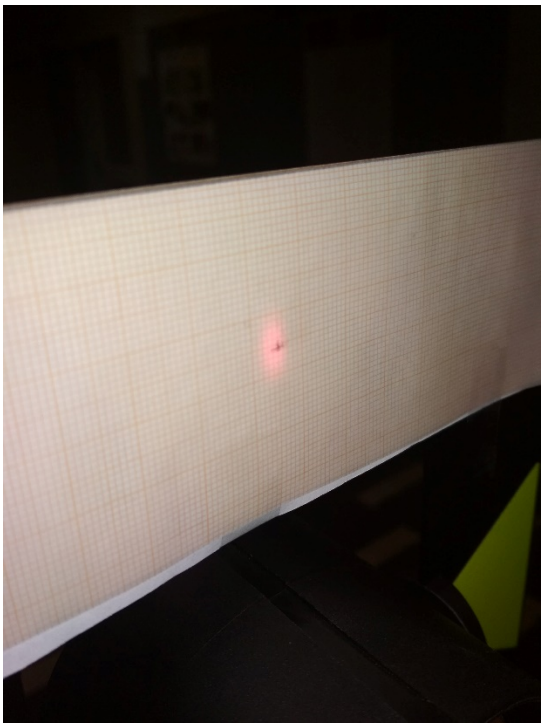
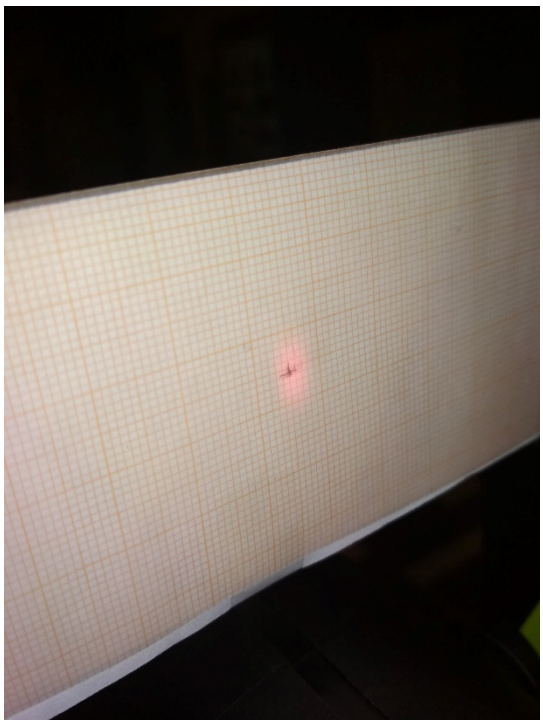
		II.	I.	I.	II.	II.	I.	I.	II.
wall	1	3.843	3.842	9.776	9.779	15.289	15.269	19.825	19.867
	2	3.844	3.844	9.769	9.789	15.288	15.270	19.809	19.874

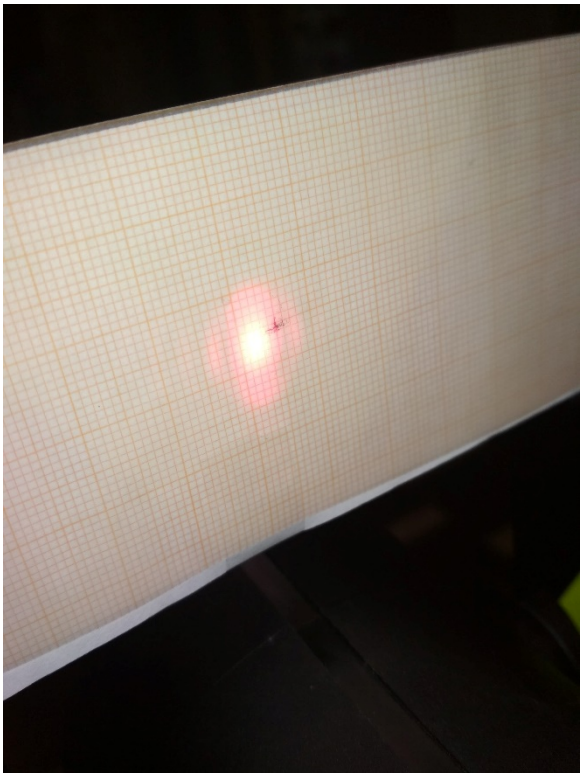
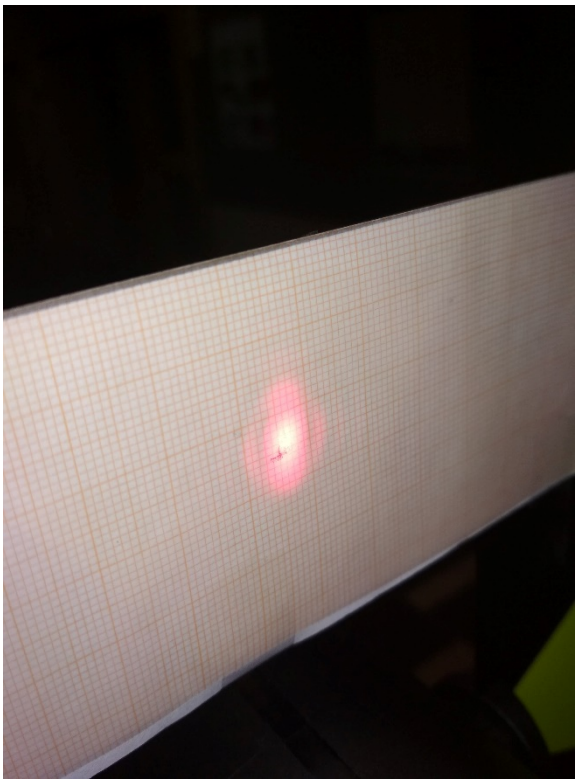
Examining the significant differences between the first and second telescope positions, we concluded that the telescope's orientation diverges from the laser. To test this, we measured on millimeter paper on two face at thirty meters distance, and the result can be seen in the following figures for the various instruments:

Low-cost total stations





Convetional total stations	
	

Mid-range total stations	
	

It can be seen from the diagrams that for some instruments the bearing and distance measurement are not centered, with a rough error. The effect of this is especially significant when measuring non-flat surfaces. Such is the measurement of the spherical surface described below.

IV. EXAMINING THE SPHERE AS A SIMPLE GEOMETRICAL TARGET

As one of the simplest target, the sphere has proven to be useful for connecting laser scanned point clouds. (4) However, if you want to use it as an interface, it is essential for larger networks to be able to define it as an interface. An example of such a network is the survey of the temple of Taransetmaria, which used factory sphere interfaces (3). However, if we want to include spherical targets in the measurement of the local area network, we need to be able to perform measurements similar to those of the scanners, sometimes with non-ideal measurement arrangements. Such tests were performed on styrofoam and metal spheres. The test measurement was performed with a low-cost and mid-range station. The spheres were placed in the center of the room, which was measured from the four points of the local area network. The points to be measured on the spheres are numbered for unambiguous identification. Only points that were clearly identifiable from the given position were measured when the angle of incidence was favorable. The network was adjusted, although we did not have classical superfluous measurements for the test points, since they could only be determined from one or maximum of two stations.

The reliability of the spherical points was ~ 2mm.

There are many references in the literature to fitting the regression sphere (1). We performed our calculations in a Matlab environment. We used a least-squares sphere fitting based on Alan Jennings's (2011) source for detail points (2). The algorithm minimizes the square sum of the radial deviations during the sphere fitting.

$$\sum((x - xk)^2 + (y - yk)^2 + (z - zk)^2 - r^2)^2 \rightarrow min$$

Where xk, yk, zk is the center of the smoothing sphere, while r ^ 2ann has the radius.

After fitting the sphere, we investigated the residual radial inconsistencies and calculated the distance of the measured points from the surface of the smoothing sphere, thus qualifying the reliability of the measurement and the fitting of the regression sphere.

The result of the calculation for a silver-plated sphere is: the mean of the absolute values of the differences is 7mm, while the standard deviation is larger, about 9mm. The radius of the adjusted sphere is 60 mm.

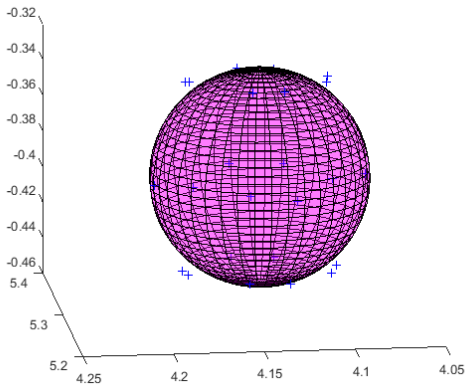


Figure 1. Measurements on the silver sphere and the balancing sphere

During the measurement on the styrofoam, we also found a point with a gross error, presumably due to the error of the telemetry, which was omitted from the calculation. For this type of anchor point, the mean of the absolute values of the deviations is 5 mm and the standard deviation is 6 mm. The radius of the adjusted sphere is 71mm.

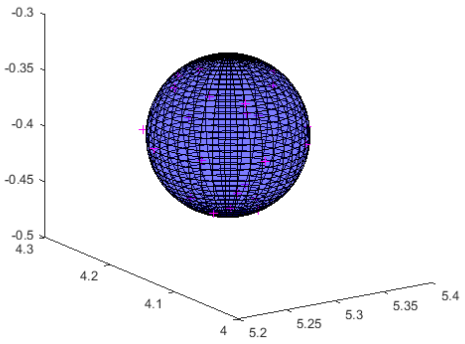


Figure 2. Styrofoam sphere measurements and balancing sphere

Overall, for both interfaces, the definition is significantly higher than the expected values for the interface. At the same time, measurements were not made with an ideal measurement layout.

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Concept and implementation of a smart mirror

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***Abstract*—In recent years, we have seen various smart devices penetrate most aspects of our lives. These devices connect to the internet and sometimes to other devices in order to offer features otherwise not possible. One of the areas in which these devices have yet to earn widespread adoption is the bathroom. Our goal is to create a smart device that can fill this role, a mirror that can identify its users and display relevant information through a display. While the idea of a smart mirror is not new, we believe we can offer new functionality via state-of-the-art facial recognition, and innovative features. In this article, we will discuss the current state of the project, our methodology in the various measurements and the implementation of modern technologies, as well as our aims for the future.**

Keywords: Face recognition, Intelligent systems, Smart device, Mirror

I. INTRODUCTION

Smart devices are becoming a part of our everyday life more and more. Most people use smartphones and other linked devices to optimize their time usage and lifestyle, living in synergy with the connected world. As smart devices are a common occurrence now, smart technologies started to appear in buildings, especially in homes, to be a part of this interconnected phenomenon that is called Internet of Things. This interconnectedness in smart homes was the theme of the article of Vincent Ricquebourg et al [1] .

One territory in the smart home landscape is still relatively uncharted. Many big brands filed patents related to smart mirrors as shown on timeline in Figure 1, but only small companies and startups have available products.

During the survey of related works many projects used similar hardware and software components:

B. Yuga Vamshi et al. envisioned an appointment alert system combined with a smart mirror [2].

Another, similar smart mirror system was described in the article of Abhishek Pathak et al [3].

Some of the inner workings of the OpenCV framework were described in the article of Piyush Maheshwari et al. [4] and Pranul S. Chheda et al. [5]

The goal of the present paper was to establish a smart mirror system, to assess the level of light transmission and to test the efficacy of face recognition in the present system.

Fig. 1 The timeline of smart mirror related patents.

II. METHODS

Light Transmission. In order to achieve an essential "floating image" look in our mirror, the light from the

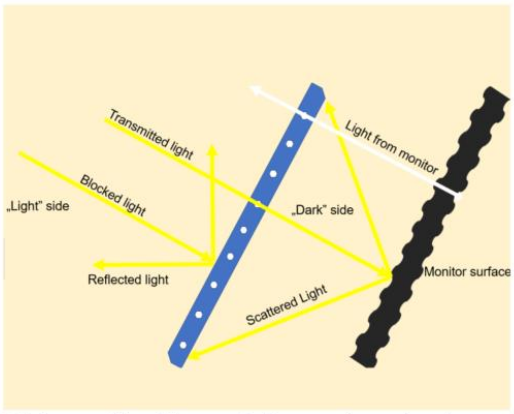

Fig. 2 The inner workings of the presented two-way mirror and monitor assembly.

display needs to penetrate the reflective material on the acrylic sheet. The inner workings of the mirror assembly is shown on Figure 2. A two-way mirror with a reflective coating that has many microscopic holes which allows light from both sides to pass through can be purchased from numerous sources, however, no information was provided about the ratio of the surface area of the light-transmitting holes to the light-reflective coating. This is crucial in determining the feasibility of this project.

If the coating blocks too much light from the monitor, the image will be too dim to see, and the opposite is also true.

Experiment 1:

Measuring light transmittance of the two-way mirror.

For this measurement, a photoresistor was used, and was attached to the surface of the monitor and the mirror using black electrical tape in order to eliminate environmental light. The electrical resistance of the photoresistor was then on both the monitor and the mirror at various color temperatures. Two different digital multimeters were used to carry out these measurements.

Face Recognition. The OpenFace open source project based on FaceNet was used for the face recognition part of the mirror. FaceNet and the OpenFace implementation uses a Deep Learning Convolutional Neural Network (CNN) to produce a 128-dimensional vector representation of a person's face. The overview of the facial recognition pipeline is shown on Figure 3. This differs from other attempts at face recognition using CNNs because the CNN is used for representation, not classification, thus it offers several advantages. Adding users to the dataset does not requires the network to be re-trained and as the representation is a vector, simple Euclidian subtraction can be used to compare faces, and adjusting the distance threshold can be used for fine-tuning the sensitivity of the classification.

Additional Technologies. Theoretically, OpenFace could be used with images captured from the camera directly, however, as it is the case with many Neural Network based applications, large input dimensions will quickly lead to memory and execution time limitations. While OpenFace is the backbone, in order to implement a real-time face recognition pipeline, other technologies, such as OpenCV, an open-source computer vision library initially developed by Intel would need to be utilized. OpenCV not only provides an easier way of accessing video feed from the camera but offers some powerful algorithms such as Haar Cascade.

Haar Cascade is an object detection algorithm. It searches for high contrast, or Haar-like features, in an input image. By using a pre-defined feature set designed for detecting human faces, the position of the face in the image can be determined and then cropping the image reduces the computational complexity of the CNN. Haar Cascade is very fast on modern hardware, mostly due to its cascading process. It divides the image into many smaller frames and looks for matching elements to the pre-defined features. This search for features is done in increasing complexity, so the algorithm quickly disregards those frames that do not match with the features it seeks.

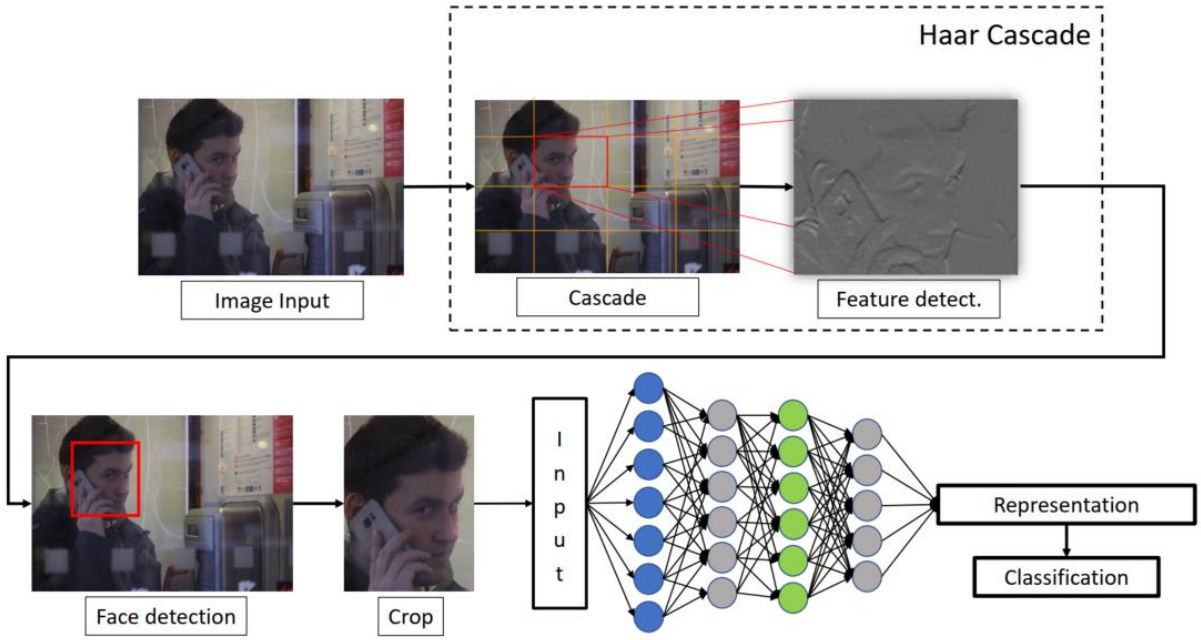

Fig. 3 The overview of the facial recogntition pipline.

In order to establish the efficacy of the face-detection algorithm, three additional experiments were also established.

Experiment 2:

The following experiment measured confidence value, the percentage which shows how sure the system is about the user's identity was used to collect data. For each user 20 pictures were provided as suggested in the paper of

Piyush Maheshwari [4]. The data collection was performed under constant light intensity, with up to 8 users.

Experiment 3:

To establish differences between different faces, confidence values were gathered in 5 different users under constant circumstances. The measurements were repeated ten times in a random order.

Experiment 4:

In order to establish the effect of the unknown image number, a systematic data collection was performed to assess the practical limit of recognition in the present setting. At each level, the data collection was repeated ten times, in a random order.

Statistical analysis. Statistica 7.0 was used to analyze datasets. A General Linear Model (GLM) was used to assess the effect of the size of the Unknown datasets. Newman-Keuls post hoc comparisons were run to establish differences between groups. The level of significance was set at p=0.05.

III. Results

Experiment 1:

The gathered values of the two-way mirror's transmittance were promising. The mirror's measured average light transmittance was 20.3%.

Experiment 2:

As Figure 4 shows that with two registered users an average confidence of 98.4% was measured, and 3 users provided an average confidence level of 95.05%. The number of users was increased to 8. Also presented on Figure 4 the confidence value of the tested user dropped significantly, down to an average of 73.69% and even lower when we introduced the so-called Unknown user. At this point the average confidence value was 67%.

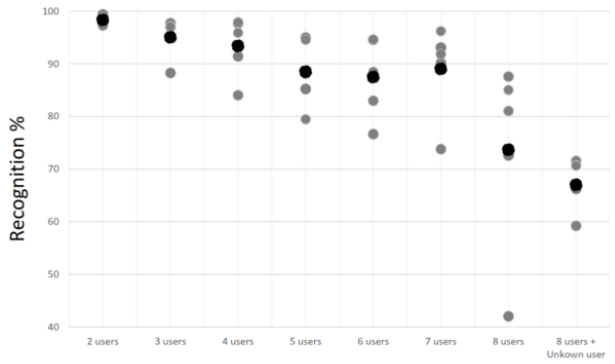

Fig. 4 Face detection success of one user with increasing number of user profiles. Black dots represents the average of 5 measurements.

Experiment 3:

In this scenario, confidence values of 5 different users were recorded. Data are shown on Figure 5. Huge interindividual-differences can be noticed. User E shows higher divergence which was likely the result of producing images with varied facial expressions during the session.

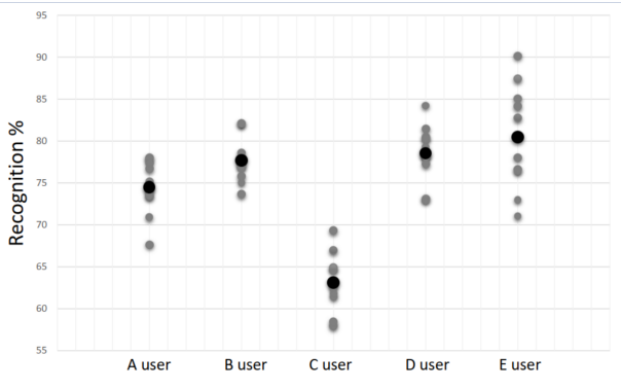

Fig. 5 Face detection success of a consecutive pool of five people, each users was measured 10 times. Black dots represent the average of 10 measurements.

Experiment 4:

The next step was to fine tune the size of the Unknown user's dataset. With every new picture a new human face was introduced into the dataset making it more ambiguous in the process. Hoping that this would increase the confidence values when dealing with more users, as the system can utilize the Unknown user as a reference point to a generic face.

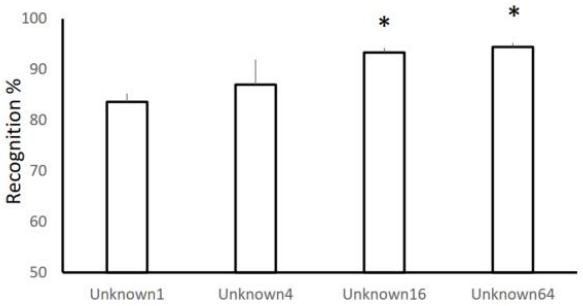

Fig. 6 Face detection success of a consecutive pool of five people, with increasing number of unknown faces. *, significantly different (p<0.05) from the smallest unknown number group revealed by General Linear Model and Newman-Keuls post hoc analysis.

Figure 6 shows that after introducing more and more faces to the Unknown user's dataset the upper and lower bounds started to raise, which was the desired effect.

IV. Discussion

The main findings of the present study were the followings. First, with the described hardware and software solutions, a smart mirror system could be outlined. The light transmission was dependent on the measured setup and the color heat and was about 20 %. The face detection was successful and provided useful information sets.

Experiment 1:

For the sake of accuracy, two different instruments were used, which turned out to be important as the measuring limit had to be changed on one of the devices after the value of the resistor surpassed 20 kilohms, resulting in reduced accuracy. Unfortunately, no data were described according to the light transmission within the patents and the published smart-mirror systems, but we suppose similar trends in those descriptions.

The following experiments were needed to evaluate the accuracy, performance and scalability of face recognition technologies suggested by other projects. Many of the projects we found during the survey did not discuss these topics. OpenFace and OpenCV was chosen because the surveyed projects seemed to prefer this framework.

Experiment 2:

The concept presented in this article was imagined as a piece of technology that can be used by the whole family. On an average there are 2.36 people in a Hungarian household as of 2011 [6] and 2.53 people in an average household in the United States as of 2018 [7]. As shown on Figure 4, these values show that this system is more than adequate for a family of 3. The number of users was further increased to represent a dormitory like use case with a shared living room.

Experiment 3:

During the data gathering many facts have been established about how a standardized dataset of a user must be created. In this scenario one picture was created with the user looking directly in the camera and other 8 was created with them looking in the 8 directions of the compass.

It has been established that this type of facial recognition technology is affected by numerous factors. Users who wear glasses need two sets of pictures with and without glasses. Users should keep a straight face during registration as smiling and other facial expressions can influence confidence values.

Experiment 4:

Experiment 2 made it clear that the face recognition solution implemented here loses confidence in the recognition beyond 2 users. To counteract the negative effect of more users, an Unknown user was added. Including more faces as an Unknown user shown that it is possible to reduce deviance this way.

Acknowledgment

The authors declare no conflict of interest. The authors would like to express their gratitude to those who have provided their help in the various experiments.

CONCLUSIONS

Smart mirror concept in general and the present smart mirror concept extend our knowledge on smart home concepts in a specific way and enhance our capabilities for using a combination of technologies extending user-friendliness on one side and practical implementation on the other side. Further data collection is required to optimize the solution that can induce a practical breakthrough in the field in terms of everyday usage.

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Analog Displaying of Digital Quantities

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***Abstract*—Everyone looked at his traditional, dial face, watch and then asked what time it was, and then had to check his watch again to get a numeric value. The phenomenon is scaled with a simple, learned reflex, and instead of 13 hours 16 minutes our brains sense a quarter-two. What's more is how much time we have so far or how much time has passed.**
For some engineering applications and in everyday life, it is better to use an analog display. The advantage of this display is that with less effort, simple, learned reflexes allow one to determine value.
Not to mention that in such focused jobs - pilots, high-complexity industrial systems - analog display is also more appropriate based on the above considerations.

I. Introduction

We came to this article with some emotional consideration and respect for the old electronic instruments [3] [2]. There are many electronic devices in our environment that routinely display in digital-mode, LCD, LED, or any other seven-segment or decimal mode.
As a starting point, we have set the goal that these devices, as one hand they are usually manufactured in large series, are very cheap or other hand already work well as part of a system, so that we can achieve an analog display without modifying the device itself [10]. In this case, the analog display is performed with a conventional Deprez instrument [8] [9].
In order to accomplish the stated purpose, conventional digital instrument is equipped with special digital-to-analog (DAC) converters that can perform analog display without changing the original equipment (Fig. 1). Of course, it is necessary to make the right scale of instruments [16] [15].

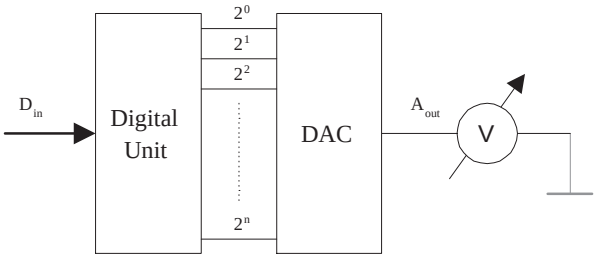

Fig. 1. Adapt Digital-Analog Converter to replace existing digital display, and connection of a Deprez instrument.

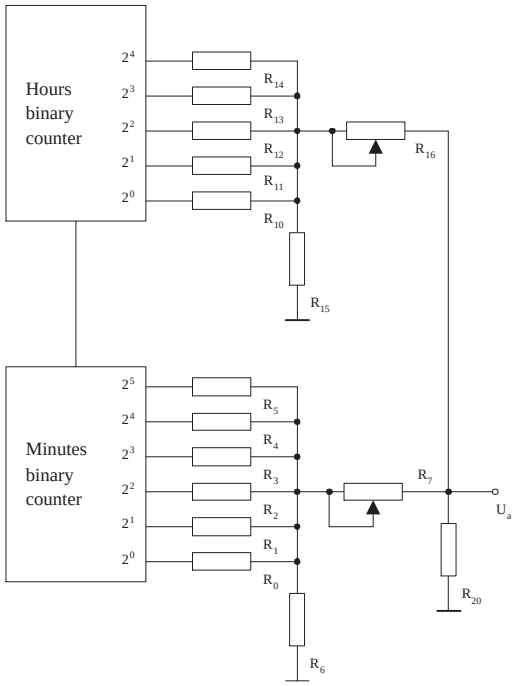

Fig. 2. Special application of the proposed procedure for one instrumented hour-minute display.

II. Theoretical Possibility of Conversion

In the conventional sense, the simplest solution is to use a summing-type analog-to-digital converter that matches the output of the existing equipment to a binary coded decimal

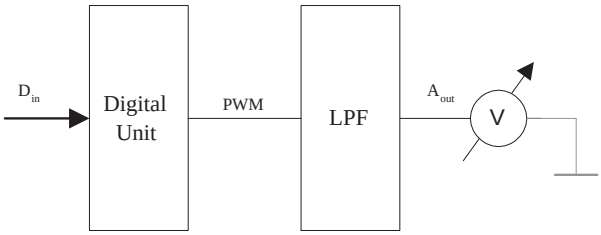

Fig. 3. Pulse width modulation (PWM) method as a digital-analog converter, and a low pass filter for fitting a Deprez instrument.

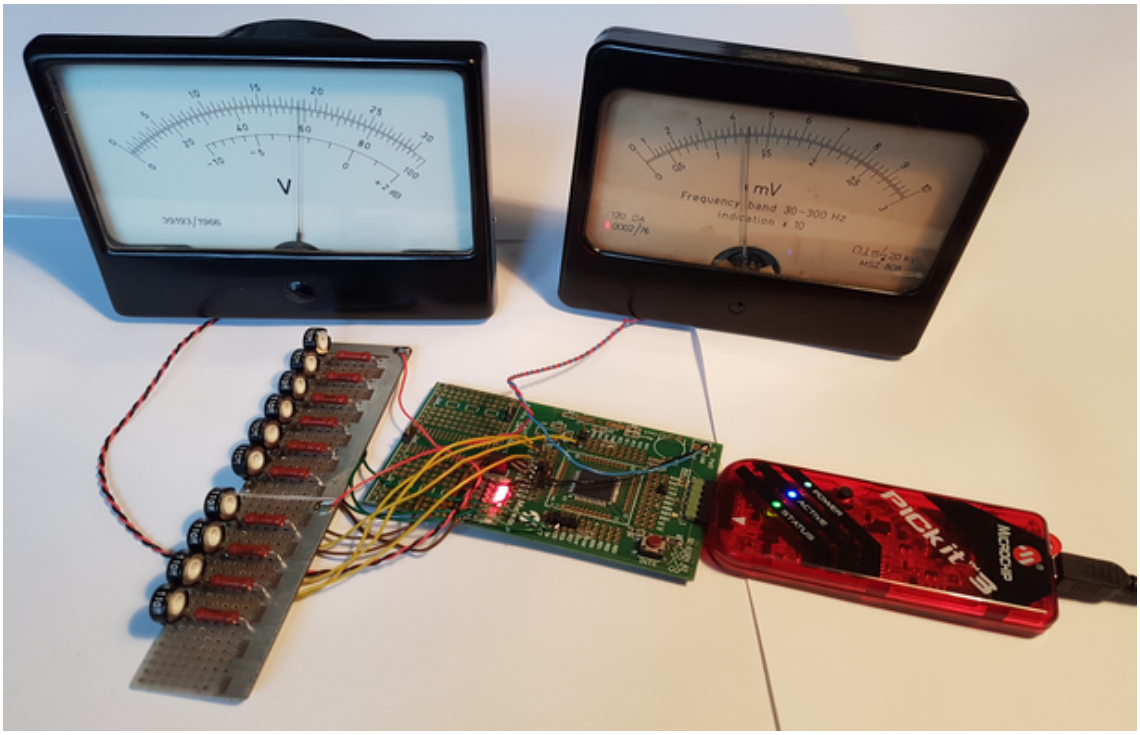

Fig. 4. Test environment for connection of microcontroller digital clock outputs with two analog instruments, by application of additive DAC. (6.27PM)

number (BCD) output (Fig. 1). The equation describing the digital to analog conversion is shown in each context. In this case, the resistances are halved from R_0 to R_n, respectively, according to the increasing binary weighting (1);

$$U_{out} = U_{oH}(2^0R_0 + 2^1R_1 + 2^2R_2 \ldots 2^nR_n); \qquad (1)$$

where U_{out} output voltage of DAC, U_{oH} is typical voltage binary digital output, and $R_0 = 2R_1$, $R_1 = 2R_2$, $R_2 = 2R_3$ $\ldots R_{n-1} = 2R_n$.

At the output of each converter, a device-matching resistor network is used, which fits the full scale of Deprez instrument. This method is the simplest, since it requires only the use of passive components, and as a result digital to analog conversion is possible.

Further considering the proposed procedure, a single instrument may be used for multiple-digit BCD displays. In this case, the numerical weighting is also solved by a resistor network (Fig. 2).

With the help of Pulse width modulation (PWM) we can also implement digital analog conversion using additional hardware. In this method, a microcontroller is connect to the output of an existing digital device (Fig. 3) and from binary information of this output, PWM signals carrying information in a duty cycle are generated [4] [6].

The average value of the PWM signals is performed with a low pass filter (LPF). Again, the filter output must be matched to the Deprez instrument input parameters (Fig. 5).

III. Practical Possibility of Conversion

Figure 4 shows a digital wristwatch with the output of hours and minutes in binary form, possibly with LEDs. The control electronics themselves are pennies, and this electronics requires only a three-volt power supply to operate. The Deprez instrument can be fitted to the output of this digital device using the additive resistive digital to analog converter described above [11].

Another example is shown in Fig. 4. Here we implemented a digital clock in a microcontroller environment (PIC 16F887), which displayed the hours and minutes on the parallel ports. The resistive digital to analog converter shown in Fig. 6 is attached to this port [1]. For example, potentiometers such as R_2, R_4, etc. were used. to adjust the weighted resistance values.

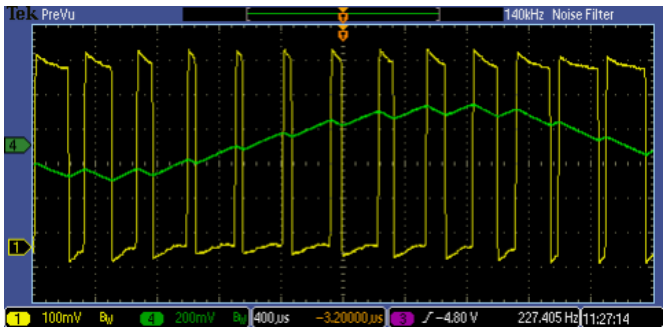

Fig. 5. Oscilloscope screen shot of Pulse width modulation (PWM) signal. (Yellow is PWM impulse and green is output of low-pass filter.) [5]

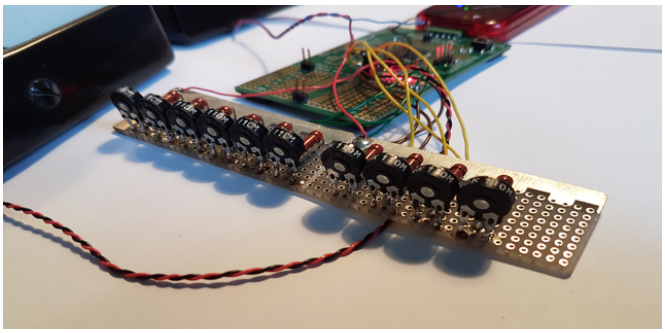

Fig. 6. Implementation of the breadboard model of additive ADC. The exact value of each resistor is adjusted using trimmer potentiometers.

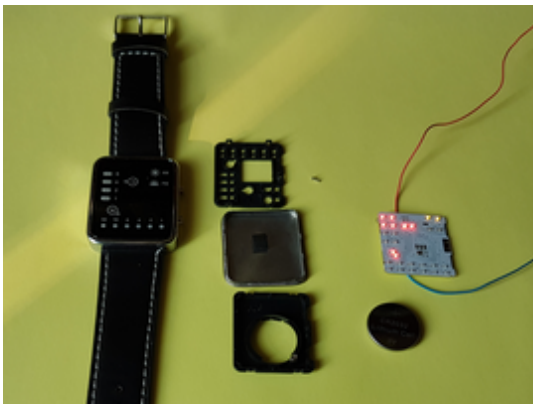

Fig. 7. Popular pillar watch with binary digital display.

A spectacular result can be achieved by converting a commercially available cheap binary digital watch (Fig. 7). To operate the control electronics, you only need one three-volt power supply. The hour and minute display LEDs are fitted as digital binary outputs to the additive digital to analog converter described above (Fig. 8). Of particular interest to the proposed solution is to continuously press one of the control buttons on the wristwatch for half a second to continuously see the time value [14]. To accomplish this, we use an astable multivibrator that performs the above operation in parallel with the switch by means of a tiny relay [1]. An additional result of this solution is that turning on the relay every second actually mimics the ticking of the clock.

IV. Conclusions

With regard to the proposed solution and the examples, we have seen that an analog instrument can simply be fitted to an existing digital display device that gives the observer some interpolation scaling result without the exact value. The stated objective thus avoids the risk of continuous calculations [13]. Another challenge is to find another low-cost, highly adaptable display that is easy to use in the context of existing, well-functioning devices.

It is important to find other options than Deprez instruments. The aim is also to investigate the applicability in the industrial environment [7] [12].

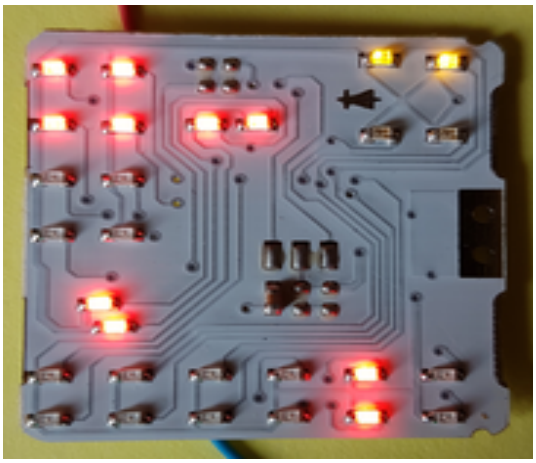

Fig. 8. Electronics of the watch. We make this display suitable for driving an analog instrument.

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Parcel analysis for the general application of remote sensing monitoring

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***Abstract*— The control of agricultural subsidies in the EU is strictly regulated. The satellites provide relevant and complete free and open data which allows monitoring of all agricultural areas in the Member States. However, narrow parcels are not suitable for inspection. Areas smaller than 0.3 ha and narrower than 10 meters should be excluded from monitoring, as recommended by the EU. The article explains how to determine the shape factors of parcels for accurate analysis.**

Keywords— shape factor, remote sensing monitoring, geoinformatics

I. INTRODUCTION (*HEADING 1*)

Monitoring of agricultural subsidies were traditionally carried out at the place in question. However, GIS-based analysis of satellite imagery has allowed remote sensing of support. The goal is to fully automate the monitoring of all parcels while reducing the rate of on-the-spot checks. Member states can voluntarily introduce the new system, which is going to take 3 years. All advanced techniques can be used, but Sentinel satellite imagery is recommended. Sentinel-2 can be used to separate soil and vegetation, to determine the characteristics and phenological status of vegetation, and to delimit non-agricultural areas. Sentinel-1 can be used successfully to determine the structure, volume and moisture content of vegetation and to examine the structure of the soil. Only aspects that cannot be controlled by monitoring require classic on-the-spot verification. Areas smaller than 0.3 ha and narrower than 10 meters should be excluded from monitoring, as recommended by the EU. Due to the fragmented ownership structure in Hungary, thousands of parcels do not fulfill this condition. [1][2]

According to the 2010 land use registry, on the average [3]:

- the number of land parcels used by a private person is 4.44 pieces
- the size of land parcels used by a private person is 9.54 hectares
- the number of land parcels used by professional farmers is 39.42 pieces
- the size of land parcels used by professional farmers is 296.38 hectares

Bipolar land structure can be found in Hungary: there are either small land holdings or large land holdings; there are no medium sized agricultural holdings (See Table I). In the last few years it has become better and better and more and more farms over 50 hectares have been made. The rate of large land holdings belongs to the lowest in the European Union. With its 3,9 % Hungary is behind the average of 11 %. Nowadays there are about 3,3 million landowners who have 2 hectare agricultural field and 1 million acquire incomings from land renting.

Although Hungary is below the EU average in terms of average farm size (Fig. 1.), screening of non-controllable parcels may be necessary in other Member States.

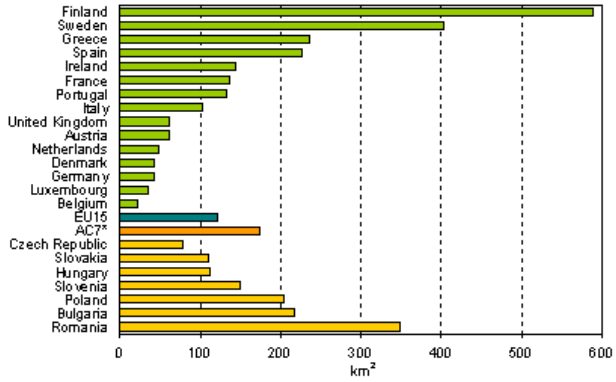

Fig.1. Average size of non-fragmented land parcels [4]

II. METHODOLOGY

A. Shape factor

The size and shape of the parcel also play an important role in evaluating the land. On the basis of experience, the shape and size factor influence the market value of a parcel by ± 10%. Area is an objective, well-defined attribute. However, width is no longer a clear category, as most of the land is not regular rectangular. A study [5] gives the following definition of the parcel shape:

$$Shape\ factor = \left(\sqrt{area}/perimeter\right) * area^{0,1} \qquad (1)$$

B. Limit calculation

Considering the average Hungarian land structure, both area and form influence the final score in the equation. This dimensionless number can be used to filter out parcels that are unsuitable for monitoring. If the shape factor of a parcel is less than 0.21, the parcel is 87.6% likely to be unsuitable for remote sensing monitoring. This threshold is based on a set of 1000 data series. The area is between 0.2 and 0.4 hectares, with a trunk of no width between 7 and 12 meters from the randomly issued mark.

If the shape or area is incorrect, the metrics in the table will have "1". If the area index or the width index is set to "1", the complex index is also set to "1". The shape factor index takes on "1" if it is less than 0.21. The parity between the shape and the complex index is shown by "Parity". Its average value after analysis of 25 different datasets is 72.44%.

TABLE I. EXCERPT FROM THE 1000-PATTERN DATASET.

Nr.	Area [hectar]	Width [m]	Shape factor	Index of area	Index of width	Komplex index	Index of shape factor	Parity
534	0.22	10	0.22	1	1	1	0	0
535	0.32	12	0.23	0	0	0	0	1
536	0.39	9	0.16	0	1	1	1	1
537	0.29	11	0.22	1	0	1	0	0
538	0.37	9	0.16	0	1	1	1	1
539	0.20	7	0.16	1	1	1	1	1
540	0.21	11	0.25	1	0	1	0	0
541	0.22	11	0.24	1	0	1	0	0
542	0.36	7	0.13	0	1	1	1	1
543	0.25	8	0.17	1	1	1	1	1
544	0.25	8	0.17	1	1	1	1	1
545	0.36	11	0.20	0	0	0	1	0
546	0.40	10	0.18	0	1	1	1	1
547	0.23	9	0.20	1	1	1	1	1
548	0.23	9	0.20	1	1	1	1	1
549	0.38	8	0.15	0	1	1	1	1
550	0.36	7	0.13	0	1	1	1	1
551	0.26	10	0.21	1	1	1	1	1
552	0.21	10	0.22	1	1	1	0	0
553	0.24	12	0.25	1	0	1	0	0
554	0.38	10	0.18	0	1	1	1	1
555	0.36	12	0.22	0	0	0	0	1
556	0.24	9	0.19	1	1	1	1	1
557	0.21	10	0.22	1	1	1	0	0
558	0.30	11	0.21	0	0	0	0	1
559	0.28	10	0.20	1	1	1	1	1
560	0.30	11	0.21	0	0	0	0	1

III. ANALYSIS IN THE SAMPLE AREA

Hungarian Ministry of Agriculture has merely provided the data of Mesterszállás for the analysis. This village is on the Great Hungarian Plain. It is 42.92 km2 and its population is 702 people. 508 land parcels have been involved in the planning.

Shape factors were calculated for all plots of the sample area (Fig. 3.). As a result of the analysis, 25 of the 508 plots are not suitable for remote sensing monitoring based on the index. Therefore 4.92% of the parcels require field inspections. This is also confirmed by the separate inspection of the parcels (Fig. 2.).

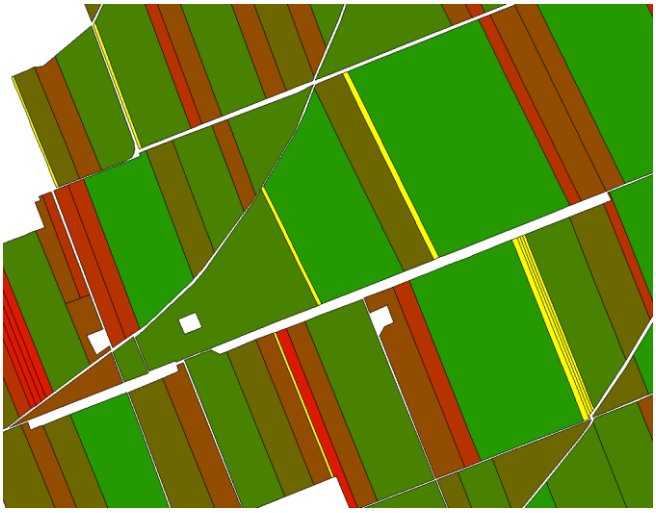

Fig. 2. Selection of parcels with a shape factor of less than 0.21

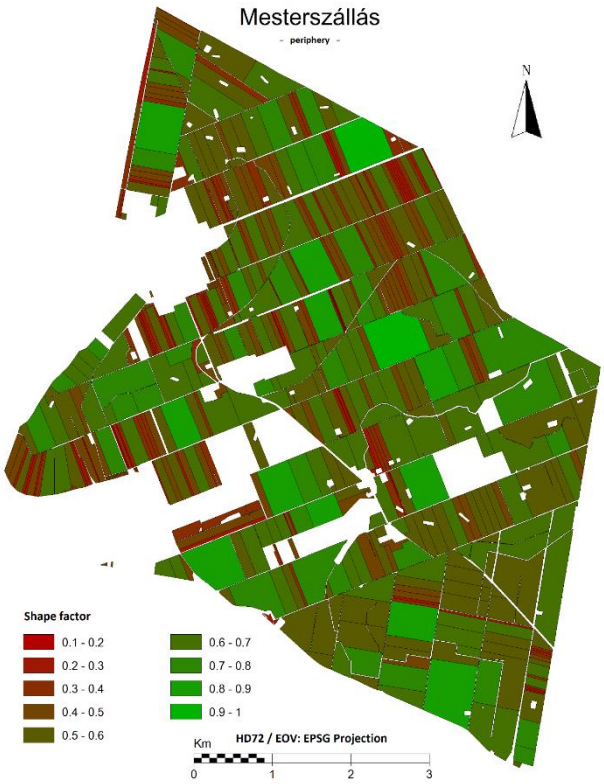

Fig. 3. Shape factor of parcels in the sample area

IV. CONCLUSIONS

There is a tendency to automatically check agricultural subsidies based on satellite imagery. However, not all parcels are capable of remote sensing control. The objective and fast method of GIS based shape factor calculation helps decision making. Based on the results presented in this paper, the shape factor, which is used to evaluate parcels, can be used to filter out parcels unsuitable for remote sensing monitoring.

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Remote sensing data in the urban GIS

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Abstract — Urban development and management require the handling of complex spatial related objects as well. Nowadays there are data acquisition and data process technologies, which can satisfy such demands. The methods of data acquisition typically provide additional information for GIS beyond geometric data. During the data processing we can get further possibilities. Data from different source can be managed jointly and the information content of the data can be multiplied. Formal times, production of the corresponding high-quality data of the objects was a time consuming and expensive procedure. GIS data acquisition technologies such as Lidar, digital photogrammetry, remote sensing, terrestrial laser scanning and GNSS positioning enable to produce a complex spatial urban database with high resolution and high accuracy. Certainly, the data collection equipment may be still costly, but due to the efficiency of the acquisition method, the measurement time can dramatically be shortened. It is also an important aspect that a complex database enables multiple analysis so that the database can serve multiple disciplines.

In this study we present some of the data acquisition and data processing technologies, which are suitable to integrate into an urban database and can provide useful information for a wide range of applications through analysis and visualization. In urban development several factors need to be considered simultaneously, such as infrastructure, environment, heritage preservation, etc. Different spatial display capabilities can illustrate object of interests one-by-one, but also it is possible to model its surroundings as well. This way such tools can be used efficiently for urban planning by the municipal decision makers. In this study, we will present how to collect and how to utilize different resolution data (Lidar, close range and aerial photogrammetry, terrestrial laser scanning) in urban areas, how to create 3 dimensional models of objects or how to generate surface model of the city based on different data. There are examples presented indicating how to use different combinations of geometric, spectral and topographic data in practice.

I. GIS IN URBAN PLANNING

The Geographic Information System (GIS) is a system created to capture, store, analyze and manage spatial or geographic data. The GIS techniques are used in a wide area of global, regional and local planning. An essential issue for GIS is the quality and suitability for the analysis of the data used in the applied database. The concept of quality nowadays means not only geometric accuracy but also the quality of the further contents of the database. In addition to accuracy, the geometrical resolution is important. Further in the case of remote sensing data, it has significance the spectral (channel number) and radiometric (BPC- bit/channel) resolution. The traditional planning techniques of architecture and civil engineering are time consuming and static procedures. Today, there are many well-known data acquisition technologies that can deliver large amounts of data on their own, and when used combined, it can multiply the information content. [2]

II. DATA ACQUISITION TECHNOLOGIES

Field data

This is the oldest data acquisition procedure. It is used when we want to determine the location of a few discrete points, i.e. the determination of the field is abstracted to appropriately chosen discrete points (Figure 1). The task of surveyor to identify and to select the characteristic points of the field and register them. It is time consuming field work and it is using a limited number of keypoints. We can use GPS for lower accuracy, but if we need high accuracy, use of total station is suggested. These devices are indispensable for the construction of engineering structures, for monitoring of their movements. The field data acquisition procedure is time-consuming and not efficient enough, but the **most accurate data acquisition method**.

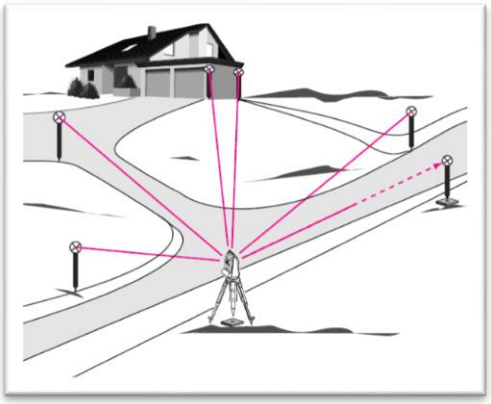

Figure 1. Measurement of discrete points [1]

Photogrammetry

Photogrammetry has advanced greatly in the last years. At the beginning of the XXI. century the digital photogrammetric cameras replaced the film-based equipments. The digital cameras with the high resolution, multi-ray imaging and high automation potential completely have renewed the photogrammetric technology. [2] In addition to traditional aerial photogrammetry, UAV (Unmanned Aerial Vehicle) platform for photogrammetry has been appeared. The use of UAV-s is having a big impact on photogrammetry. Due to the lower flying altitude, significantly higher resolution became available (1-2 cm, see Figure 2). Making aerial photos of larger areas still have to be carried out with traditional aircraft-mounted camera. For the urban GIS, close-range photogrammetry can also be efficiently used. Software have been developed that can process images taken with an amateur camera, as the use of non-metric cameras is widespread. Based on handhold images, one can create 3-dimensional models of buildings or other objects.

Sensors used in photogrammetry are very diverse in geometric, spectral and radiometric resolution. Their greatest advantage in urban environments is their geometric resolution (from mm to cm), which can be exploited in many areas. Detailed survey of small area, condition observe, open trench survey, rapid documentation of archaeological excavations, illegal construction supervision, engineering environmental management, waste management, intelligent transportation, and other aspects can be mentioned as relevant examples.

Figure *2*. High resolution UAV image

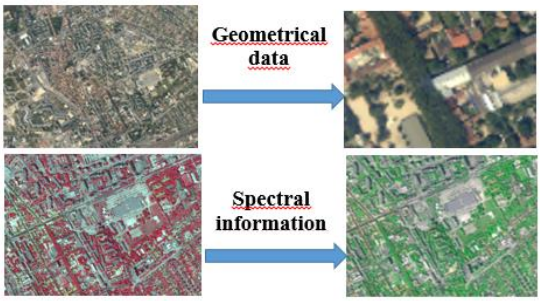

Figure 3. True colour and false colour othophoto of Székesfehérvár based on aerial images.

In aerial photogrammetry, there is a widespread method of shooting: in addition to the classical Nadir shooting at a given position (Figure 3), images can be taken forwards, backwards and sideways (Figure 4). These 'oblique' images make it possible to produce a spatial model of cities.

Figure 4. 3-dimensional model of Székesfehérvár by using oblique images

Photogrammetry is now being integrated into many activities involving geospatial data.

Remote sensing

Satellite remote sensing is capable of producing more data types, that expand the possibilities of urban information databases. The geometric, spectral and radiometric resolution of the satellite images have improved a lot in the recent years. Formal times, they had less applications in urban environments due to their poor geometric resolution. By now, this has changed. For example, the WorldView-2 is a commercial Earth observation satellite. WorldView-2 provides commercially available panchromatic imagery of 0.46 m (18 inch) resolution, and eight-band multispectral imagery with 1.84 m (72 in) resolution. [6]

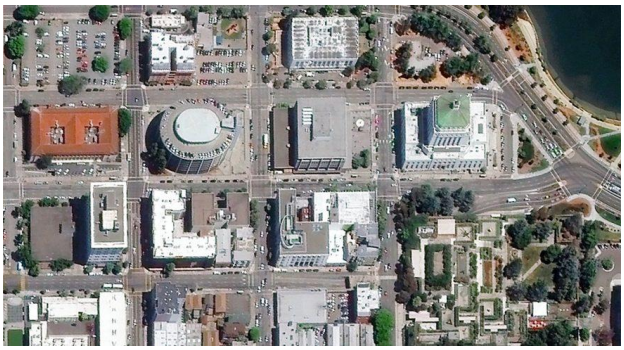

Figure 5. Figure Image of downtown Oakland captured by DigitalGlobe's WorldView-2 satellite. [6]

LIDAR

The invention of laser has started in the early 1960's. The main product of LIDAR (Light Detection and Ranging) survey is a 3D point cloud. The density of the point cloud depends on the sensor characteristics (scanning frequency and repetition rate), as well as the flight parameters (see an example on Figure 6). Assuming that the scanner is pulsing and oscillating at a fixed rate, the point cloud density depends purely on the flight altitude and speed of the aircraft. It is also important to understand that LiDAR sensor is only sampling positions without RGB (spectral information), creating a monochrome dataset which is challenging to be interpreted. To make it more meaningful, the data is often visualized using false-color based on reflectivity or elevation (Figure 7). [3].

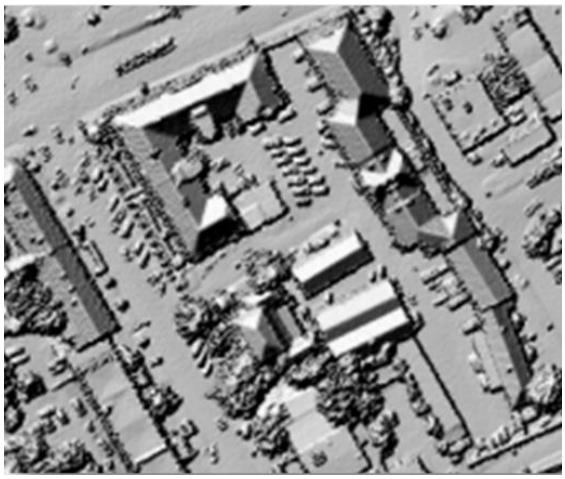

Figure 6. Surface based on LIDAR point cloud. (0,15m absolute and 0,05 m relative vertical accuracy)

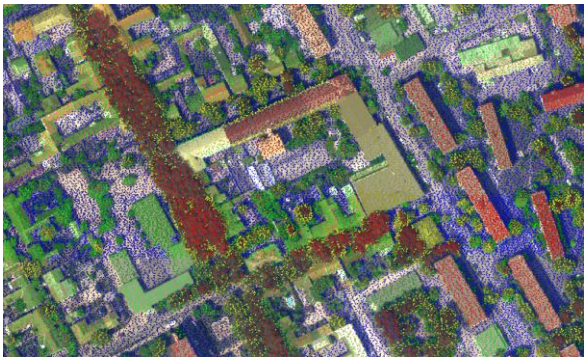

Figure 7.a Figure Orthophoto and point cloud [1]

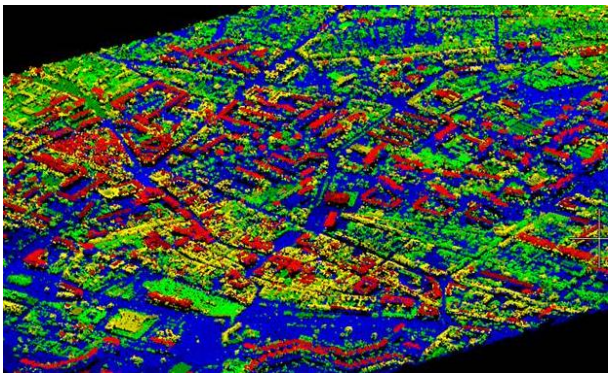

Figure 7.b 3D point cloud visualized using false-color based on elevation [1]

The LIDAR technology collects highly accurate geometrical data with high density, but the analysis and semantic interpretation require application-specific data processing methods. It is possible to overlay color on the LiDAR data in the post-processing phase based on supplementary information, such as images or other data sources. The color can also be added based on

classification. [2,3] As the size of LIDAR equipments become smaller, they not only mounted on aircraft, but also on UAVs, increasing both the resolution and the accuracy.

Mobile laser scanner and terrestrial laser scanner

Mobile laser scanning technology combines the use of a laser scanner, the global navigation satellite systems, and an inertial measurement unit (IMU - adjusts input data for vehicle movements) on a mobile platform to produce accurate geospatial data. Terrestrial Laser Scanners has been developed for as-built modeling of architectural and engineering structures. They can be used for high-resolution modeling of terrain objects over limited distances in the range of 50–300 m. These equipments are a key player in the sector due to their low cost, durability and simplicity of usage. A point cloud can be quickly and easily produced, and the process is expected to become more affordable and automated. Mobile laser scanned measurements are characterized about by 30 mm absolute and 3-5 mm relative accuracy on distances less than 10 m. [7] Examples are shown on Figure 8a.;8b

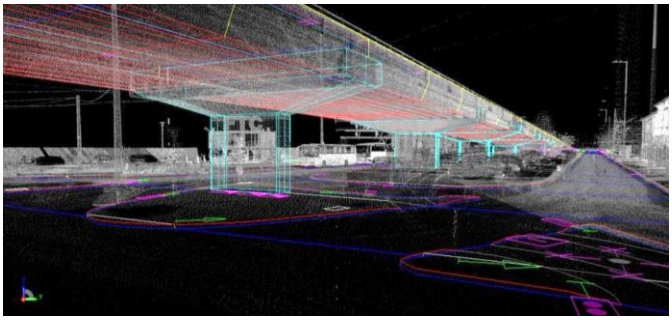

Figure 8a. Mobile laser scanned point cloud at a busy traffic junction in Budapest [8];

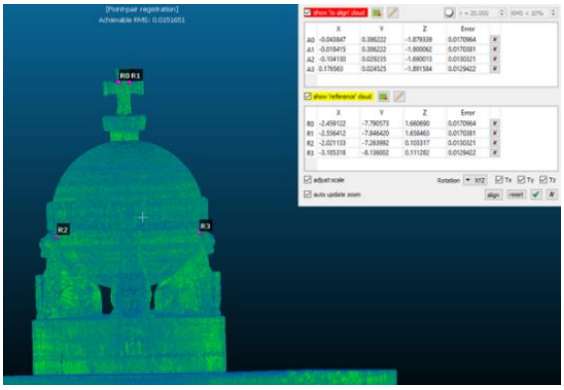

Figure 8b. Terrestrial laser scanned point cloud of the statue „Országalma" in Székesfehérvár [5]

Digital Terrain Model from analog maps

Low-resolution and accurate data, that can be derived from analog topographic maps can be used well for global city planning. They provide 3D information about the entire city (Figure 9).

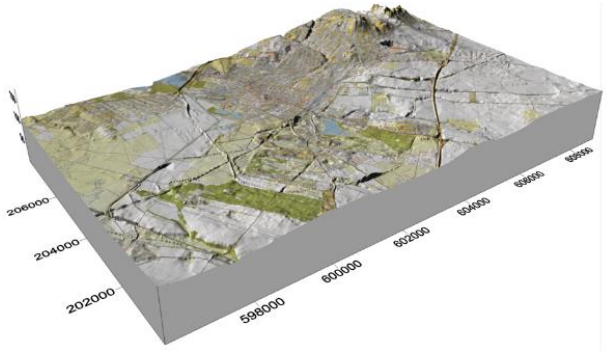

Figure 9. Visualisation of topographic maps on digital terrain model of Székesfehérvár (20 m grid size)

The approximate evaluation of the recorded data

	Field data collection	Photogrammetry	LIDAR	Mobile laser-	Terrestrial laserscanne	Multispectral remote
Horizontal accuracy	*** **	**** *	***	**	*** *	*
Vertical accuracy	*** **	***	*** **	**	*** **	-
Spatial resolution	*	**** **	***	*** *	*** **	*
Semantic resolution	*	***	*	*	*	*** **
time required	*	**	*	*	*	*** **
cost efficiency	*	**** *	**	*	*	***

Table 1. summarizes the strength and weakness of the different data acquisition methods. It may help to find the optimal method for urban planning, which satisfies the needs of resolution and accuracy, and provides information on cost efficiency. Data from different source can be managed together and the advantages can be added.

Examples are shown on Figure 10 to Figure 15.

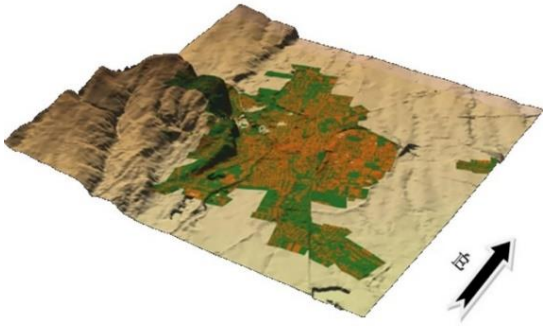

Figure 10. Green and artificial land cover, classified satellite image draped on DTM (20m grid size) [10]

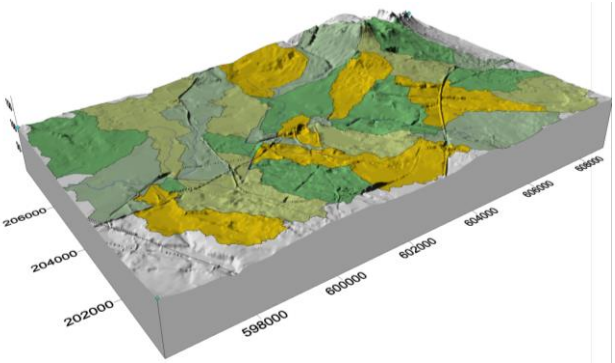

Figure 11. Watersheets of Székesfehérvár on DTM for global planning

Figure 12. Figure 3-dimensional urban model, applied of LIDAR data (0,5 m) and high resolution true orthophoto (~0,2m), Székesfehérvár

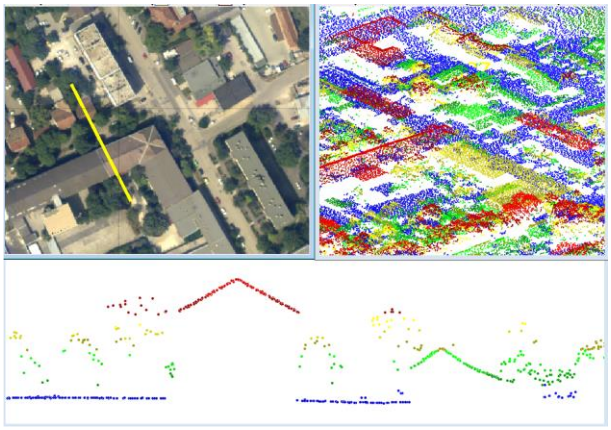

Figure 13. Orthophoto and LIDAR point cloud, Cross-section of a street.[1]

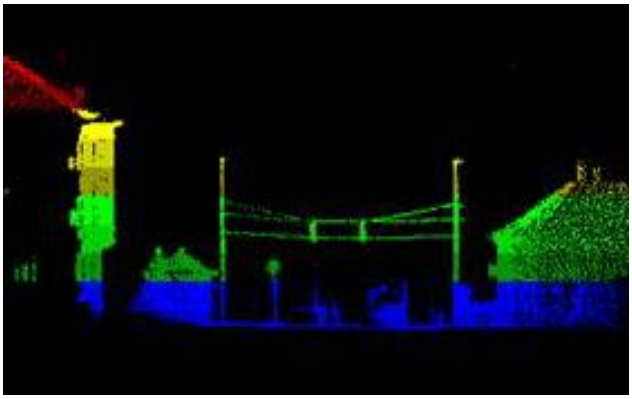

Figure 14. Cross-section of merged LIDAR and terrestrial laser scanned point clouds[2]

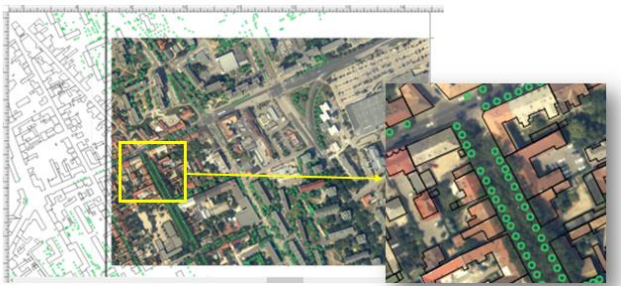

Figure 15. Cadastral map, high resolution true orthophoto and depicted individually measured trees in a common reference system

CONCLUSIONS

Data acqusition and processing techniques show different resolution and accuracy. It is important to understand that all of technologies have their strength as well as limitations, defined by the application they have been developed for. Usually, they can be used complementary, so joint use of these techniques is often recommended. None of these technologies is better than the other and none of them can be used optimally for all cases. The geometric resolution of LIDAR is better than the resolution of a satellite image, but the LIDAR itself has no continuous spectral information from the surface. We can prepare an industrial investment map using UAV technology, but the structure must be assigned field geodetic measurements. The technologies have changed, but the rule remains. The accuracy needs and efficiency demands are the primer factors to decide on the proper data acquisition method, and we choose the technique which best suits for our purpose.

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Art and IT in a STEAM subject

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STEAM pedagogy is a promising alternative to solve the crises of STEM. In a Hungarian secondary school, a group of inventory teachers of different majors planned and implemented a series of STEAM projects. Their goal is to make research in STEAM didactics and methodology.

In the series of projects, a new school subject is one of the elements: Media-2, which is an optional art subject. The subject is planned on STEAM bases. The model of a healthy human being is the unity his spiritual-emotional-artistic and rational side. In the subject the joy of creation and modern digital techniques form a perfect alloy. In the pilot year the main goal was re-arranging the school's website and focus on how sway-s can best contribute to school-life. The students love the course, it has high reputation.

We report on this work, thus give qualitative proof for STEAM pedagogy.

I. STEM IN CRISES

On 23rd March 2015 President Obama [1.] ascertained the intent of science education like this: "(Science) is more than a school subject, (.....). It is an approach to the world, a critical way to understand and explore and engage in the world, and then have the capacity to change that world...."

Science is included is STEM. We consider STEM as an acronym, a collective field of these studies:

- S is for Science,
- T is for Technology,
- E is for Engineering, and
- M is for Mathematics.

The U.S. Department of Education states [2.]: "In a world that's becoming increasingly complex, where success is driven not only by what you know, but what you can do with what you know, it's more important than ever for our youth to be equipped with the knowledge and skills to solve tough problems gather and evaluate evidence, and make sense of information. These are the types of skills that students learn by studying science, technology, engineering, and math—subjects collectively known as STEM."

The Bureau of Labor Statistics, (in United States Department of Labor) in May 2015 published an article from an economic point of view: "STEM in crisis or STEM surplus? Yes and yes." [3.]. We learn from the study about employment: the academic sector is generally oversupplied, while the government sector and private industry have shortages. Also, the geographic location and the discipline of the position affect ease or difficulty. Still, the in article, the researchers assert that "the vitality of the STEM workforce will continue to be a cause for concern".

Linda Rosen, the Chief Executive Officer of "Change the Equation" points out the following [4.]:

- The truth hurts: the STEM crisis is not a myth.
- In the U.S. even in the years between 2009 and 2012, there were nearly two STEM focused job postings for every unemployed STEM professional.
- Unemployment in STEM was over 4%, while the same value for non-STEM workers is 9.3%.
- STEM workers are paid more than non-STEM workers.
- She refers to estimates that STEM technicians get paid 10% more than non-STEM jobs with similar education requirements.
- She points out that the focus is on the need to make all young people STEM literate: STEM for all!

II. FROM STEM TO STEAM

The main goal of STEM pedagogy is bridging the gap between Science classes and Science adventures. Didactical and methodological solutions of active pedagogy is still a topic well-worth of research.

But what we mean by STEAM can be perceived on Figure 1.

Figure 1. Ingredients of STEAM

STEAM is a new perspective appearing on the palette. In the acronym A stands for Art: arts, skills and reativity are added to the teaching and learning practices.

Is implementing Music, Ballet, Fine Art, Literature, rhymes, P.E., jokes or songs into our classes

worth its time? Many colleagues find they make good use of these, but "relevant and reliable research is urgently needed", as Professor P. S. Taylor points it out in his article, "*Enriching STEM with the arts to better prepare 21st century citizens".* [5.]

Can we build on the students' artistic skills in Science Education? Does STEAM prepare students with higher-order abilities to deal positively and productively life? Professor H. Salmi shares his results in "*How creativity, autonomy and visual reasoning contribute to cognitive learning in a STEAM hands-on inquiry-based math module"* [6.]

III. INTRODUCING MIG

It is a privilege and an obligation to teach or study in Madách Imre Gimnázium, Budapest (MIG - http://mig.hu/en/).

The school was founded by Ágoston Trefort (Lorand Eötvös's uncle) in 1881. The motive was to give high level secondary education for Hungarian boys aged 10-18. It was the first Hungarian state school in Budapest, Hungary.

The list of former students of the school speaks for itself: Imre Kertész (Nobel Prize winner writer), Andy Grove (the father of the microprocessor, founder of Intel), Pál Selényi (experimental physicist), Pál Turán (mathematician), Robert Capa (photographer). The list is very long of well-known singers, artists, painters, comedians, actors and actresses, etc.

Nowadays the school provides co-educated high-level education for students aged 14-19. Based on the results of the institute it is ranked to the from 13th to the 19th place from the 2416 secondary schools. MIG surely deserves the honoring elite school title. However, the best academic results are in literature, drama, history and languages.

The school is in the center of Budapest, in the imposing original building. (Figure 2.)

Figure 2. MIG in the center of Budapest

IV. STEAM PROJETS IN MIG

MIG gives excellent opportunity for didactical research of STEAM.

There were 2 preliminary STEAM projects giving qualitative proof for didactical research that students and teachers are willing and able to cooperate in new ways.

A) The "Art-pieces of gravity" project in 2018

The topicality of our first STEAM project is the Nobel Prize in physics in 2017. The LIGO experiment proved the existence of the foretold gravitational waves.

Elements of the studies of gravity are in the syllabus, and the information in the media turned our focus to this topic. We promoted an optional task to our students and fellow colleagues two ways:

- personally, in visual art and physics classes
- via the internet, on the school's website.

It was a great success: more than a hundred course works were handed in. The list proves how creative our students are: a picture-poem, graphics, a design-dress (Figure 3.), poems in English and Hungarian, mandalas, tableaus, oil paintings, and many interesting solutions.

The design-dress inspired by the scientific phenomenon focuses on the different fall of different materials. This is the combined effect of gravity and the characteristics of the materials. It is an exciting composition of the natural colours, the glossy and matte surfaces, the geometrical figures, and the various textures. The ornaments are peculiar, the traditional accessories are reinterpreted.

Figure 3. "Gravity dress" and the designer, Miss Hanna Márkus

From the best pieces we arranged an exhibition in the schools' social hall.

B) The "Retiring the Grand K" project, 2019

Since 1875 the idea of making a coherent scientific unit system led to birth of the System International (SI) in 1889. This system consists 7 basic quantities and their units derived from the nature. "Le Grand K" is the world standard of kilogram, the SI unit of mass. Le Grand K had been is service for 130 years by 20th May 2019. It is the last one to retire of the 7 world standards. There were the "Avogadro project" and the "Watt/Kibble Balance" project to take over.

The students of applied physics at grade 10 set memory to the occasion on the school's notice board (13th-27th May 2019). Figure 4. shows it.

Figure 4. Notice board saying farewell to the Grand K

The group of innovative teachers addressed the students for a competition.

Table 1. shows the distribution of course works.

Type of work	no. of works	on display
fine art	17	4
poem	6	2
essay	8	2

Table 1. Number of the course works for the farewell

Fine art works included drawings, paintings, illustrations, tableaus, a figurine and also fashion jewellery.

The exhibition (Figure 5.) in the social hall of the school promoted our project for another two weeks.

Figure 5. Farewell to "Le Grand K" in MIG

V. A NEW SUBJECT: IT & MEDIA

A) Planning and defining the bases of a new subject: terms, conditions, motivation

Based on the success of the previous projects we planned and implemented STEAM pedagogy into a new media subject.

An optional art subject for two years in MIG:

In MIG, students can choose one art subject for their grades 11 and 12. The course they choose is for a two-year-long period of their studies, the senior years. The actual group is from the members of the four (or five) classes attending the same year, but from different classes: 130-160 students. The course takes one double lesson (90 minutes) each week. There is a range of possibilities, like: theatre, media, radio, dancing and music, visual culture, drama, journalism, etc.

We decided to give a try to a new subject, called Media-2. We introduce our conceptions.

Our model of the student was and is "a healthy human being, in whom the rational and the emotional-creative areas are in a personality defining equilibrium. It not only the model of a healthy human being, the unity of the rational and the spiritual-emotional side, that recalls peripatetic pedagogy. We appointed the role of the teacher also in parallel with the peripatetic model: the teacher is more like a mentor.

The pedagogical model of our work is Dale's model on active pedagogy. On Figure 5 we highlight the most effective didactical tools in red. "Do a real thing" grabbed our attention, we will explain how we intended to implement the idea in our project.

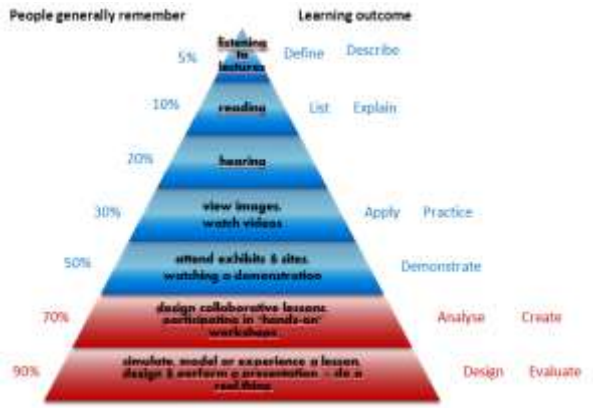

Figure 5. Dale pyramid of active pedagogy

Our school has just had a new homepage. It is becoming very popular and higher and higher valued. Also, the Department of IT teachers introduced (in close collaboration with the system administrator) a new website of the school including Microsoft Office facilities. It is not easy to take the first steps in the introduction and use. Our purpose was also to help our student get to know more, therefore help their fellow students and possibly even their teachers to make the most of the new possibility.

All in all, our intention is to alloy the joy of creation with modern digital techniques. Ancient pedagogy and brand-new IT make sure that this subject is very peculiar.

B) Contents of the subject, a report on the pilot year

First, we give some information on the pilot year. The course did not have any preludes. We gave our short perspective only. Many applied to the course. The human and technical facilities gave a strict limit to the number of participants. Finally, 19 students were excepted for the course.

One of the highlighted motives is to do a real thing to get the best of best of the effectiveness of active pedagogy. The content of the subject is everything that can be related to the everyday life of the school and digital techniques. These tasks are in the syllabus:

- we take and edit pictures
- we shoot and edit films
- we plan, design and make websites and homepages, etc.

The new website of the school shows what our students can achieve with expert guidance (Figure 6., 7.).

Figure 6. The new homepage of MIG
http://mig.hu/

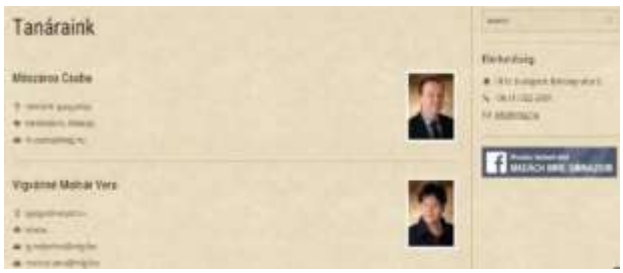

Figure 7. Introducing the staff (on the students' demand)
http://mig.hu/tanarok/

Among the students the course is often called "the sway making course". It shows that sways are very popular in the course and have a praising feedback among the protagonists of the school-life.

Sways are brand new tools in IT. They can be best defined as web-ppts. One of the greatest advantages is that they are platform independent. It means that they can be well used on PCs, laptops, tablets, smart phones, etc.

There are 45 sways giving information about different programs that happened in the academic year of 2018/2019. These are attached to a timeline, as Figure 8. shows.

Figure 8. Sways attached to a timeline

This timeline is on the website:
http://mig.hu/diakelet-2018-2019-tanev/

We can assume that this part of the project is very productive.

We also present the sways on the previously mentioned STEAM project on Figure 9. and 10.:

Figure 9 Art-pieces of gravity on the timeline

https://sway.office.com/03GTejbW1X6TRCR7?ref=link

Figure 10. Sites from the sway

We can underline in Figure 11. that also foreign language competences are developed in the course with a sway in English. Hopefully more and more will follow the model.

Figure 11. A sway in English promoting STEAM physics
https://sway.office.com/DjynkOdCF9Amwt2F?ref=Link&fbclid=IwAR1AtppRk-s3J5o6k-6x0sMy0-cCpkElrrnCtKkwz68DWb0oCuoYymeW3fg

The sway is well-prepared if it gives back the atmosphere and events of the occasion it gives information about. The students need to learn how to work in a group to best contribute to the "product". It is not an easy task to find the strength of each individual participant.

What skills did the students use and develop? Many, but especially these in the teamwork:

- collaborative,
- manual,
- stylizing,
- methodizing,
- artistic,
- systematizing,
- social,
- typing,
- foreign languages,
- and many more.

Surely, the teacher needs to take responsibility what "products" can be displayed on the site. Students need to learn also some critics and based on them to revisit their work to work on it for better.

C) Further plans

We find that Media-2 is a popular course among students. For the new academic year (2019/2020) there were many ho chose as their optional subject. Still, the facilities are limited, so only 21 students can take part in the course. This time we wanted to learn how the course works, so planned and began implementing quantitative didactical research. We used multiple choice questions in finding out more about the specific competence (2 out of its 3 aspects). Surely, we used the possibility given by our Microsoft Office.

The pilot group has already reached their grade 12, so new content and new perspectives are present in the second part of the course.

VI. CONCLUSION

We proved that colleagues of different majors can plan and implement STEAM projects in secondary schools.

We proved that secondary school students are eager to participate in STEAM projects, thus combine their knowledge & skills gained in the study of many school-subjects.

We have experienced that exhibitions raise the interest of those students also, who did not prepare a course work.

We can plan our next project in a pedagogical research setting to gain quantitative proof how STEAM projects work.

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ACKNOWLEDGMENTS

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We thank our fellow colleagues and students for supporting our work by paying interest, making comments, participating in the projects and many other ways.

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Surface deformation determination and monitoring in deep mining areas with InSAR technology

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***Abstract*—In this study the applicability of the InSAR technology will be examined in the Márkushegy Mining Facility as test site during the period of 2014-2019. In this period the Facility undergone the final mining then the re-cultivation process. In the paper we present the surface deformation trends during these phases by using Sentinel-1A and 1B radar images.**

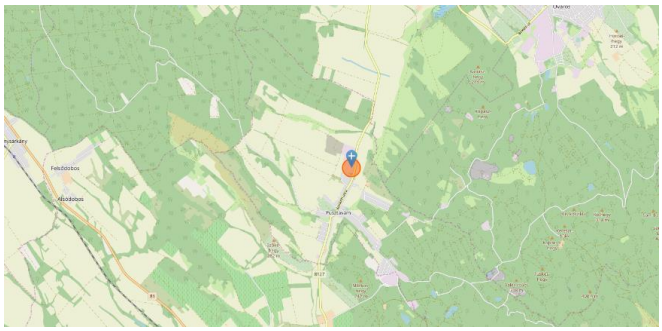
I. INTRODUCTION

In our previous papers, the focus of the research was on the large-scale deformation monitoring, like the vertical motion effects of earthquakes and volcanic eruptions. Since Hungary is rarely affected by these phenomena the need to find an application area where significant deformations could occur and also the validating measurements possibility is given. Our choice was for the application field of deep mining, since the deformations occurred by it can affect relatively large surface area, and the deformations itself can reach the range of tens of centimeters.

Until the recent days to determine the exact value of surface deformations only traditional geodesic techniques (precise leveling) could be used. These methods are costly since they require many on-the-field measuring hours for at least 3 people so in this paper we examine the possibility of a substitute method of an InSAR based technology [1][2].

II. THE TEST SITE

The test area we examined is the Márkushegy Mining Facility (c.f. figure 2.) located in Oroszlány coal-basin (c.f. figure 1.) where the main mined mineral was not surprisingly coal. When we use "was", it is intentional, since the mine closed in 2015 January, and the re-cultivation finished by mid-2016. So, we have the unique opportunity to process data from the last part of a mine's life cycle, when the water-pumps are stopped, then the mine-shafts refilled.



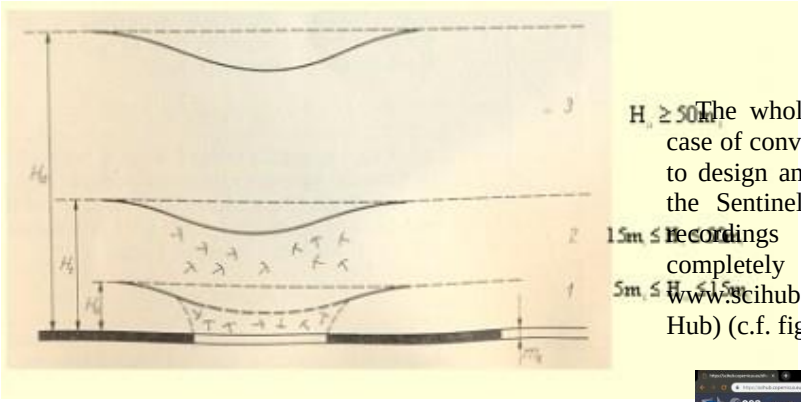
1. Figure Pusztavám area

The underground areas of the mine reaches 4-500 meters in depth and the total length of underground trench system is more than 50 kilometers. To the mine area belonged a surface excavation site called Doba-depo which we excluded from this research, since we focus now on the effects of underground mining.

2. Figure Area of mining facility within Pusztavám

In areas where deep cultivation has been carried out, there is a continuous investigation of surface movement caused by mining. These movements are triggered by mining extraction processes and recultivation. Underground movements start from mining passages and other cavities and sometimes reach the surface. As a result of the abandonment technique, no matter how careful the reloading motions are occurring because of the results from the material and composition of the charger and the environment.

Movements underground after the passages have ceased, under certain parameters (height of the exposed cavity, thickness of the covering rocks), different ranges of movement are formed in the underground layers. These can cause various deformations on the ground.



3. Figure Cross section of the under mined earth layers

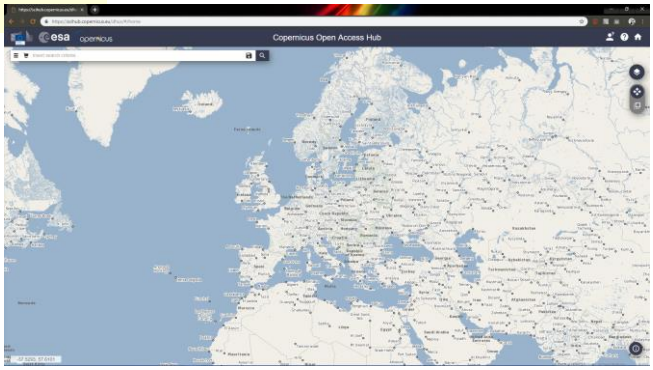
- In Zone 1 (overlap zone), the layers loosen but do not break, causing a ditch on the surface.
- In Zone 2 (cracked zone) the rock layers break but remain in one.
- In Zone 3 (crumbling zone), the overlying layer is highly fragmented. The rocks will loosen and may collapse.

The movements resulting from mining extend beyond the size of the open spaces. Artificial and natural features on the surface, in the dune, can be damaged by the movement, causing them to lose their stability, limit or even eliminate their use.

There are basically two purposes to measuring movements, which are to regularly survey the surface and artificial features of the mined area, and to provide data for the examination of rock pressures.

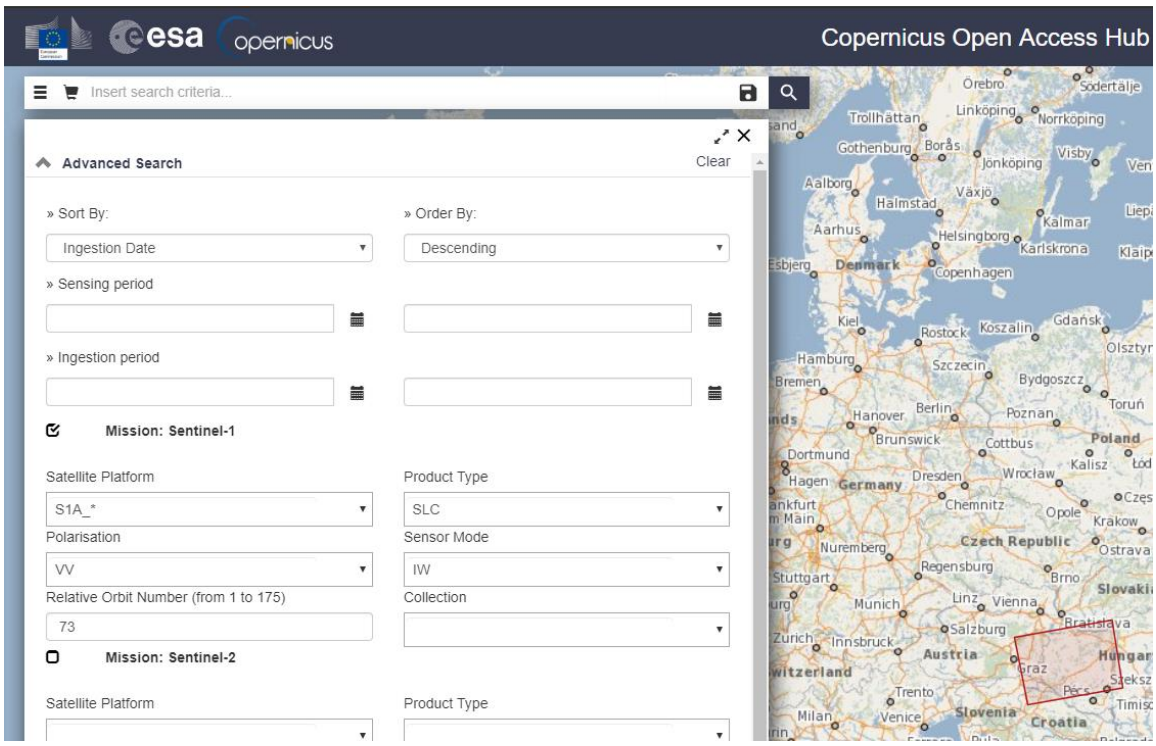
III. Data Processing

The whole process started with data mining. In the case of conventional measurement, this would be the step to design and perform field measurements. In our case, the Sentinel-1 satellites have already done this. The recordings were made available from an online, completely accessible site. This is www.scihub.copernicus.eu (Copernicus Open Access Hub) (c.f. figure 5.). [7] [8]



5. Figure Copernicus Open Access Hub

The search criteria can be used to accurately specify the area, type of recording, and time that is used to evaluate the time frame analysis at the same time intervals for the same seasons, in order to eliminate differences and their effects from such differences (c.f. figure 4.).



4. Figure Parameters and geographical location of the data search

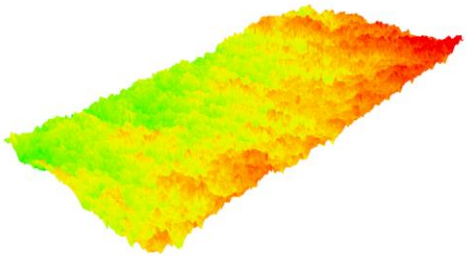
The studied time interval was the period 2014-2019, since the recordings are available from 2014, so we could process the effects of the last year of mining, the re-cultivation and the following period. In terms of dates, we chose March, which, as it turned out, wasn't the luckiest choice.

Compared to our previous research, the present looks a bit further back in the past, so downloading the recordings was done in a different way than before. After the search, we had to specify which images we would like to use, which became available for download only after 24 hours, the time it took from the archive to upload to active storage, and the images were only available for 3 days before returning to archive status. A user can only request two recordings at a time, so downloading took longer than usual and required more careful planning.

The processing work was routinely carried out in the manner presented in our previous publications, using Sentinel 1A satellites for the present study as shown in the table below (c.f. figure 6.).

6. Figure Steps of processing [6] [8]

The final evaluation of the results required a visual representation using ArcGIS. From the processed images, the areas affected by the mine cultivation and their vicinity were cut out and the displacement ranges were set to the same value. Spatially, this meant the village of Pusztavám and its two-kilometer zone, as the mining activities were carried out beyond the boundaries of the village. The next step was to separate the mining site and its immediate surroundings for better evaluation of the results. Finally, the results were evaluated in a three-dimensional manner (c.f. figure 7.).



7. Figure Results represented in 3D

IV. PROBLEMS DOURING PROCESSING

The task was not very easy due to the many minor obstacles due to the technique and the fact that SNAP software was originally developed to run within less limited hardware capabilities. Among other things, I have often encountered freezes, sudden shutdowns, and similar problems of the programs I use. As a suggestion, I would suggest that the computer or laptop on which we are processing should be equipped with a minimum 8 core processor to reduce unwanted program stoppages. This is the level where hardware imperfections can be handled with proper parameterization.

There were also obstacles to obtaining the recordings. One year back, we can download almost all at once, but older ones need to be downloaded after they are selected, which is usually done after a day. This is because only the 'fresh' recordings are on the central server, the old ones are stored on the secondary server and then accessed from there.

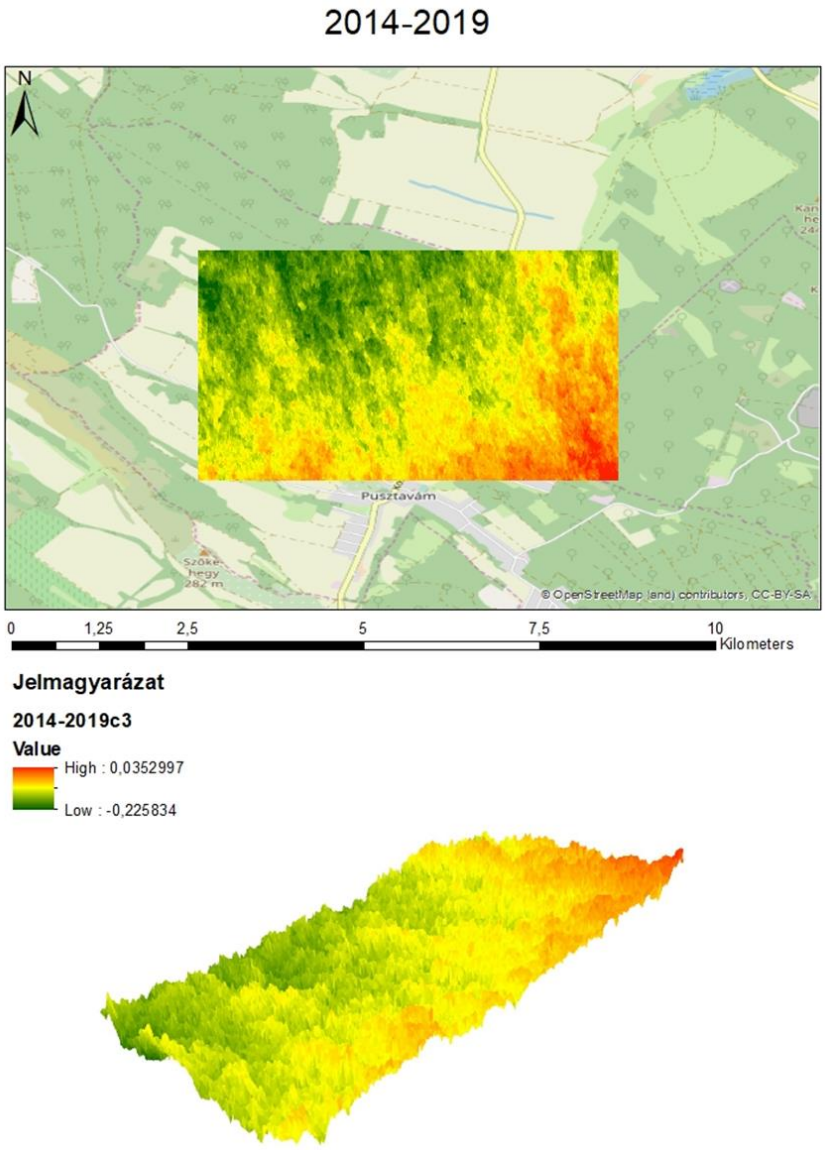
V. CONCLUSIONS

In my dissertation I presented the steps of the theoretical solution of InSAR based evaluation. The following figure summarizes the differences between the two dates. Of course, these values cannot be considered true motions in the present state of processing. The figures also contain clear regular errors in the evaluation. Further investigations are warranted to determine the reasons for this. In the future, I would like to limit my investigations to specific areas where actual surface movement due to mining is expected. Of these areas, I would like to investigate the surface not covered by outlying vegetation. To determine the actual, high-precision surface motion, a PS InSAR technology, which is not discussed in the dissertation, could be a more appropriate method, which would provide a motion detection solution for specific points.

In order to evaluate the results, validation measurements using the traditional method would be necessary, but this would be much more than the work of such a thesis. It is in the process of being discovered that during the period under review, these accurate leveling measurements were made in the field, the results of which could possibly be used for comparison.

In addition, an accurate mining map would be a useful component of such an investigation to know which areas are affected by mining.

It can also be seen from the above that this is only the first step of a larger series of research, which I hope will be completed in a deeper study.



8. Figure Final results on map and in 3D

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Comparison of 3D Photogrammetric Modeling Methods

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***Abstract* – Close range photogrammetry is a commonly used process in the 3D modeling of existing structures. Two modeling methods have been developed for photogrammetric processing. One of them is the photogrammetric assisted CAD editing. The other one is the application of TIN surface based on dense point cloud. I examined the two methods by the 3D modeling of a structure with non-regular surface. My paper studies and compares the two modeling methods and lists advantages and disadvantages, as well as the expected accuracy.**

***Keywords* – close range photogrammetry, digital photogrammetry, 3D modeling**

I. INTRODUCTION

3D modeling of structures is a widespread engineering process nowadays. The spatial geometric model of structures may be used for visualization, archiving, but also as a design model. One method of the 3D modeling of structures is the photogrammetry-based modeling. In this case the spatial location of points of the model can be extracted from images, taken about the object. The result of this procedure is a surface model. The main advantage of photogrammetric 3D modeling is its low cost. This procedure does not require expensive and complex instrument, data acquisition can be done with a simple digital camera.

II. 3D MODELING

The model is defined as a data system representing the physical object. In computer modeling a digital representation is performed by describing object in mathematical way. The resulted geometric model can be displayed or modified with IT tools. The modelled object can be imagined, or real and existing model. In digital modeling we try to describe complex object with a simple, easy-to-use data structure.

The creation of the model is possible using geometrical elements that can be produced in mathematical form. For modeling characteristic point of the object, curves and surfaces, and in certain cases volume elements are used. Depending on the type of geometric elements used for model creation, the 3D model may be a wireframe model, a surface model or a volume model. (See Fig. 1.)

Another option is the point cloud, which is suitable for spatial modeling. But using point cloud alone for modeling has a limitation in the engineering.

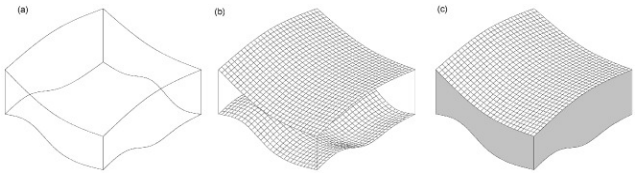

Figure 1. 3D model types: wireframe model (a), surface model (b), solid model (c)

A. Wireframe model

The wireframe model was the first 3D modeling technology. It is the simplest method where little data needs to be stored and the data structure is simple. With the wireframe model the edges of the physical object can be represented. The wireframe model consists of points (or vertex) and curves connecting the points. Despite its simplicity, the wireframe model is less frequently used because of its disadvantages. It cannot represent surface, so that the texture of the physical object cannot be displayed. Furthermore, the visibility of edges cannot be solved by using this method.

B. Surface model

Surface model or shell model can be considered as a further development of the wireframe model. The principle of this technology is the fact that physical objects are bounded by surfaces, either by regular or irregular surfaces. Surface is bounded by curves, and curve is defined by points. Triangular irregular network is often used to approximate irregular surface, where the triangle of the network itself is a regular surface.

The surface model is the most commonly used method in the photogrammetry-based modeling. Texture and shading can be defined on the surface model, and the result will be a realistic-looking model. The texture of model is extracted from photos. Because of its realistic-looking properties, the surface model is popular in visualization and animation.

C. Solid model

The solid model represents volume. It provides realistic modeling, but the process requires high computing power. There is a greater role of solid modeling, where the material nature of the physical object is important. Accordingly, it is mainly used in product development and production, in CAD and CAM systems. During manufacture additive or subtractive processing is performed, resulting in the modification of volume characteristic of the object. Solid modeling is performed by using primitive volume bodies.

For modeling of structures and buildings, the solid body is less interesting. At the same time the outer geometric dimensions and other attributes (such as wall thickness, surface quality, texture) are more important. However, in some cases solid model can be useful in geoinformatics. The recently appeared voxel (volume pixel) technics is becoming more and more popular in the 3D modeling where the volume model is built from small elementary volume blocks.

III. Modeling with photogrammetric data extraction

Creating a spatial model requires measuring points of the modeled physical object. Then these points (primarily vertexes, intersections or characteristic patterns) can be represented in the model coordinate system.

In modeling, we can also create fictional model that does not exist. These models are used in design and can be defined by calculation or by defining in editor programs.

In the case of modeling of an existing physical object, the first task is to perform data extraction by measuring the object in a fixed coordinate system (that may be local or geodetic coordinate system). There are several ways to gain data. Using laser scanner (LIDAR) is widespread and commonly used nowadays. Furthermore, a conventional measurement method can be used, too like measuring tape or total station.

In addition to the above-mentioned data collecting methods, photogrammetric measurement and processing is a fast, efficient and cost-effective way to obtain spatial data. It is an advantageous feature of the photogrammetry that texture of the surface can be extracted easily from photos, while the laser scanner does not provide a coherent texture.

During the photogrammetric survey of buildings and structures the so-called close-range photogrammetry is used, when the collection of photography is performed from lesser distance than the traditional aerial photogrammetry survey is done (usually closer than approximately 100 m).

When a photo is taken, a central projection has been performed to the image plane. The spatial data will then be lost and as a result we will get a two-dimensional flat image (or projection) of the physical object. In the photogrammetry process the spatial position of the image will be restored. (See Fig. 2.) If the spatial position of the image pair from different view is known, the coordinate of the common point marked on the images can be calculated, resulting in the point of the model.

During the photogrammetry procedure for 3D modeling, the classical photogrammetry workflow is performed. Main steps of this workflow are the following:

Planning of acquisition. Before performing image capture, a plan is necessary to specify the number and overlap of photos required for photogrammetric process. It is especially important if an UAV is used.

Capture process. The number of photos depends on the method of modeling. For recording using digital cameras is widespread in photogrammetric survey. It can be performed from the ground, but using UAV is becoming more typical.

Internal orientation. A two-dimensional coordinate system is assigned to the image plane. This ensures that the points of projected object can be identified in a plane coordinate system.

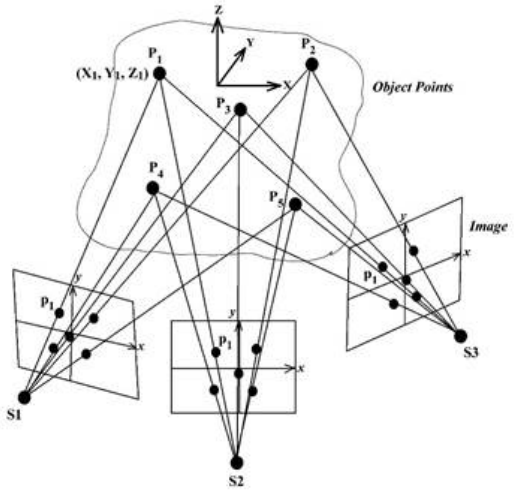

Figure 2. Schematic view of photogrammetric process. There are three images from different view with projection center (S). Object points (P) are projected to the image plane

External orientation. It means the definition of location of the image in the space, namely coordinates of the projection center and angle of rotation of image plane. This is solved by numerical solution of non-linear equation system.

Calculation of points of the model. If spatial locations (coordinates of projection center, angles of rotation) of images are known, using stereo pairs the spatial location of associated pixels on image pair can be calculated. As a result of this processing, every specific points of the model we need can be defined. Using these points in the model space, a required model can be built with various modeling methods.

IV. Model construction

For photogrammetric surface modeling, two typical procedures have been performed. The oldest is the manual or semi-automatic editing and drawing using CAD style application with photogrammetric assistance. In such a system the photogrammetric module provides data for editing and drawing. Using this manual method (or with

some semi-automatic assistance) characteristic point of model can be edited by intersecting lines of sight. A wireframe model can be fitted to these points and then surfaces are fitted on the frame.

Development of computing technology made the automatization of digital photogrammetric process possible. Image matching procedures allow to automatically recognize matching points in stereo photo-pairs, and automatic generate dense point cloud. A triangulated irregular network can be placed on points of the dens point cloud. The TIN mesh makes possible to approximate the complex surface of the object, while the TIN mesh consists of regular triangular surfaces.

Because of the increase of computing power and the spread of convenient, easy-to-use automated photogrammetric software, the generation of dense point cloud and photorealistic surface model is simple and efficient. For this reason, the photogrammetry modeling technology based on point cloud became the dominant one nowadays, while manual modeling with regular surfaces has lost its importance.

V. MODELING EXAMPLE

In this paper the characteristics of the two above mentioned modeling technologies are presented through a specific example.

As a modelled structure, the Gold Bull monument in Székesfehérvár has been surveyed for photogrammetric processing and modeling. This structure bounded by regular and irregular surfaces, it has complex surface, so that it is capable of testing strengths and weaknesses of these two modeling methods.

For manual modeling the PhotoModeler software was used, which is essentially a photogrammetry assisted CAD editing program.

The dense point cloud-based modeling was carried out with the PhotoScan (lately MetaShape) software that allows automatic image matching, orientation, and generation of point cloud and mesh. However, it is a software with higher automatization, a sophisticated setup is possible.

For taking photos about the structure a Sony Alpha A350 digital camera was used that was previously calibrated. A total of 161 photos were taken. About two dozen of photos were used for modeling in PhotoModeler, and all of them were used in PhotoScan.

Ground control points (GCP) were also surveyed for transformation model into the World coordinate system and for analytics of accuracy of the model [5].

VI. COMPARISON OF METHODS

The two software that were used for 3D modeling, make two different modeling concepts.

A. PhotoModeler

PhotoModeler is essentially a photogrammetry assisted CAD editing tool with a software module, that is capable of gaining spatial data for 3D wireframe and surface modeling. This software is a quick and efficient tool for manual editing and modeling of simple, regular shapes. This model is economical, storing of model data requires less memory, and rendering and displaying are quick. This procedure requires fewer photographs. If the projection rays intersect at right angle or close to it, this method has good accuracy.

However, using this method for modeling of objects that have complex and irregular surfaces is not ideal, the process is time consuming and has difficulties. Because of the irregular surface the errors of model will be larger than expected. For this reason, and because of the widespread using of UAVs, PhotoModeler has been developed and a point cloud based automatic photogrammetric module (PhotoModeler Scanner) has been added to the software. Using PhotoModeler Scanner could have been more efficient in recent case, but the manual editing method was used with PhotoModeler to evaluate the two different modeling methods and to compare these methods by empirical means.

There were significant errors resulted by manual editing in the PhotoModeler software. This is due to the fact that some parts of the structure are not visible on photographs, and some surfaces are visible only from very small angle. Therefore, in the editing of points, the tie point selection was characterized by uncertainty.

B. PhotoScan

PhotoScan provides highly automated photogrammetric processing. It produces TIN surface model based on point cloud. It can be used for modeling of structures with complex, non-regular surfaces. Using today's computing power, processing time is already acceptable.

Figure 3. The point cloud model generated by automatic image matching procedure (PhotoSacn)

The need of many photographs with high overlap can be considered a disadvantage. For this reason, the photogrammetric surveying requires more time. In some cases the software tends to calculate wrong points. However, the software is highly automated, but this does

not mean that there is no need for manual intervention, the point cloud should be cleaned of wrong points.

The detection of points may be defective in certain places, especially where projection rays intersect in small angle. In this case the photogrammetric procedure does not recognize points belonging to the model that will have holes on the surface. (See Fig. 4.)

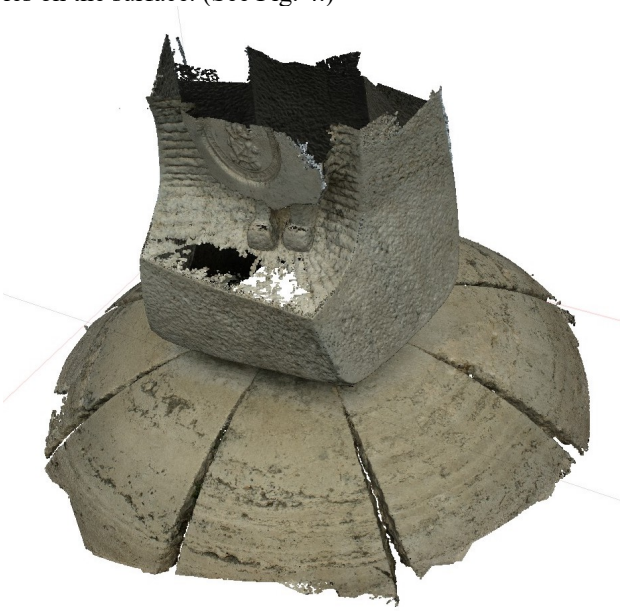

Figure 4. A fragment of the model with discontinuities of the surface

The data representation of point cloud based on TIN surface mode needs big storage capacity. The point cloud consists of points detected randomly as a result of the automated image matching.

Figure 5. Orthogonal view of surface model generated by PhotoModeler

Both methods indicate that taking photographs of appropriate quality is important. The improved light conditions increase the accuracy and visual appearance of the model. Instead of direct sunshine, it is better to take photos in diffused light. For modeling larger object, it is advisable to use aerial survey by taking photos from an UAV.

VII. ACCURACY ANALYSIS

During the modeling task presented in this paper an accuracy test was performed, too. For this test control points were used, which were surveyed by geodetic method. Six of the surveyed points were used as ground control point for coordinate transformation to the geodetic coordinate system.

The remaining points were used to calculate errors. Using these points, the difference between coordinates of control points in the models and coordinates of the real object were calculated. From these values root-mean-square error (RMS error) were calculated in X, Y and Z direction, and in the XY plane.

RMS error was calculated with the following formulas:

$$M_x = \sqrt{\frac{\sum_{i=1}^{n} \Delta X_i^2}{n-1}}$$

$$M_y = \sqrt{\frac{\sum_{i=1}^{n} \Delta Y_i^2}{n-1}}$$

$$M_z = \sqrt{\frac{\sum_{i=1}^{n} \Delta Z_i^2}{n-1}}$$

$$M_{xy} = \sqrt{\frac{{M_x}^2 + {M_y}^2}{2}}$$

where M indicates the RMS error, Δx, Δy and Δz indicate errors of model points.

In both cases the RMS error is around the expected centimeter value, which is a tolerable and typical error in modeling of structures by performing close range photogrammetry process.

TABLE I.
RMS ERRORS OF THE TWO MODEL

	RSM error [m]	
	PhotoModeler	PhotoScan
M_x	0.0218	0.0074
M_y	0.0277	0.0065
M_z	0.0182	0.0129
M_{xy}	0.0249	0.0070

In the Table 1. RMS errors can be seen resulted by modeling with PhotoModeler and PhotoScan software. PhotoModeler's RMS error was slightly higher (2 cm) than it was expected. This is due to the complexity of the surface of object, resulting bigger errors at some points. These errors affected the accuracy of the model as a whole. It also justifies the assumption, that manual editing complex surface is less appropriate, while using TIN mesh provides more accurate model.

VIII. EXTRACTING GEOMETRY FROM POINT CLOUD

Using point cloud in the photogrammetric processing is widespread because this method can be well automated. The process is quick, and the model as a result is accurate. However, it is less advantageous in the practice of engineering. The point cloud is not structured, there is no topology in the cloud and the TIN model provides only representation of the surface. It is no easy to handle point cloud model in the engineering design systems or GIS applications. For these applications the regular model is more practical.

To use model in engineering systems, shapes should be extracted from the point cloud. This process is mainly manual or semi-automatic nowadays. Object detection and identification require human spatial ability. However, automation of the spatial object detection is in progress already, machine learning and artificial intelligence have opened new opportunities in this area of technology.

The question of generalization and level of details should also be mentioned. In many cases, the detailed model of object or structure is not needed. For example, minor roughness of a plain wall in not an important information that should be presented on the model. Generalized model meets the requirements in many cases.

Typical example of application of generalized model is the Building Information Model (BIM), where storing data about small details of the real object are not required. Main geometry dimensions can be extracted from photogrammetry and the generalized BIM model consisting of regular surfaces can be produced from point cloud [1]. (See Fig. 6.)

Engineering design software offers a number of solutions to perform point cloud-to-BIM task. One of the widespread applications with point cloud data to BIM capabilities is the Autodesk Revit, that is capable to generate model from point cloud by using manual, semi-automatic and automatic ways.

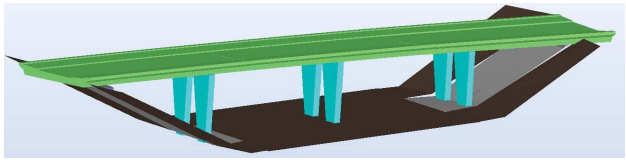

Figure 6. BIM model extracted from point cloud. Source: BIM Handbook, p. 196.

IX. CONCLUSIONS

Using of point cloud in photogrammetric processing is widespread because of its efficiency, but regular CAD models can be better used in engineering tasks. However, manual modeling based on photogrammetric data extraction is simple and fast in case of modeling of regular shapes, so that this method also has the right to exist today. For irregular, complex object the manual editing method is difficult and time-consuming.

Spatial modeling based on close range photogrammetry ensures cm-level accuracy, which is sufficient in geodetic and engineering practice.

Storing of the point cloud data is a resource consuming method, so that it is a preferred way to extract regular CAD model from the point cloud for use it in engineering systems. The extraction of regular geometric model performed by manual, semi-automatic and less frequently automatic method.

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Application of robotic systems for fire exploration

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***Abstract*—Robotic systems find their application in many areas of people life nowadays. This research work summarizes the using of a quadcopters for fire exploration with an information-reading algorithm, methods of processing of image color component data, and processing video for fire detection.**

***Keywords*—robotic system, quadcopter, fire exploration, processing of image, fire detection.**

I. INTRODUCTION

Nowadays, it is actual using robotic systems in different areas. One of the important problems in Kazakhstan is fire safety and the researches on it has been and remains substantial in Kazakhstan. The relevant application of robotic systems and information technologies in fire safety is using quadrocopters for fire exploration.

Quadrocopters are quite expensive devices that require certain management skills and craftsmanship. In this regard, the use of copters in fire safety is not as extensive as we would like. The widespread use of quadrocopters in the prevention of fire and early detection is the future of fire safety of Kazakhstan. For fire prevention and early detection of fires, quadrocopters are used as surveillance and reconnaissance devices. These quadrocopters are provided with special video cameras and thermal imagers. Quadrocopters are used to monitor large areas, difficult to access and few passable places. [7]. Such locations include forests, peatlands, swamps, mountains, steppes, landfills and more. Copters are also used to check thermal points from satellite images.

There are facts of using quadrocopters for patrolling and monitoring the fire condition of large enterprises and warehouses. Previously, this function was performed by numerous security officers and fire brigades, with constant patrolling and bypassing the territory. Subsequently, their work is performed by several trained employees who, with a certain periodicity, fly around the territory. The most effective actions of which are noted at night, when patrolling the territory of the object using a thermal imager.

During a fire, the key to extinguishing is the choice of the decisive direction for extinguishing the fire. To make such a decision, it is necessary to have as much information as possible about the fire and the object of the fire. But due to the large areas of facilities, complexity and location, it's difficult for a person to come to a fire to assess the scale of the incident and make the right decision as quickly as possible. In connection with the above, progress came to the aid of firefighters [3].

At the moment, the main task of quadrocopters is a fire exploration from the air. Upon arrival to the fire, the specialist as soon as possible launches the quadrocopter and begins to collect information about the fire, namely:

• location of victims in the territory of the fire;

• the location of people at risk from fire and secondary factors;

• determination of sources of ignition;

• threat of fire spreading to other buildings and structures;

• convenient places of approach and access to places of burning and evacuation.

Detection of fire or flame by remote photography or video recording of controlled terrain and their automated analysis are important tasks. Now widely used computer systems using digital image processing. The paper proposes an approach to solving this problem, based on the use of a quadcopter as an unmanned aerial exploration robot and data processing of the image from the robot, which contain or not contain a fire.

Fig.1. Quadcopter with camera for fire exploration

II. METHOD OF FIRE DETECTION

Analysis of digital video. The functioning of monitoring systems can be based on the analysis of photographs or video sequences, in other words, static or dynamic images. There are two main approaches: the detection of moving objects and color analysis.

The basic idea of building the algorithm (Fig. 2) is that the optimally selected combination of different approaches, each of which allows determining a specific flame feature with high accuracy, it must determine the presence of a flame on video frames received from a quadcopter camera with a high probability.

The flame has a large number of different signs, such as color, variability (dynamics), shape, and the behavior of the smoke that appears with the flame, etc. In this work, following the article [1], attention is focused on two basic signs - color and variability (dynamics).

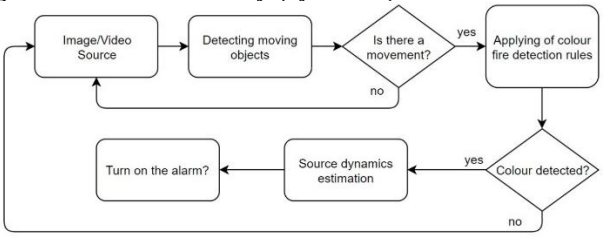

Fig.2. Proposed Fire Detection Algorithm

The principle of detecting moving objects is often used to highlight fires by subtracting successive frames or a background image [2]. In the first case, it finds changes in the images when moving from one frame to another. The main

disadvantage of this method is that overlapping areas in images can be mistakenly taken as background.

In the case of subtracting the background image, the dynamic areas are extracted from the static background image, the main disadvantage is that the area can be extracted erroneously, if the background image is not updated on time or incorrectly. However, this method can be used to assess the characteristics of the fire, for example, to measure the coordinates of a fire front.

Another way to detect areas of fire is color analysis. Specific implementations of this method are based on space analysis of abstract mathematical color models, which are sets of 3-4 numbers. The most common color models are [6]:

- RGB describes each color with a set of three coordinates, each of which corresponds to the decomposition of a color into red, green and blue components;
- YCbCr is one of the ways to encode RGB information, where Y is brightness, Cb and Cr are characterize gamma correction;
- HSL or HSI describes each color with a set of three coordinates - color hue, saturation, lightness [8];
- HSV describes each color with a set of three coordinates - hue, saturation, value

Based on the methods describing the flame in the RGB color model, we find belonging of pixel to the flame image based on the rules by the system [3]:

$$\begin{cases} R(x,y) > R_{mean}, \\ R_{mean} = \frac{1}{K}\sum_{i=1}^{K} R(x_i, y_i), \\ R(x,y) > G(x,y) > B(x,y) \end{cases} \quad (1)$$

where, $R(x,y), G(x,y), B(x,y)$ - red, blue and green values in pixel *(x, y)*, K - total pixels, R_{mean} - average intensity of red color on the basis of three selected rules, according to which the saturation of each possible pixel of the flame image must be greater than a certain threshold value [5].

In some cases, it is possible to describe a flame image in the YCbCr color space, using a fuzzy inference system [4] to make a decision about whether a pixel belongs to a flame image.

Dynamic characteristics of fire allow allocate it from other objects of similar color. Analyzes for temporal changes in intensity for each pixel on several consecutive frames [8]. If these changes exceed a certain threshold value, it is taken for a pixel that belong to the image of the flame. It is assumed that the height of the flame changes with time due to the movements of its tongues, therefore the height is the main dynamic characteristic of the flame [9].

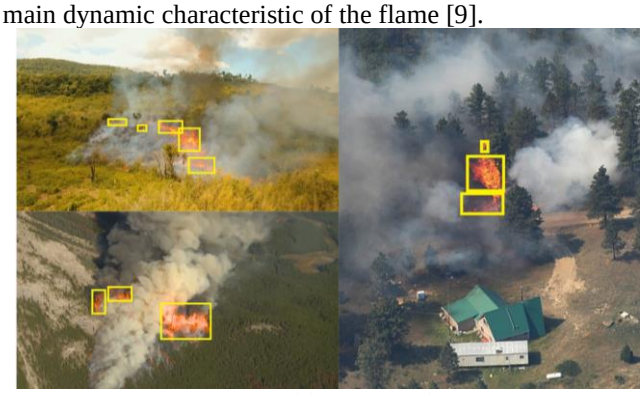

Fig.3. Examples of fire detection from video

In some cases, we take the history of changes in the red channel of each pixel of an RGB image belonging to the fire contour during a short period of time [9]. This data is then used as input in the analysis.

Experimental works carried out based on the above methods of detecting fire. The main aim of this example is to automatically detect fire in video (Fig.3), using computer vision, implemented in real-time with the aid of the OpenCV library. Given the computer vision and image processing point of view, stated problem corresponds to detection of dynamically changing object, based on his color and moving features [11].

III. CONCLUSIONS AND FURUTE WORKS

Thus, the existing results suggests that robotic systems with information technologies can be used for fire exploration and fire detection. Theoretical researches and practical experiments shows that the quadcopter is a multifunctional device that combines automatically the execution of a flight program from takeoff to landing, transmitting the necessary information to detect fire by using data from photographing controlled areas with subsequent computer processing of data. The use of modern image processing tools can significantly improve the efficiency of solving many practical problems. Based on this, future work is the optimization of an automated fire exploration system, the improvement of fire exploration methods using robotic devices.

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Embedded LED lamp control system based on the ESP8266 microcontroller

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***Abstract*—The article provides an analysis of energy consumption in the field of artificial lighting and identifies areas for reducing energy consumption for lighting. The application of LED light sources with embedded systems is considered as one of the promising directions. Such a combination leads to increased energy efficiency of lighting devices and the possibility of their implementation in the technology of the "Internet of things" (IoT). The popularity of the concept of the "IoT" has forced manufacturers of semiconductor technology to develop microcontrollers with technical parameters that support the transmission of signals (information) via local or global networks. The advantages of the NodeMcu V2 board based on the ESP8266 microcontroller for developing embedded lighting control system for rooms implementing the concept of the IoT are demonstrated.**

Keywords—embedded system, LED, microcontroller, control, energy efficiency

I. INTRODUCTION

The problem of sustainable energy use against the backdrop of scarce resources and growing consumption is one of the most pressing problems of the global community, the solution of which is becoming a strategic objective for many countries. The steady growth of natural energy resource pricing, environmental concerns, abatement of pollutant and greenhouse gas emissions all make it crucial to find solutions for the problems of energy conservation and efficiency.

According to the International Energy Agency (IEA) [1], mains electric lighting consumes 19% of the global electricity generation of which 20 to 40% is spent on lighting in buildings [2, 3]. Power consumption associated with lighting accounts for 6-8% of greenhouse gas emissions [4].

In Kazakhstan, artificial lighting accounts for 12-14% of total power consumption [5]. Lighting devices in public and residential buildings consume some 40-60% of that power, which is 2-3 times higher than in European countries [6].

Based on its analysis of the global economic and energy efficiency trends, the IEA has made a forecast that the demand for artificial lighting is going to grow by 60% over the next 20 years. Without advanced technology and new energy efficiency policies, such growth in electricity generation will result in increased consumption of energy resources, which are mostly non-renewable, and in degradation of the environment due to the higher hydrocarbon fuel-associated emissions.

Lighting is a segment with high energy conservation potential. It is estimated that power consumption in Kazakhstan can be reduced by some 30%-35% [7].

Investing in energy-efficient lighting is also one of the most cost-effective ways to reduce CO2 emissions [8].

Studies show that modern technology will reduce electricity for lighting by 50% [9,10].

One way to achieve significant energy efficiency is to use new semiconductor (LED) light sources and the development of lighting devices based on them. World experience shows that street and office lighting based on the automation of LED technology improves the quality of life while ensuring economic benefits and environmental safety.

There are two directions of technological development in the field of electric lighting. The first is to improve the light-emitting components and designs lighting equipment: an increase the light output of the light source, reduction of power density; improving lighting and energy characteristics. The second trend involves the development of methods and modes of operation of lighting products: optimizing the placement of lamps depending on the purpose of visual tasks; efficient use of natural light with view of the diurnal cycle, seasonal and climatic region; implementation of lighting control systems.

With the introduction of digitalization and the creation of smart homes and cities, great interest is shown in the development of Internet devices. The most common are devices that have their own monitoring and control measurement systems. This became possible with the advent of microcontrollers with a small size and high technical characteristics. Currently, much attention is given to the creation of effective devices and systems with embedded intelligent controls [11, 12].

A key factor in the work of embedded systems and their feature is efficiency. This means that it is not always enough to perform a given function to solve a task. The solution must be unconventional. For example, a system must be fast or energy efficient, or cheap. And therein lies the difference between developing embedded systems and traditional software.

The reason for these restrictions is that for most of these devices it is very important to reduce their cost as, for example, for consumer electronics devices.

The embedded system is the applied computer system created for management of a number of functions. Because of the rapidly evolving technology, the importance of embedded systems is a highly fluctuating definition. Development of technologies leads to decrease in cost value and allows to implement different equipment and program components in the embedded systems. The embedded system intended for a specific objective usually consists of inputs, outputs and small processing unit. The majority of the embedded systems are jet systems. The information received by the system is constantly processed, and the system acts information on the basis that changes depending on the interaction system and environment.

A variety and range of complexity of such systems are huge. These are systems from the controller of office door lock or a garland to infocommunication "stuffing" of the plants automatic machines, intellectual power generating systems, buildings, the transport systems and even the «smart» cities. Examples of some largest scopes: industrial automatic equipment, transport, avionics and military equipment, telecommunications, medicine, intellectual building, housing and public utilities, household appliances, etc.

Simple embedded system includes [13]:

– microprocessor module with memory;

– peripheral system (sensors, executive elements and control units for communication with the control object, user interface device);

– electric power supply system;

– design of the device;

– software for control.

The main features of the embedded system are:

– real-time operation;

– different, often heavy, operating conditions;

– autonomy of work;

– high requirements for reliability and safety of functioning;

– limited resources.

Significant progresses in microelectronics technology have made it possible to increase miniaturization of embedded systems. This trend leads to the development of tiny embedded systems integrated into an increasing number of household items and will create a world of smart devices.

II. Main part of the research

To implement lighting control systems in the premises companies offer a wide range of functionality based on modern sensors and software. Such systems are quite difficult to connect and operate, and also have a high cost, which is not attractive even if you save energy and save the environment.

The popularization of the Internet of Things technology has led to an increase in the production of miniature microcontrollers with the additional ability to control various devices (for example, lighting lamps) from a distance by transmitting a signal to a local network or the Internet via Wi-Fi, Bluetooth, Ethernet or a cloud server.

Structural scheme of the embedded lighting control system in the room is shown in Fig. 1. The LEDs in the lighting device can be controlled automatically (software) or remotely (by the user) from a mobile device.

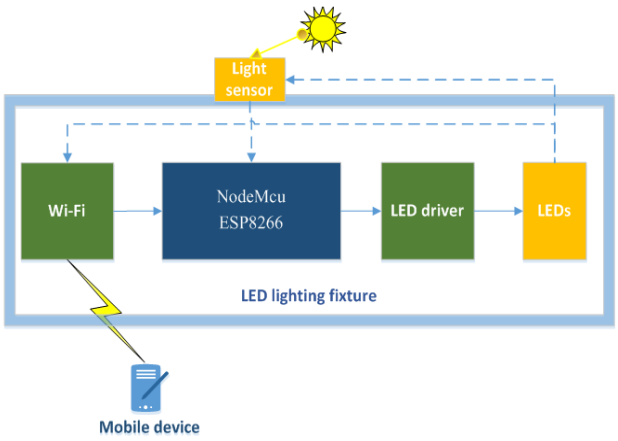


Fig. 1. General scheme of the embedded lighting control system

Automatic control. The brightness value of the LED is determined by the photoresistor, the analog signal from thephotoresistor goes to the microcontroller, where it is converted to a PWM signal. The PWM signal is sent to the LED driver. The driver sets the brightness value on the LEDs in accordance with the received signal.

Remote control. The change of mode to remote control occurs through the mobile device by the user. The wireless connection of the microcontroller with the mobile device is provided through the Wi-Fi module. Control from mobile device is carried out using a graphical interface. The brightness value of the LED is set by the user, which is transmitted to the microcontroller and converted into a PWM signal. The LED driver sets the brightness value in accordance with the received PWM signal.

The market for manufacturers of microprocessor technology provides an extensive selection of microcontrollers for developing devices for the Internet of things. It is worth noting that the initial process of developing a new device involves the stages of debugging and testing the device. For a rather long period of time, two debug boards Arduino and STM32 occupied the leading position in the engineering community. Debug boards have gained popularity due to a number of positive aspects, the main of which are the ability to collect a prototype of the device under development without soldering, using a breadboard and connecting wires. The second point is not so clear, this is the ability to flash the microcontroller directly without additional programmers.

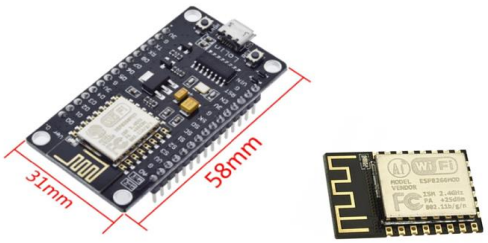
The above brands include a wide range of debug boards. Despite this, the microprocessor technology market is constantly being updated and provides an opportunity for an alternative choice. Our attention was drawn to the ESP line of microprocessors.

ESP8266 is microcontroller of the Chinese producer Espressif Systems with a Wi-Fi interface. The ESP8266 is an on-chip SoC that includes 32-bit microcontroller Tensilica, standard digital peripheral interfaces, antenna switches, a

radio frequency simulator, a power amplifier, a low-noise receiving amplifier, filters and power management modules, all located on a small chip size (Figure 2). In addition to Wi-Fi, the microcontroller is distinguished by the absence of a user non-volatile memory on the chip; user programs are executed from external memory with the SPI interface by dynamically loading the necessary program elements.

The microcontroller attracted attention in connection with the release of products based on it at an unusually low price. For comparison, today its cost is about $ 2.5, which equaled the cost of the Arduino Uno board [14].

Applications for the ESP8266 include automation systems, various smart home systems (wireless control, wireless sockets, temperature control, addition to alarm systems), mobile electronics, ID tags, children's toys, Mesh networks.



a) b)

Fig. 2. Appearance of the NodeMcu board (a) and the microcontroller ESP8266 with Wi-Fi module (b)

On the basis of ESP8266 microcontroller has an extensive range of debugging boards [15]. We have been chosen NodeMcu v2 ESP8266-12E.

The NodeMcu v2 was designed specifically for the Internet of Things (IoT). The NodeMcu v2 board contains ESP-12E chip with integrated ESP8266 microcontroller with a clock frequency of 80 MHz and a 4 MB flash memory. ESP8266 includes a Wi-Fi transceiver, so you can not only connect to a Wi-Fi network but also create your own network.

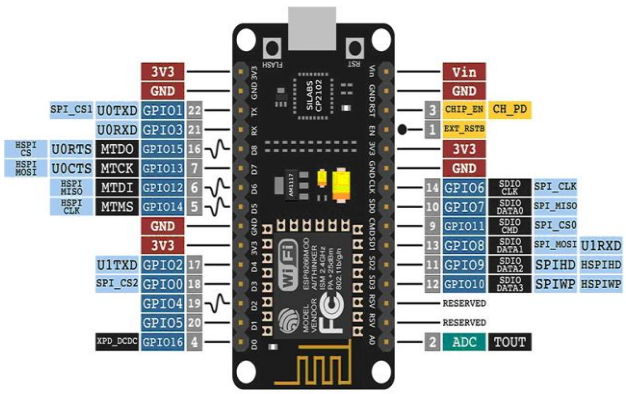


Fig. 3. Pinout for NodeMcu v2 board on ESP8266-12E

For programming NodeMcu, or rather ESP-12E, the board has a micro USB connector and a USB-UART CP2102 controller (Silicon Labs), which converts the USB signal to a serial port. The NodeMcu module is powered through the built-in micro USB connector or from an external 5 V voltage source connected to the VIN and GND pin. Since the operating voltage of the ESP8266 is from 3 V to 3.6 V., the voltage regulator AMS1117 is installed on the board with an output voltage of 3.3 V and a current of up to 600 mA. For convenience and the ability to connect external devices (sensors), 3.3 V is additionally output to the side contacts of the NodeMcu board with the designation 3V3. [16].

NodeMCU has total 30 pins output from both sides of the board, of which 17 are GPIO pins. The pinout for the NodeMcu v2 board on the ESP8266-12E used in our project is shown in Fig. 3 [17].With the help of boards based on the ESP8266 microcircuit it became possible to implement intelligent projects. This is due to the function of the microcontroller to act as a web server and connect to an existing network, and also set up a network of its own [18].

III. Practical Results

A schematic diagram for designing an experimental layout is shown in Fig. 4. Despite the simplicity of this circuit, the possibilities of the proposed system are quite wide. The system allows data exchange with a mobile device and a personal computer.

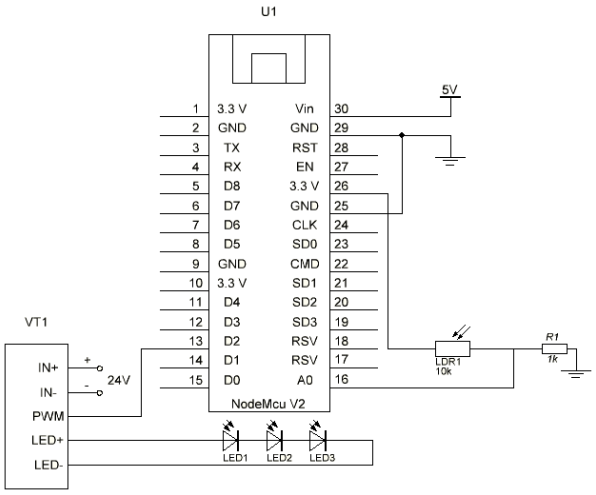


Fig. 4. Circuit diagram

To provide communication with a mobile device and to set the operating modes of the LEDs, an algorithm was developed (Fig. 5).

The popularity of the concept of “Internet of things” gave impetus not only to the development of microprocessor technology, but also to software. The RemoteXY application was used to develop a user interface and to control the level of illumination through a mobile phone. The RemoteXY system is presented in the form of two modules: the editor of mobile graphical interfaces for controlling the controller, as well as the RemoteXY mobile application that allows you to connect to the controller and display graphical interfaces [19].

It should be noted that RemoteXY offers a large list of components for design. For communication between the controller and the mobile device you can use Bluetooth, WiFi in client and access point mode, Ethernet by IP address or URL, Internet from anywhere through a cloud server. Widely used integrated development environments such as Arduino IDE, FLProg IDE, MPIDE are supported. The interface source generator works with the main types of Arduino, WeMos, ChipKIT microcontroller boards, as well as NodeMCU V2, NodeMCU V3 boards.

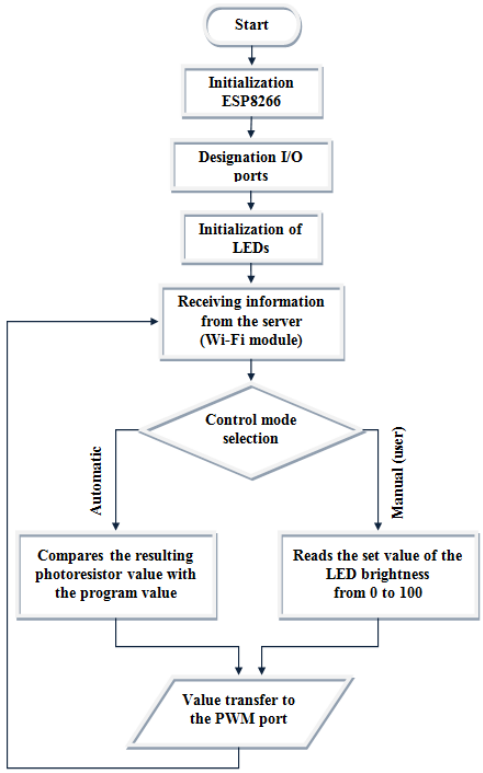


Fig. 5. The algorithm of the embedded control system

The developed interface for a mobile phone is shown in Fig. 6. The interface offers a switch between automatic and manual modes of the system and the ability to regulate each mode separately.

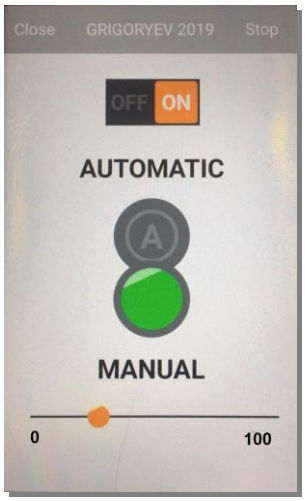


Fig. 6. The mobile device interface

In our project, the ESP8266 module is configured as a standalone Wi-Fi access point. For this mode of operation, no binding to an existing Wi-Fi network is required. To connect, the mobile phone is connected to the access point we created (in our case, Grigoryev2019).

It should be noted that the configuration of the graphical interface is recorded and stored in the controller. When connecting, there is no interaction with third-party servers in order to load the graphical interface. The user interface configuration is loaded into the mobile application from the controller.

Conclusion

In the era of the Internet of Things (IoT), classic indoor lighting control systems give way to embedded systems based on modern microcontrollers that combine the necessary technical parameters, small size, low cost and the ability to develop lighting devices that support the IoT concept.

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Voice Recognition Management System

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Abstract – **The report discusses the algorithm of the recognition system for isolated words, the main stages of recognition, the mechanism of a digital system for processing an audio signal, cepstral coefficients as well as the implemented software project - a computer model of a system for recognizing words in Visual Studio using built-in functions.**

Keywords – **recognition, digital processing system, discrete Fourier transform, Kotelnikov theorem, Hamming window**

I. INTRODUCTION

The relevance of this topic for many years remains the most fruitful area of research, both in mathematics and in the field of programming. The task of speech recognition remains relevant today.

Since the advent of the first computers (electronic computer), one of the most important issues in the development of computer technology has been the process of human-machine interaction. For a long time it was available only to narrow specialists - technologists "communicated" with the machine through an intermediary - a programmer. This situation lasted until the appearance of the dialog interface, when the user was able to personally enter the command addressed to the machine from the keyboard and receive a meaningful answer. The appearance of a graphical interface, in which there was no need for a person to know any commands, led to the widespread dissemination of personal computers.

However, man has always sought a more universal and natural way of interacting with computers. The creation of natural means for a person to communicate with a computer is currently the most important task of modern science, while the voice input of information is carried out in the most convenient way for the user.

Speech recognition problems are studied by: Carnegie Mellon University (USA) [1], University of Illinois (USA), Oregon Institute of Science and Technology (USA), Computer Center of the Russian Academy of Sciences (Yu. I. Zhuravlev, V. Ya. Chuchupal), Institute for Information Transmission Problems of the Russian Academy of Sciences (V. N. Sorokin), Institute of Mathematics SB RAS and Novosibirsk State University (N. G. Zagoruyko and V. M. Velichko), Moscow State University named after M.V. Lomonosov (O. F. Krivnova), Moscow State Technical University N. E. Bauman (Yu. N. Zhigulevtsev), Moscow Power Engineering Institute (A. I. Evseev), Moscow State Linguistic University (R. K. Potapova), Moscow Technical University of Communication and Informatics (Yu. N. Prokhorov), St. Petersburg State University (V. I. Galunov), St. Petersburg Institute of Informatics and Automation of the Russian Academy of Sciences. [2]

Such companies as IBM, Philips, Dragon Systems, Cognitive Technologies, Istrasoft, Sacrament and others conduct research in this area, which indicates its relevance.

Analysis of existing speech recognition systems [3] (Dragon NaturallySpeaking, Sakrament ASR Engine, Voice-Mode, SIRIUS, etc.) showed that developers create either large specialized speaker-independent systems or complexes for developing speech applications that give high recognition accuracy with a small dictionary of commands; or user applications that enable voice control of the computer and voice input of text. This class of systems needs training for a specific speaker and, in this regard, does not provide high quality recognition.

In most systems, Fourier transform is used to create models of speech units, only a few support the Russian language, since additional studies of the linguistic component of the process of recognizing Russian-language speech are needed.[4]

The digital audio signal processing system involves representing the analog speech signal in digital form. As a result of analog-to-digital conversion (ADC), a continuous signal is translated into a series of discrete time samples, each of which is a number. This number characterizes the signal at a point with a certain accuracy. The accuracy of the representation depends on the width of the range of numbers obtained, and, therefore, on the resolution of the ADC.

II. MATERIALS AND METHODS

The frequency of digitization is also of no small importance. The human ear perceives sound in the frequency range from 16 Hz to 22 kHz. In fact, the boundaries of audible frequencies depend on a particular person - his age, gender and health.

The possibility of transmitting a continuous signal by its discrete samples was justified by V. A. Kotelnikov in 1933 [5]

The human voice corresponds to a frequency range of 300-4000 Hz, therefore, in order to restore the voice signal without loss, it is necessary to use a sampling frequency greater than 8 kHz. The optimal value of the frequency in the conditions of the problem under consideration is 12 kHz.

According to Kotelnikov's theorem, if a continuous signal has a spectrum limited by frequency, then it can be completely and unambiguously reconstructed from its discrete samples taken at time intervals.

$$T = \frac{1}{2 \cdot F_{max}}, \quad (1)$$

With a frequency of $F_d \geq 2 \cdot F_{max}$, where

F_d is the sampling rate;

F_{max} is the maximum frequency of the signal spectrum.

In other words, the signal sampling frequency (ADC sampling frequency) should be at least 2 times the maximum signal frequency that we want to measure.

In order to calculate the signal spectrum from its discrete samples, the discrete Fourier transform (DFT) is used.

The classic approach for digital sound processing is the conversion of the amplitude-time dependence into the frequency form. It allows you to adequately describe in frequency coordinates all types of signals; frequency-truncated Fourier components describe the data more plausibly than any other power series. The individual components are sinusoids and are not distorted during transmission through linear systems, which allows them to be used as good test signals.

The direct Fourier transform has the form:

$$X_k = \sum_{k=0}^{N-1} x_n e^{-\frac{2\pi i}{N} kn}, \quad (k=0,\dots, N-1) \qquad (2)$$

where X_k are the spectral samples, x_n are the samples of the discrete signal, N is the conversion length.

Human speech is a sequence of sounds. Sound, in turn, is a superposition (superposition) of sound vibrations (waves) of various frequencies. The wave, as we know from physics, is characterized by two attributes - amplitude and frequency. In order to save the audio signal on a digital medium, it is necessary to divide it into many gaps and take some "average" value on each of them.

The process of solving the problem of recognizing isolated words can be divided into four main stages:

- signal input from the external environment into the system;
- finding the endpoints of a word;
- extraction of signal characteristics;
- determination of the recognition result.

Separating a word from a continuous stream of incoming information is a difficult task due to the characteristics of the voice, the environment and the equipment with which the sound signal is recorded.

Sound signals, propagating in real conditions, passing through various real mediums of sound transmission, change their shape beyond recognition. In the Nature of sound waves, there is only one wonderful sound wave, in which something remains always unchanged, regardless of which mediums of sound transmission it passes through and from which many surfaces this wave is not reflected (adding up with all its many reflected waves). [6]

Definition of word endpoints

The main unit of processing a digitized signal is a frame - an array of samples corresponding to a specific time period.

Frames are a more suitable unit of data analysis than specific signal values, since it is much more convenient to analyze waves at a certain interval than at specific points. The location of the overlapping frames allows smoothing the results of the analysis of frames, turning the idea of frames into a certain "window" moving along the original function (signal values).

It was experimentally established that the optimal frame length should correspond to a gap of 10ms, "overlap" - 50%. Considering that the average word length (at least in my experiments) is 500ms - this step will give us approximately 500 / (10 * 0.5) = 100 frames per word. [7]

To isolate a word from a continuous stream of information in real time, a simple but at the same time quite effective method for determining the Rabiner-Sambur endpoints based on the calculation of the frame energy and the frequency of zero-crossing can be used. This method requires less computation due to the lack of additional signal conversion from the time domain to the frequency domain.

In this case, the frame energy is understood as the normalized sum of the absolute values of the amplitudes of the discrete samples of the signal (1).

$$E = \frac{1}{K} \sum_{n=1}^{N} A_n, \qquad (3)$$

where K is the normalization coefficient, N is the frame length.

To calculate the energy value, other calculation methods can be used, for example, finding the Euclidean norm. Since the minimum memory unit for signal processors is 2 bytes, as well as the fact that the resolution of the audio codec used to digitize the audio signal is 16 bits, arrays containing double-byte elements are preferred as structures for storing information. The normalization of the final value is necessary in order to avoid overloading the discharge grid.

The normalization coefficient is selected from the following considerations: since the resolution of the codec is 16 bits, and the amplitude value can be either positive or negative, the maximum value possible in absolute value, which can be stored in a two-byte signed type, is 216-1 = 32768 , and the maximum sum of the absolute values of the amplitudes is 32768 * 512. Based on the foregoing, as well as the fact that the energy value is stored in a double-byte signed type, the normalization coefficient is chosen equal to the length of the frame.

The zero-crossing frequency is defined as the number of times the original signal changes sign and its value is above the noise threshold. This value does not need to be normalized, since the maximum value of the parameter is N-1.

III. SOLATION OF CHARACTERISTICS OF SPEECH INFORMATION. CHALK-CEPSTRAL COEFFICIENTS

One of the stages of the speech recognition process after extracting a word from the input data stream is the extraction of parameters (characteristics), where different techniques are used, for example, the method of searching for cepstral coefficients. The main task at this stage is to isolate certain parameters of the signal, such that the number of these parameters should be minimal in order to speed up the comparison with the sets of characteristics from the library, and at the same time, these parameters should be such that they can be used fairly accurately compute a specific word. [9]

Mel-cepstral coefficients are a peculiar representation of the energy of the spectrum of an audio signal.

Human hearing aids have the property of frequency masking - a situation where normally audible sound is covered by another loud sound with a close frequency. This characteristic is dependent on the signal frequency and varies from 100 Hz for low frequencies to 4000 Hz for high frequencies.

The range of audible frequencies can be divided into a certain number of critical bands (division into 24 critical bands is accepted), indicating a drop in ear sensitivity for the highest frequencies. Critical bands are considered another parameter of sound, similar to its frequency. But, unlike the frequency, completely independent of the organs of hearing, the critical bands are calculated in accordance with auditory perception. As a result, they form some measures of frequency perception, for which the units of measurement - bark and chalk.

The barks scale (Figure 1) is associated with critical hearing bands, and since the width of these bands is uneven, increases with increasing frequency of sound vibrations, the scale is uneven. The direct and inverse relationships between the tone frequency in Hz and the pitch in barks are calculated by formulas (4) and (5), respectively:

$$b = 13\,\mathrm{atan}(0.00076 \cdot f) + 3.5\mathrm{atan}(\tfrac{f}{7500})^2 \quad (4)$$

$$f = \frac{52548}{b^2 - 52.56b + 690.39} \quad (5)$$

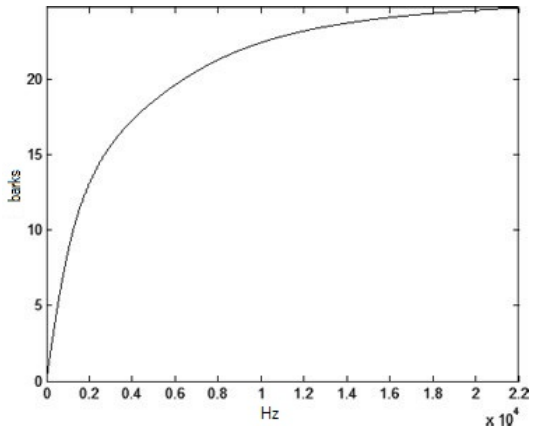

Figure 1 - Audible frequency range: barks scale.

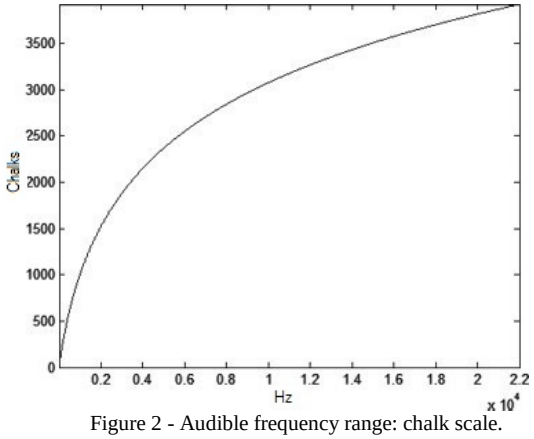

Figure 2 - Audible frequency range: chalk scale.

The chalk scale is uneven (Figure 2). The chalk scale is based on the statistical processing of a large amount of data on the subjective perception of the pitch of sound tones. According to the results of studies, we can say that the pitch of the sound is mainly related to the frequency of oscillations, however, it depends on the sound volume level and its timbre. The direct and inverse relationships between the tone frequency in Hz and the pitch in chalk are calculated by formulas (5) and (6), respectively:

$$m = 1127.01048 \cdot \ln\left(1 + \frac{f}{700}\right) \quad (5)$$

$$f = 700(e^{\frac{m}{1127.01048}} - 1) \quad (6)$$

The frequency range of a person's voice is limited and ranges from 300-4000 Hz. Therefore, by modeling a band-pass filter, one should discard the frequency components that are located outside this range and, therefore, do not carry a semantic load.

The studied signal is divided into frames based on the Welch periodogram method - the signal sample vector is divided into overlapping segments (using 50% overlap), after which each frame is multiplied by the weight function and the discrete Fourier transform is calculated for it (2). The Hamming window (7), which is shown in Figure 3, is used as the weighting function. Using the weighting function allows weakening the spreading of the spectrum at the junction of frames.

$$x_n = 0.53836 - 0.46164cos\frac{2\pi n}{N-1} \quad (7)$$

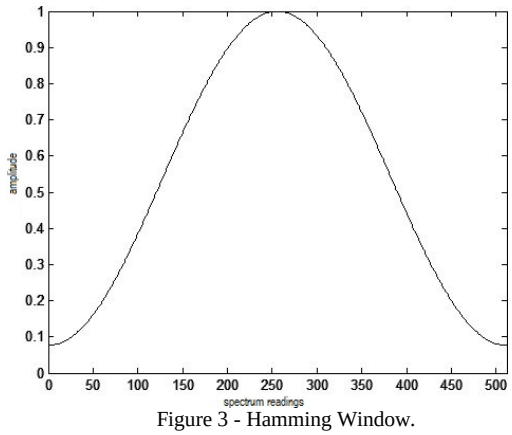

Figure 3 - Hamming Window.

Research results in the field of psychophysical perception say that the most significant information is in the actual frequency spectrum, therefore, after the Fourier transform algorithm for further analysis, the actual signal spectrum is determined, where phase information can be omitted.

Results and Discussion

Speech processing begins with an assessment of the quality of the speech signal. At this stage, the level of interference and distortion is determined. The evaluation result is sent to the acoustic adaptation module, which controls the module for calculating the speech parameters necessary for recognition.

The start window of the program is shown in Figure 4. The process of recognizing isolated words begins after a user clicks on the picture (Figure 4). After clicking, the working form opens, where (by opening the form) the microphone of the computer is turned on. The user speaks certain words from the software "dictionary", which are statically registered in the program. Speech information is fed to the PC microphone, if the degree of similarity of words spoken by the user with the dictionary is more than 50 percent, the corresponding result will appear on the screen.

In the signal, sections containing speech are highlighted, and speech parameters are evaluated. Phonetic probabilistic characteristics are distinguished for syntactic and semantic analysis. (Evaluation of information about parts of speech, word form, and statistical relationships between words.)

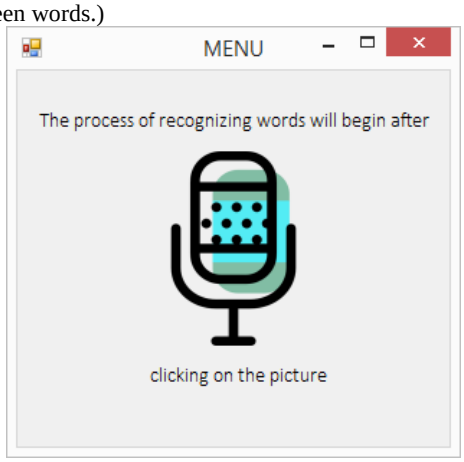

Figure 4 - The start window of the program " Word Recognition".

Further, the speech parameters enter the main unit of the recognition system - the decoder. This is a component

that compares the input speech stream with the information stored in acoustic and language models, and determines the most likely sequence of words, which is the end result of recognition. The work of the program "Word Recognition" is shown in Fig. 5-6.

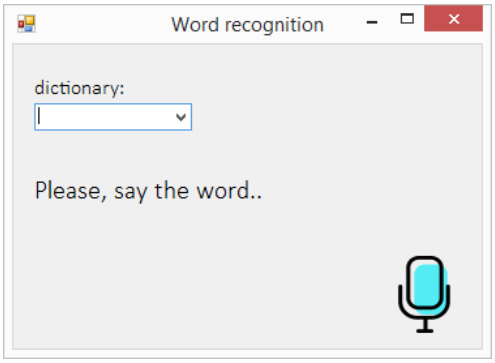

Figure 5 - The window of the program “Word Recognition”.

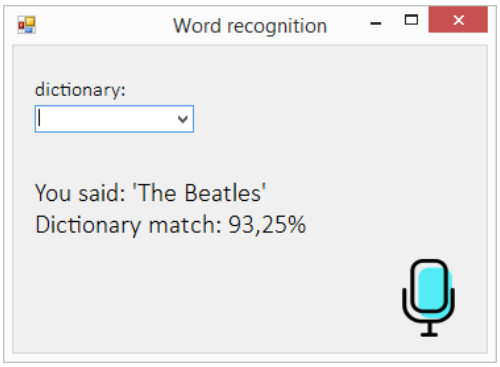

Figure 6 - The result of the program.

In the course of the work, a mathematical model for the automatic recognition of individual words was developed, and an algorithm for a program for recognizing isolated words was also built.

Conclusion

The result of the work is a computer implementation of the algorithm for recognizing isolated words using Visual Studio 2018. In the work, a program was developed in the high-level programming language C # .net, which implements the described algorithm for modeling speech recognition.

The results obtained showed the possibility of using the distinguished parameters of speech signals for speech recognition.

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Plans for the Security Analysis of IPv4aaS Technologies

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***Abstract*— This paper focuses on the IPv6 transition technologies, our aim is to identify the potential security issues within these technologies infrastructure and finding the best implementation platform for the technology itself. The paper surveys many transition technologies, their security analyses, their vulnerabilities and what are the best applicable ones in terms of smooth transition and more secured network.**

Moreover, the paper focuses on 464XLAT, its mechanism, architecture, DFD diagram and it gives a summarized overview on the technology, its possible gaps and prioritize these vulnerabilities from the most vulnerable point to the least one.

Keywords—IPv6, DNS64, DNS system, NAT64, Dual Stack, Tunneling, NATing, STRIDE, 464XLAT.

I. INTRODUCTION

After the wide spread of the internet usage all over the globe, IPv4 public addresses started to be liable to depletion which happened in 2011[1]. The transition operation itself is expected to be on the run for three decades [2].

Some of the protocols have security vulnerabilities and they are sensitive to different kinds of attacks.

IPv6 was defined in a draft RFC in 1998 [3], while the actual deployment of it took way longer than it should have because of the technical issue it faced with the old equipment and its compatibility with the new proposed IPv6. A lot of technologies were presented to overcome the depletion of IPv4 and to start the transition process to IPv6, such as Dual Stack, Tunnelling and Natting.

A very informative book by Adam Shostack[4] presents us STRIDE theory, which stands for Spoofing, Tampering, Repudiation, Information Disclosure, Denial of Service, Elevation of Privilege, those are the terms that can be applied on each possible potential security threat and can be analysed accordingly.

So, this paper's goal is tackle some network security concerns with the idea designing a systematic method to identify the possible security issues of IPv6 transition technologies using STRIDE Theory[5] with understating its DFD (data flow diagram) and trying to come up with new enhanced DFD for the transition structure.

The remainder of this paper is organized as follows. Section II is an overview of the IPv6 transition technologies. Section III is a short summary of the STRIDE method. Section IV is the application of SRIDE to the 464XLAT transition technology.

II. TRANSITION TECHNOLOGIES

❖ DUAL STACK

The main idea of dual stack is to have a certain node where both IPv4 & IPv6 are usable, with a priority to IPv6. According to [6], dual stack has what is called "Happy Eye-Balls" to choose the better IP version for the packet delivery. However, it doesn't handle the shortage of IPv4 addresses and it isn't a cost-effective solution.

❖ *Tunneling*

There are different types of tunnling used for IPv4aas puposes

6 IN 4 TUNNELLING

Due to the unfinished infrastructure of IPv6, 6in4 tunnelling was used to carry IPv6 address through IPv4 tunnel to connect IPv6 islands. It normally uses static preconfigured tunnels between two ports [7].

4 IN 6 TUNNELLING

The idea is to encapsulate IPv4 datagram over IPv6 packer header as defined by RFC 2473 [8].

❖ NATTING

NATting is a solution to handle several problems including the shortage of IPv4 addresses, and it has various types: static, dynamic, PAT, etc [9].

A. Translation Type Technologies

1) Single Translation

There are several single translation technologies who caught the attention of many researchers in the field.

[10] classified some of those technologies as their priority goes such as DNS64, NAT64, SIIT, etc.

❖ DNS64 + NAT64

In [11], the process of NAT64 + DNS64 was carefully explained in detail. As shown in Fig. 1, the process consists of 10 steps. It starts with the IPv6 only client

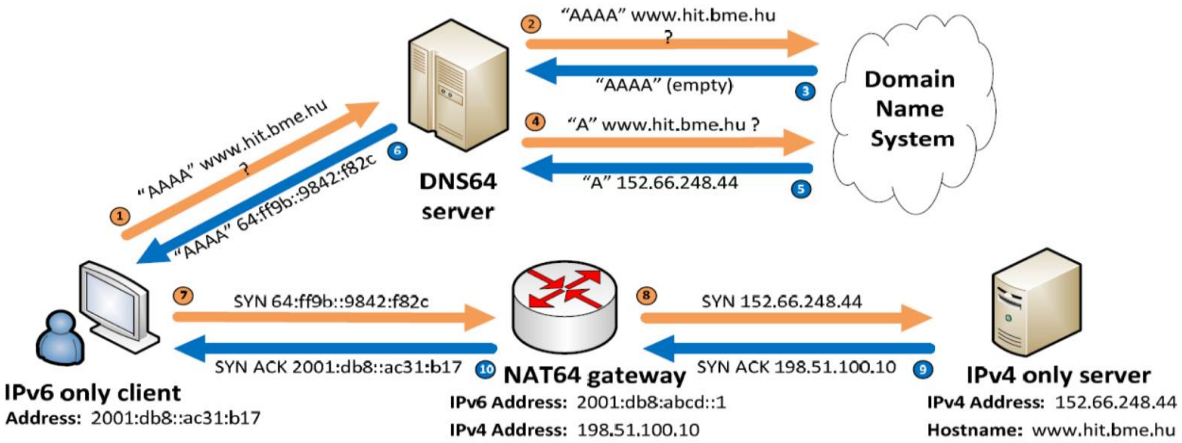

Fig. 1 DNS64+NAT64 Process, IPv6 Only Client contacting IPv4 Only Server [12]

sending a request (AAAA query) to DNS64 asking for an address of IPv4 only server and ends up with the IPv6 only client contacting the IPv4 only server and receives an acknowledgment as well.

The solution is good enough but not perfect as another distinctive drawback emerged to the surface. Some IPv4 only applications don't work with this solution like Skype, Netflix, etc.

- SIIT

  SIIT is the well-known stateless IP/ICMP Packet header translator as defined by RFC 7915s. The idea of SIIT being stateless does put some restrictions on it, while facing with public IPv4 pool depletion [9]. However, it proved to be a sufficient solution coupling with other technologies such as 464XLAT [13].

- SIIT-DC

  This technology focuses on Data centres and its servers' compatibility with IPv6 in terms of serving IPv4 only clients [14].

- NAT-PT

  The old conventional terminology of NAT refers to translate of IPv4 to another IPv4. While NAT-PT is about translating an IPv4 to IPv6 and vice versa. As defined by [15], NAT-PT is to be used when there are no native IPv6 or IPv6 over IPv4 tunnelled ways of communication exists, which means that the main function of NAT-PT is to translate between IPv6 only node and IPv4 only node, without depending of Dual stack whatsoever.

2) Double Translation

This type of translation involves translating an IPv4 packet, when it reaches boundaries of an IPv6 Network into IPv6 packet and then translates it back to IPv4, when they leave IPv6 network and gets back to an IPv4 network. There is one drawback though, and it is that IPv6 packet cannot be carried upon IPv4 packet due to size & data storage limitation issues [10]. There are several Double-Translation methods such as 464XLAT, MAP-T, 4rd, dIVI, etc. In this paper, we are focusing on some of them due to their importance.

- 464XLAT

  So, to go around the problem that NAT64 +DNS64 couldn't solve by their own, a new solution emerged, and it's called 464XLAT [16], the technology was adopted by an American company called T-Mobile. According to [1], this new technology allows IPv6 only networks to run on IPv4 only devices and applications.

  RFC 6877 described 464XLAT as single/dual translation technology [13]. 464XLAT allows ISPs to use only IPv6 in their infrastructure.

  According to [13], CLAT device always placed at the client edge, which performs stateless NAT64 and it normally translates the packets of IPv4 only network into IPv6. It also translates back the returned IPv6 packets to IPv4 so it can be readable within IPv4 only network applications. So, CLAT performs SIIT (stateless Translation algorithm).

  Meanwhile, in the ISP side, there is another device called PLAT which performs Stateful NAT64.

  In conclusion, IPv6-only clients do get IPv6 addresses and they can reach IPv6 servers while they need DNS64+NAT64 to reach IPv4-only servers without the need for double translation process. However, IPv4-only clients need CLAT double translation process to perform the full 464XLAT operation.

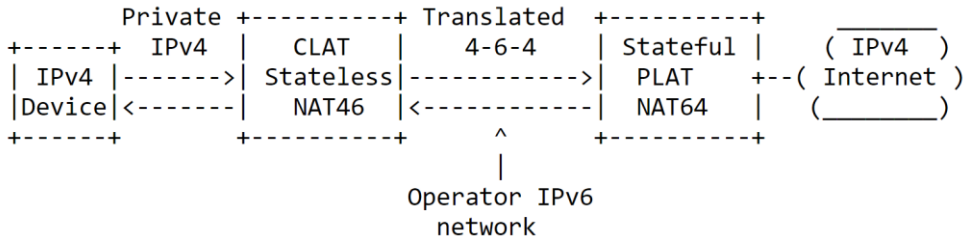

Fig. 2 Overview Architecture of 464XLAT [17]

According to [1], no previous testing process was conducted on CLAT on its different platforms because CLAT run on the customer edge and it could be anything like (iPhone, Android, etc.).

Fig. 2 presents the overview architecture of 464XLAT, it shows the chain of communication and translation steps that being conducted in order to ensure that IPv6 is being used on every platform no matter what even within IPv4-only applications.

❖ MAP-T

MAP-T [18] was adopted by an IETF RFC-7599 and its high-level operation is similar to that of 464XLAT, but MAP-T is much more complicated. It uses different set of terminology and equipment such as: -

- CE (Customer-Edge): according to [18], performs NAT44 in order to maintain a low users port number of TCP /UDP, then it conducts a stateless translation from IPv4 to IPv6 encoding IPv4 source address & port number into the IPv6 source address. The process has two scenarios, the first one is that the packet will be destined to another user within the IPv4 network, where another CE process will occur, but if the packet is heading toward a destination which is outside the IPv4 network, then BR will come in handy as explained below.
- BR (Border-Relay): performs the transformation where a packet has been translated by CE and wants to go out from the IPv4 network.

B. Encapsulation

❖ MAP-E

As defined by [13], MAP-E uses stateless algorithm in order to embed part of IPv4 address into the IPv6 prefix which allows huge number of clients to be provisioned using single MAP rule. At CE, the router runs a stateful NAPT44 operation in order to translate IPv4 private source address and source port into an address and a port range. Moreover, at the CE router begins the encapsulation of IPv4 packet inside IPv6 packet and send it to another host within the MAP domain or to BR if the destined packet to area not covered by MAP rules. The BR will start the decapsulation procedure from his side (decapsulating IPv6 into IPv4).

❖ DUAL-STACK LITE

An IETF RFC 6333 defined DS-Lite.

In CE, DS-Lite uses "Basic Broadband Bridging" B4 to encapsulate IPv4 into IPv6 packet then send it through IPv6 network to AFTR (Address Family Transition Route) which will perform the encapsulation / decapsulation process of the 4in6 data and then it performs a Stateful NAPT44.

❖ LIGHTWEIGHT 4OVER6

Lightweight 4over6 is an extension of DS-Lite, but it has some different aspects where the NAPT function is relocated from AFTR to customer's B4 element which is called "lwB4". In this case, AFTR conducts A+P routing (Address + Port number) and 4in6 encapsulation / decapsulation.

Direct communication between two lwB4s is being done through hair pinning traffic through lwAFTR, RFC 6333.

III. STRIDE IN A NUTSHELL

Stride stands for Spoofing, Tampering, Repudiation, Information Disclosure, Denial of Service and Elevation of Privilege and they are general attack types explained below in details:

- Spoofing: in general, it is claiming to be someone that it is not you, or someone pretends to be your website [4]. Concerning computer networks, it often means the usage of the IP address of another device as source IP address to gain unauthorized access to some resources or to hide the real identity of the attacker [1].
- Tampering: the attacker might play and change something in the flowing data while it bounces back and forth between two nodes [4].

Element	Spoofing	Tampering	Repudiation	Information Disclosure	Denial of Service	Elevation of Privilege
Data Flows		✓		✓	✓	
Data Stores		✓		✓	✓	
Processes	✓	✓	✓	✓	✓	✓
Interactors	✓		✓			

Table. 1 Vulnerability of different DFD Elements to different Threats [1]

- Repudiation: is the claim that a host didn't do something or not responsible or a specific act / behaviour [4].
- Information Disclosure: An attacker getting confidential information that he shouldn't have got it [1], like the TTL value of specific packet within DNS64 server.
- Denial of Service: The attacker floods the targeted network server with huge number of useless requests (queries) which causes preventing the legitimate user from contacting or accessing the designated server [1]
- Elevation of Privilege: incorrectly allowing a user /hacker to access an un-authorized server/ service [4].

The STRIDE method uses the DFD (Data Flow Diagram) of the examined system for its security analysis. The DFD is build up by four types of elements: Data Flows, Data Stores, Processes and Interactors. Each one of the four elements is susceptible to some of the before mentioned threats but not susceptible to some others. Table. 1 shows the DFD elements and the threats that they are susceptible to marked with a ✓ sign.

IV. Towards the Threat Analysis of 464XLAT

In this chapter, we will be focusing on 464XLAT, its security analysis by applying STRIDE theory and analysing its DFD diagram focusing on possible vulnerable spots and taking in consideration the previous implementation handled by [1].

Fig.3 shows the DFD for the threat analysis of 464XLAT. By applying the STRIDE method on this DFD, the threats that might face each element within 464XLAT architecture may be discovered.

My plan to perform STRIDE on DFD in Fig. 3 is to check all possible vulnerabilities (Spoofing, Tampering, Repudiation, Information Disclosure, Denial of Service, Elevation of Privilege) at each DFD element (1-14) and prioritize the level of threat at each element then come up with analysis of the most vulnerable element within the DFD and classify the threats based on number of their possible occurrence in order to tackle them top to bottom.

Conclusion

Among all surveyed transition technologies, 464XLAT proved to be a suitable one while it has some security threats. It solved the problem of IPv4 only applications in an IPv6 environment and the CLAT+PLAT solution is very practical solution for this issue. Further research is required in this area and that requires testing the NAT64 gateway and examine its behaviour under different circumstances using some free (open source) software.

Acknowledgment

Thanks to my Supervisor; Dr. Gabor Lencse, Budapest University of Technology & Economics, who helped me all the way through with my research.

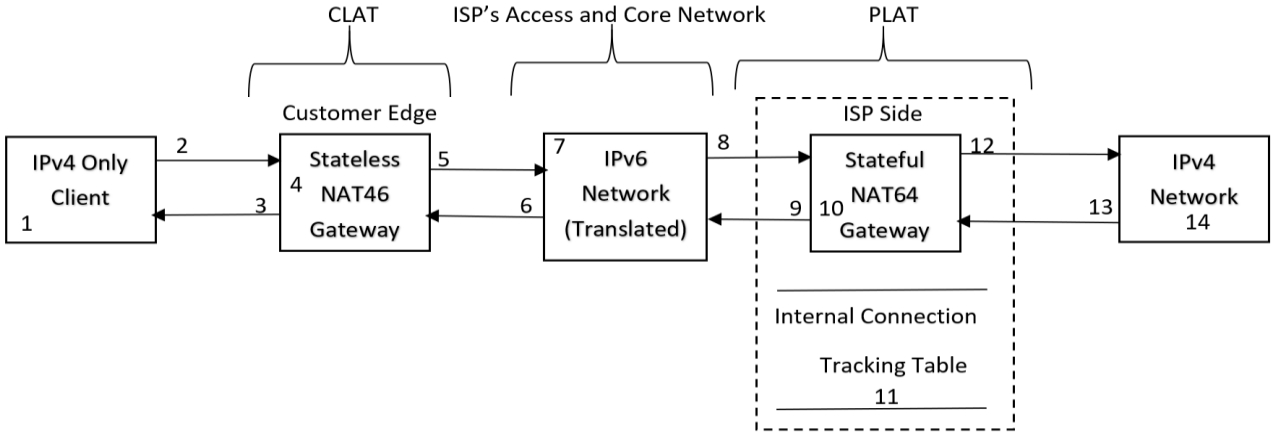

Fig. 3 DFD of the threat Analysis of 464XLAT (CLAT + PLAT)

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A review on robotics in life science automation

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***Abstract*— Automation is gaining importance in life science laboratories, where special robots are increasingly applied for tasks such as liquid handling and sample transportation. Robots play an important role in achieving the vision of the laboratory of the future, where automated devices are integrated into a continuous process and the need for human intervention is minimized. This paper provides an overview on the technological concepts that are already commonly applied for laboratory automation, and furthermore gives an outlook on novel technologies, such as mobile manipulators.**

Keywords—Laboratory automation, robotics, life science engineering, laboratory transportation

I. INTRODUCTION

Automation's gaining importance in the industry started from the manufacturing sector but is recently reaching a broadening spectrum of application areas ranging from smart homes and self-driving cars to service- and medical robotics [1]. The benefits automation brings vary from sector to sector, but in general it aims to raise productivity, to ensure constant quality and to free humans from repetitive tasks.

Automation in biotechnological and pharmaceutical research is already relatively common, especially for high throughput (HTP) applications, where a huge number of samples are processed. For this purpose, automatic pipetting robots, so-called liquid handlers, are commonly utilized, which can be considered a relatively mature technology.

In general, laboratory automation covers devices, processes or software that minimize the need for human intervention. The spectrum ranges from automated units, such as liquid handlers, centrifuges and readers, through means of sample management, such as storage carousels, robots and conveyors all the way to software for workflow creation, device control and data collection. The sector is estimated to expand globally from US$ 4.3 Billion in 2017 to US$ 5.9 Billion by 2023 by a CAGR of around 5% [2] and is considered to be an important application area for novel technologies of automation, mechatronics and robotics.

II. PROBLEM DESCRIPTION

Pharmaceutical sciences are one of the sectors that could benefit from utilizing automation technologies in their laboratories. Automation and robotization is inevitable, especially in laboratories where samples are processed in high amounts, such as in the HTP laboratory of the Takeda Pharmaceutical company. In the first part, this paper gives an overview on the technologies that are already applied for this purpose, such as robots for liquid handling and sample transportation. In the second part, novel technologies, such as mobile robotics were also considered, as means of bringing more flexibility to automated laboratory systems.

III. MARKET REVIEW

A. Laboratory robotics in Europe

A report for the European Laboratory Research & Innovation Group summarizes the status and prospects of laboratory robotics within the Horizon 2020 program [3]. This review is used as the backbone of the present section, because it provides an excellent overview on the present and future of laboratory robotics. Practical examples from the HTP laboratory of Takeda are also shortly introduced, which are then discussed in detail in the following sections.

In their report, the authors estimate the laboratory robotics sector to be worth between €2-3 billion and they describe it to be dominated by European suppliers. From the fields of application, pharmaceutical product development was identified as one of the most significant ones. There, laboratory robotics is already present in high-throughput screenings and in other laboratory processes that operate with high amounts of samples and require high repeatability. Such screening processes include procedures such as sample preparation, chromatography and optical reading, where small amounts of liquids are transferred into carriers and are processed in multiple steps. Since samples can be of various states of matter and of different forms, manipulators must have a wide variety of configurations. Although the most common way of processing samples is using multi-well plates (microtiter plates) with 96, 386 or more wells holding microliters to milliliters of liquids, other types of carriers, such as tubes, vials, cuvettes, flasks and bottles are also frequently used. Many manufacturers offer modular configuration options for their laboratory robots along with dedicated consumables and reagent kits. This approach enables a business model strategy, where supplies of such consumables, optional hardware and software upgrades, as well as service offerings can represent a significant contribution for gaining revenue in addition to selling the devices themselves.

In the above-mentioned paper, compact XYZ gantry robots are described to be the most commonly used type, which are usually equipped with liquid handling- and plate manipulating arms. Fig. 1 shows a liquid handler of type Tecan EVO (EVO) robot, which has two arms for plate manipulation, as well as an eight-channel pipetting arm. In the HTP laboratory of Takeda, five units of this type are in operation – although, with different configurations.

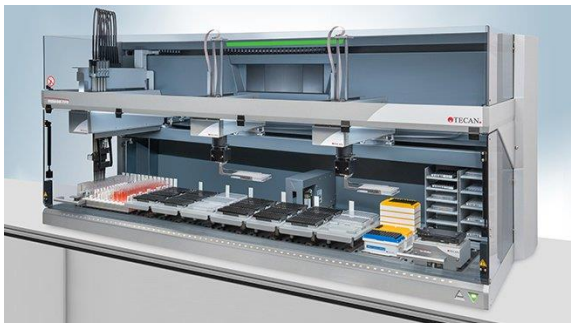

Fig. 1: Tecan Freedom EVO 200 liquid handler [4]

As means of sample transportation, articulated robots and Selective Compliance Assembly Robot Arms (SCARAs) are also referenced by the authors, along with compact table-top plate stacking mechanisms. For Takeda, a specialist company designed a similar robotic plate transportation system, which utilizes a SCARA and a conveyor to transport plates between the devices.

Also in the above-mentioned paper, mobile robotics is described as an emerging sector within laboratory robotics, providing a possible solution for implementing transport between automated islands and stand-alone devices. Examples, such as blood delivery applications in hospitals, and various research projects are mentioned including LISA from Fraunhofer IFF and the Adept Lynx.

As a barrier of the development, the users' lack of complex skills is identified, as well as the industry's fragmentation, which induces a lack of shared standards. However, a huge innovation potential is identified to lie in new technologies. These include miniaturized electro-mechanical solutions, 3D perception to manipulate complex solids, artificial intelligence to implement robotic laboratory assistants, co-bot systems and, ultimately, a deeper level of integration covering the whole workflow. Challenges are also identified, such as motion planning for robot arms considering the orientation and acceleration to avoid liquid spillage.

B. Turnkey robotic solutions for plate transportation

The first company that has been contacted by Takeda in connection with the automatic plate transportation system is the US-based Biosero. The company suggested that the EVOs be placed on custom-made frames, which would additionally house the two rails for the two SCARAs as well as the conveyor system under the table's surface. The chosen robot arms were identified as the so-called Precise Flex, the supplier of which proved to be Precise Automation (See section D).

A highly similar concept was provided by the Netherlands-based company Lab Services, which also utilizes the same type of robots, a custom-built frame and a similar conveyor (See Fig. 2).

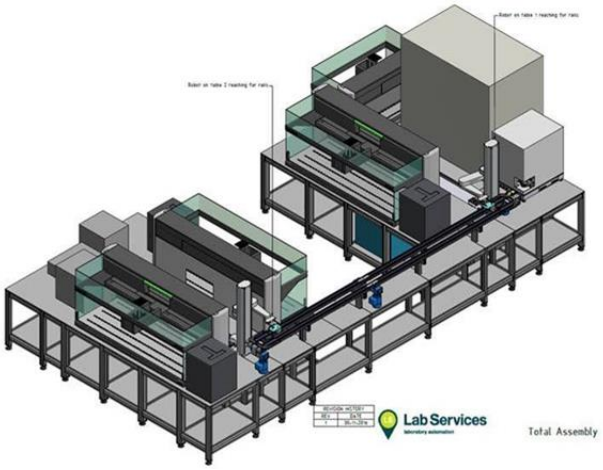

Fig. 2: Concept from Lab Services [5]

C. Further laboratory automation companies

Several other companies were identified that are active in the laboratory automation sector and that provide similar solutions to the ones described above. One example is the Swiss Aurovis AG, which specializes in AUtomation, RObotics and VIsion Systems – hence the name. The company is a distributor among other brands of Precise Automation, which is the manufacturer of laboratory robots, as well as of Tolomatic, which is a producer of motion solutions ranging from gearboxes and brakes to pneumatic actuators and complete electrical linear motion systems [6]. Aurovis offers engineering services and customized solutions based on the components it distributes.

The USA-based company HighRes Biosolutions also provides life science automation solutions, namely in the form of a modular system that consists of robot cells, docking stations and mobile modules (See Fig. 3). In their product range, a SCARA named ACell is listed, which has the same design and specification as the PreciseFlex from Precise Automation (see section D).

Fig. 3: HighRes Bio's modular laboratory automation solution [7]

The company's scheduling software, named Cellario, is capable of integrating with Laboratory Information Management Systems, provides an interface to create workflows and processes, and has various device drivers, including the support of Tecan EVO liquid handlers [8].

Agilent Technologies, provide laboratory instruments, services, consumables and applications, one of their most important markets being pharmaceutics [9]. The company's laboratory automation solutions include the software Vworks Automation Control, which has similar functionality as Cellario from HighRes Bio. Device drivers also cover the Tecan EVO and the company's own tabletop SCARA, BenchBot [10]. Complex automated workstations, such as the company's own BioCel [11], are controlled by the so-called Automation Control Unit, which can interface with various devices from Agilent and from other manufacturers.

The UK-based company Peak Analysis & Automation – PAA provides complete design-and-build service in laboratory automation for clients from the pharmaceutical and biotechnology industries, including Takeda [12]. Its control and scheduling software, Overlord™, is capable of controlling various third-party instruments, such as the Tecan EVO, as well as the company's own robots, which range from SCARAs designed for tabletop operation to larger variants designed for OEM applications.

D. Components of a sample transportation system

1) Robot arms

For handling microplates, robot arms provide flexibility by being able to reach diverse devices organized along a line or a circle. Fig. 4 shows a comparison by Precise Automation, between a circle pattern for a six-axis robot and a linear pattern for a rail-mounted SCARA. The latter, the PreciseFlex arm – or variants of it –, occurs in the product range of multiple system integrator companies, as seen inFig. 5.

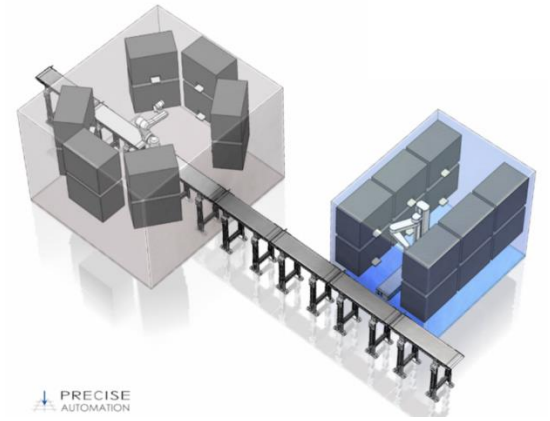

Fig. 4: Precise Automation's comparison of robot layouts [13]

The PreciseFlex arm has collaborative features, such as hand-driven teaching possibility and cage-free operation, thanks to collision force limitation in accordance with the ISO/TS 15066 Standard on Collaborative Robots. The four-axis SCARA is available in various sizes, as summarized in Table 1. The robot's interfaces range from RS-232 through Ethernet to an E-stop input alongside with 12 digital inputs and 8 digital outputs. Various methods are available for the programming and operation, such as a web-based interface, advanced programming interfaces and PC control using the TCP/IP Command Server [13].

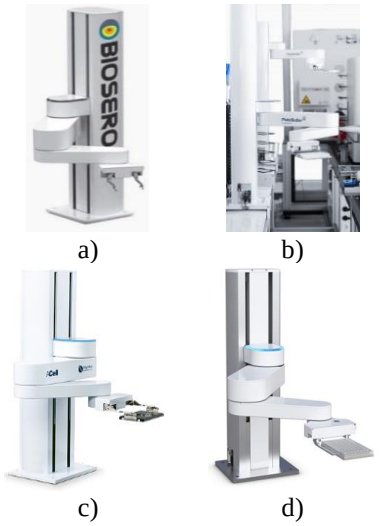

Fig. 5: Table-top SCARA solutions from various companies
a) PreciseFlex from Biosero [16]; b) PlateButler from Lab Services [17];
c) ACel from HighRes Bio [8]; d) Benchbot from Agilent [11]

Dimension	Options
Linear Z-Axis length	400 mm or 750 mm
Maximum reach	576 mm or 731 mm
Linear rail length	1 m, 1,5 m or 2 m

Table 1: Dimension options for the PreciseFlex robot

Alternative to SCARAs, articulated robots with four to seven joints could be applied. For them, similar linear extensions are also available referred to as a seventh axis. Vention and Rollon S.p.A. are two companies that provide seventh axis solutions for arms from Universal Robots. These systems are, however, optimized for industrial applications, their dimensions being too large for laboratory automation purposes [14], [15].

2) Grippers

In a laboratory, a robot may have to transport various types of objects, such as microplates, tubes and bottles. These objects are different in size, and because of that, a different gripping width is needed for each of them. Plate transporting robots, such as the liquid handling arms of the EVOs, or the PreciseFlex are often equipped with a gripper that is not capable of closing all the way, but only to a with, which is appropriate for gripping plates either in the landscape or in the portrait format. Universal grippers, such as the RobotiQ 2F series [16] on the other hand are capable of closing all the way, which enable gripping thin objects. However, to retain the gripper's ability to grip wider objects, such as plates, a wider variant is needed, which increases the weight and the costs. To overcome this, one possible solution is to use custom-made fingers that have multiple gripping points for different kinds of objects, such as on the robot used in Fraunhofer's AUTOSTEM setup [17].

Fig. 6: Multi-gripper from Fraunhofer [17]

The use of automatic tool changers (ATC) would also be a possible solution. Although, making the whole gripper automatically interchangeable requires a complex interface, which provides both mechanical and electrical connection. Instead of this, Tecan implemented a finger swapper mechanism for its Fluent series liquid handlers [18].

3) Conveyors

In many laboratories, the devices cannot be reached by one robot arm on a single rail, but an additional conveyor system is required to transport the microplates between multiple robot arms, serving as the backbone of the system. In the case of Takeda's laboratory, the linear conveyor will be located along the wall and will be approximately 4 m in length. The transportation task requires one or more carriers that travel between the two end positions, where the robots can place or pick up the plates.

A magnetic conveyor system similar to MagneMotion's Magnemover Lite was identified to be integrated in the concept of Biosero (See section B). The system, which is recommended among other fields for laboratory automation, consists of modular motorized track segments, which can be combined into various configurations.

IV. Literature Review

After reviewing the commonly available laboratory robotics solutions, this section discusses some novel technologies that are subject to academic and industry research.

A. Academic research regarding laboratory robotics

The Center for Life Science Automation (CELISCA) is an institute of the Rostock University, which is specialized in topics that highly overlap with the context of this paper. Because of this, several research projects of the institute were reviewed, and are summarized in this section.

Laboratory automation could not be achieved without the appropriate software to control and monitor the processes and workflows. Li et al. present a 4D simulation system that integrates a Process Control Software (PCS), a Data Management System (DMS) and 3D animations [19]. Laboratory Information Management Systems (LIMS) are essential tools of laboratory automation for tasks such as data processing, workflow management, resource planning, sample management, quality control and instrument integration. Blazek et al. [20] provide a comparative evaluation of open source LIMS software in the context of academic research. The ability to access and change the code of the software ultimately brings the possibility of customizability, but security vulnerabilities may occur thanks to custom scripts and plugins not being kept constantly up-to-date.

Xianghua et al. survey the integration possibilities of laboratory equipment [21]. The study provides methods to use robot arms to manipulate laboratory devices that are not designed for automation, but for human operation, as seen in Fig. 7. In their paper, both aspects for mechanical interfaces and aspects for software interfaces are discussed. For the latter, workarounds, such as UI-manipulation with mouse- and keyboard emulation and optical character recognition (OCR) were used.

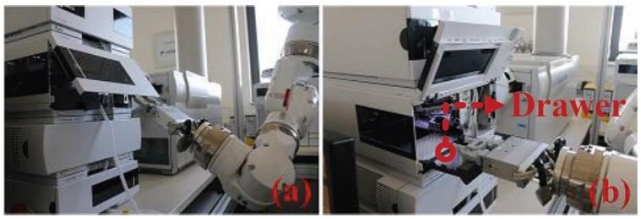

Fig. 7: Manipulating laboratory equipment with robot arm [21]

Robots in a laboratory are expected to work alongside humans in a collaborative manner, and to achieve this, safety is a critical aspect. Kirschner et al. provide a list of relevant parameters of sensitive collaborative robots from various manufacturers such as ABB, KUKA and UR [22]. The authors conclude, that the specified maximal collision force of a robot is only valid for certain velocities, thus they recommend evaluating every hazardous situation, when applying a collaborative robot. The safety of collaborative mobile robots depends on even more factors. Kim et al. [23] discuss service robotics and review the related ISO standard (ISO 13482) in the aspect of Protective Stop Space and Safeguarded Space. They present a method to determine the radii of these areas taking the robot's braking performance, the relative velocity as well as a perceived safety into account.

In CELISCA, besides stationary robot arms, mobile robots are also utilized, mainly for transporting various labware between workstations, rooms and even between floors [24]. In this application, a four-layer control system is responsible for assigning tasks to the specific robots, calculating paths and executing the task, while the navigation of the robots is implemented with ceiling landmarks and a StarGazer camera system [25].

Liu et al. [26] discuss the control system, the door control and a robot-human interaction proposing an XML-based command structure as well as a multi-robot communication architecture. The mobile robots at CELISCA are also capable of navigating to their charging stations when necessary. Thurow et al. [27] discuss a waypoint-based navigation method in the facility throughout multiple floors. This task requires the robots to operate the elevators and automatic doors as well. A concept for the grasping of lab ware with the help of a Kinect-sensor is also presented. Lab ware manipulation is discussed in detail by Ali et al. [28]. In their concept, the Speeded-Up Robust Features (SURF) algorithm was used for the recognition, and multiple grippers were designed.

A compact mobile manipulator is under development by the Fraunhofer Institute for Manufacturing Engineering and Automation IPA under the name Kevin [29]. The idea behind

this concept was to transport microplates between different laboratory workstations autonomously, while retaining flexibility and the ability to move arbitrarily. For this purpose, the mobile robot base Care-o-Bot 4 was equipped with a PreciseFlex SCARA, which can grip standard microtiter plates. The base is an omnidirectional mobile platform equipped with laser scanners and is capable of autonomous navigation. Similarly to most mobile platforms, the positioning accuracy of the base alone is insufficient for grasping plates with an indicated value of 2-3 cm. To overcome this, a camera system and optical markers were used to detect the position of the carriers relative to the robot. Since both the base and the SCARA are commonly used in environments shared with humans and are certified, the combined mobile manipulator is also suitable for collaborative operation.

B. Industry research

Laboratory automation companies, such as the ones introduced in chapter III also started to experiment with mobile manipulators for transportation applications. Biosero, for example developed a system consisting of a mobile base of type Omron LD, a PreciseFlex SCARA and a Cognex industrial camera [30]. The concept highly resembles the one of the Fraunhofer Institute, but Biosero's robot can also be controlled by the company's scheduler software, Green Button GO™.

V. Conclusion

Robots are gaining more and more importance in laboratory automation applications. Gantry robots are commonly used for liquid handling tasks, while SCARAs and articulated robots are often utilized for handling objects, such as microplates, tubes and other labware. In many applications, the robot arms are mounted on linear rails to expand their working area. However, to achieve the vision of the laboratory of the future, where the whole laboratory process is automated in a continuous manner, and human workload is minimized, connecting the separate stations is also necessary. The application of mobile manipulators for solving this problem represents a promising field of research; however, it brings challenges such as finding a solutions for the platforms' insufficient accuracy, and for a collaborative operation.

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Modeling manufacturing for collaborative and industrial robotics

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***Abstract*— Collaborative robotics is a novel and important topic in education and in the manufacturing area, because it is about the mutual work of human and machine. This technology doesn't have generally accepted standards yet that makes it an interesting topic in education. The paper presents the application of collaborative robotics in a sample manufacturing process involving circuit design, end of line testing, in-circuit testing, visual inspection and image processing for position recognition.**

Keywords—collaborative robotics, practical education, industry 4.0, smart manufacturing

I. INTRODUCTION

Technical and technological advances involve new risks and new requirements [1]–[3], thus safety requirements of industrial robots in the classic sense are changing. In today's factories, robots operate physically separate from humans in a space enclosed by fences and sensors. Looking to the future, the goal is to change this situation so that humans and the robot can work together in one space, sharing the work, relieving workers of monotonous work and supporting precision operations. This innovative technology brings economic benefits and demonstrates significant performance gains also. However, it is important to carefully plan workflows and establish proper human-machine communication [4], [5].

The automation of certain work phases has been simplified due to advanced technology, but there remain jobs where human activities cannot be performed by robots on their own. In such cases, the use of collaborative robots can be of great help [6]–[8]. Collaborative robots have been developed to be able to perform a specific task in a common space with humans at the same time. Human operator controls and monitors production processes while the robot takes on the heavy work. The responsive, lightweight collaborative robot is able to work hand-in-hand with people, without the need for a fence, applying innovative security solutions.

The idea for the collaborative robot was born in 1995 as a result of a research project sponsored by the General Motors Foundation. The goal was to develop robotic applications that work directly with people. Nowadays collaborative robots are becoming more widespread, yet few can sum up how they differ from traditional industrial robots.

II. PROBLEM DESCRIPTION

A. Man-machine teamwork

We see classical industrial robots as power plants that perform their tasks according to a predetermined program, ignoring other work around them: humans, operators. To prevent accidents and hazardous situations, robots are separated from the production area by cages and barriers.

Collaborative robots, on the other hand, are not "born" to replace humans, but are meant to support human activities. Instead of being surrounded by protective fences, they are located directly in the human environment, helping them with tasks that cannot be 100% automated, but providing machine assistance to operators to solve them. They can be used, for example, for conveying materials, lifting heavy workpieces or clamping.

B. Taking on dangerous tasks

Collaborative robots, instead of humans, can perform riskier work tasks, such as moving sharp, pointed or hot workpieces, or assembly in tight spaces. This reduces accidents and allows operators to focus on tasks that require human intervention and capabilities.

C. Flexible and secure

These robots are fully developed for reliable and secure interaction with humans. Thanks to sensitive sensors, they can be controlled with gentle touches to avoid dangerous situations. They do not require the use of fences and grilles.

D. Clever and teachable

Teaching collaborative robots is very simple: unlike traditional industrial robots, which require advanced programming skills, some collaborative types can learn independently. For example, the robot arm is able to re-write the path the operator has led him through. Other types are taught through a graphical programming interface. It follows that the reprogramming of collaborative robots is much simpler than that of their classic counterparts.

E. Applicable anywhere

Not only are they easy to teach they are also moved and installed easily! They are easy to move and apply to other production tasks. Most collaborative robots can be assembled and fixed on any surface, either horizontally, vertically or even on the ceiling. And their weight is usually so low that it is not a challenge to relocate them.

F. Standards for collaborative robotics

The legal background for collaborative robots is not yet clear in terms of safety at work. The standards available on this subject are guiding, but many situations arise during their practical application which are not answered. The main reason for this is that collaborative robot technology is extremely innovative and has a short history of application.

Currently known and applied standards are:

- MSZ EN ISO 10218-1:2011
- MSZ EN ISO 10218-2:2011
- MSZ EN ISO 12100:2011
- MSZ EN ISO 13850:2016

- MSZ EN ISO 13855:2010
- ISO/TS 15066

There are three main concepts that can be distinguished for the definition of the man-machine common workspace as it can be seen in Fig. 1.

Fig. 1: Coexistence, cooperation, collaboration [9]

III. Experimental setup

The purpose of the experimental setup is to demonstrate the advantages and disadvantages of industrial and collaborative robots in an educational environment. Accordingly, the laboratory environment is also a training room, which, besides the production cell, contains the PCs needed to run and train the simulation environments (see Fig. 2). The experimental setup shall meet the following requirements:

- tight space
- quiet environment
- clean workflow
- easy to walk around
- visibility of processes

Fig. 2: Robotics laboratory

The industrial robot is represented by a Fanuc education cell (see Fig. 3), Which allows the presentation of the following topics:

- Collision Detection
- DCS Position/ Speed Check
- DCS Safe I/O Connect
- Motion Optimisation
- Constant Path
- Program Shift
- Multi Tasking
- FTP Interface
- Condition Monitor
- High Speed Skip
- Image processing (iRVision)

Fig. 3: Fanuc education cell

The collaborative robot is represented by a UR5e (see Fig. 4), a 5 kg e-series robotic arm from Universal Robots. This robotic arm has a built-in force and torque sensor that ensures the collaborative requirements. The figure also shows that unlike the Fanuc cell, the UR5e robot is not surrounded by a fence in a collaborative workspace. Although the robot itself is collaborative, designing the working environment like gripper, sharp corners, etc. they include non-collaborative elements, the illustration of which is important in educating this topic.

Fig. 4: Universal Robots education cell

When designing the sample process, the basic goal was to present as many important elements of robotic manufacturing as possible. Therefore, we chose testing and assembly of a printed circuit board (PCB) (see Fig. 5). The manufacturing process has four main tasks:

- in-circuit testing
- iRVision positioning
- assembly
- visual inspection

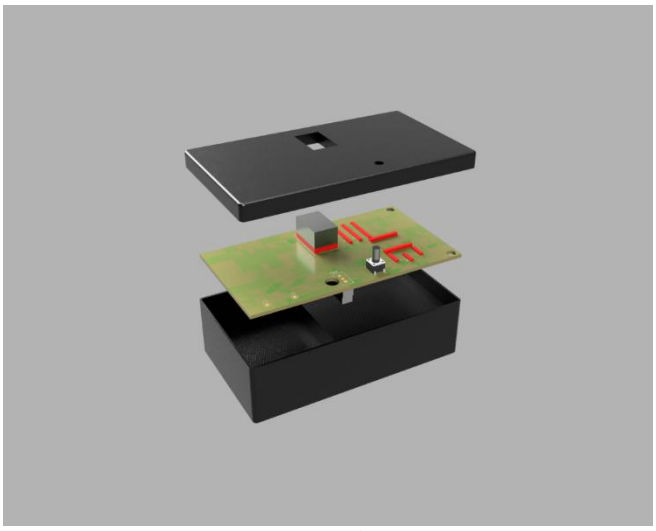

Fig. 5: Assembly of the product

The PCB itself performs a simple task: after pushing a button a random number is displayed on a seven-segment display (see Fig. 6). The role of the circuit in the process is the demonstration of real manufacturing processes thus it has to be compatible with in-circuit testing. Accordingly, there are test points on the circuit where the probes can perform automated testing.

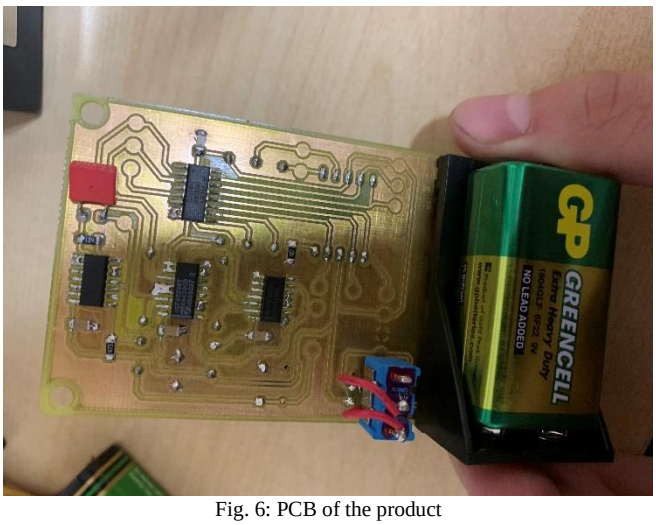

Fig. 6: PCB of the product

The in-circuit testing of this PCB is performed using the bed of nails tester shown in Fig. 7. The most important element of the system is the fixture, which is used for clamping the circuit to be tested. This ensures the contact between the circuit test points and the system. The mechanical strength of the clamp is ensured by a metal frame. The bed of nails is usually placed in an epoxy resin matrix form.

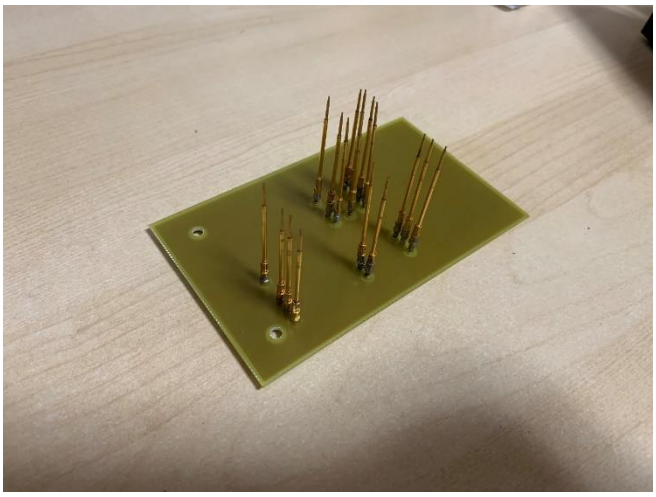

Fig. 7: Bed of nails tester

Of the four main tasks, the URe performs the in-circuit test, while the Fanuc cell uses the iRVision to determine the position of the workpiece and to assemble it. The two robot cells are connected by a conveyor belt.

In industry 4.0 an important requirement is the collection, processing, and application of data [10]–[14] like vibration measurements for predictive maintenance [15]–[18]. Accordingly, each component of the system sends and receives data to the database via the Manufacturing Execution System (MES) (see Fig. 8). This database is also used by the Enterprise Resource Planning (ERP) to assist the management processes [19].

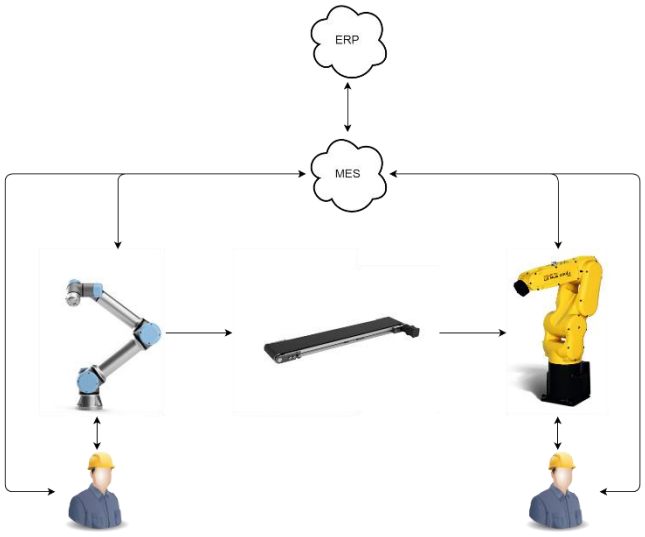

Fig. 8: Hardware architecture

The process is shown in Fig. 9. The UR5e container is filled by an operator, from where the robot arm puts the PCB into the in-circuit tester. If the PCB passes the test, UR5e will move it to the conveyor belt, which will transfer the product to the Fanuc cell. Since the exact position of the PCB is not guaranteed, its position is determined by the Fanuc cell using image processing (iRVision). It then assembles the finished product and sends it to the operator for visual inspection. With both tests, the system provides the option to remove

defective products. At the end of the major subprocesses, report generation occurs.

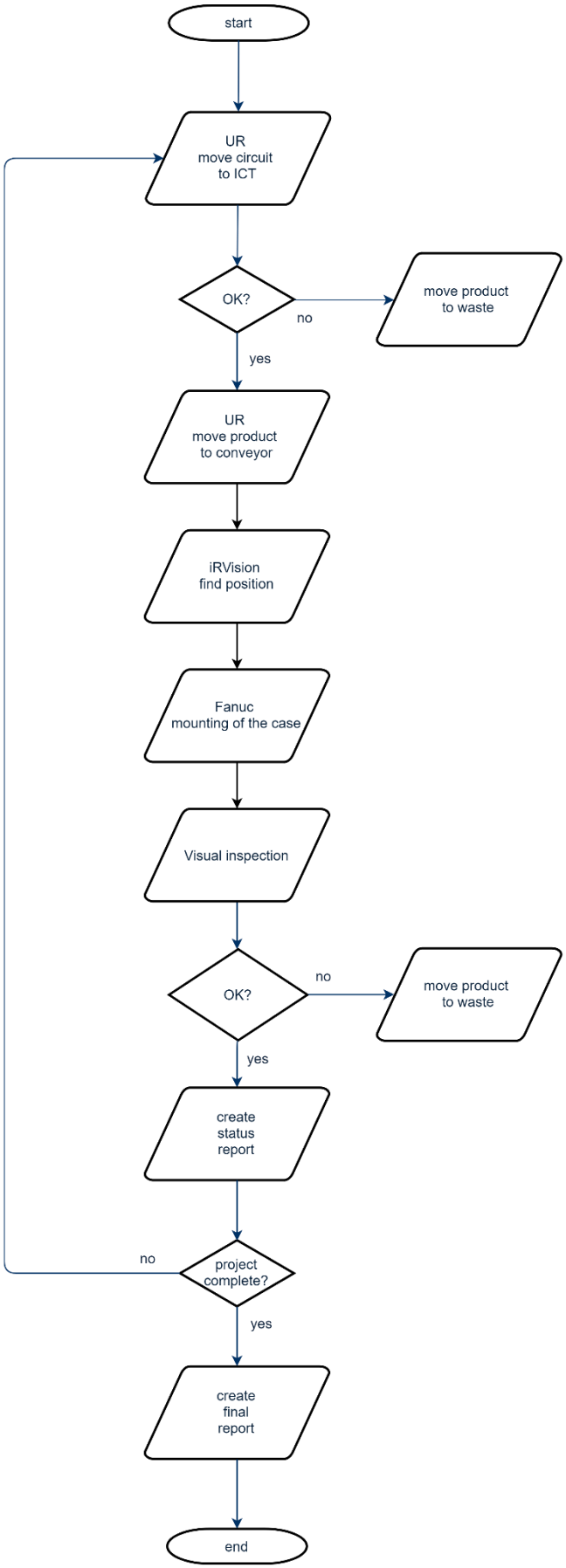

Fig. 9: Process workflow

IV. Conclusion

This paper presents an experimental setup of collaborative industry 4.0 manufacturing cell for educational, development and research purposes. The experimental setup provides an opportunity to compare classical industrial robots with collaborative robots. It demonstrates basic elements of robotic manufacturing and blocks of industry 4.0. This makes the experimental setup capable of teaching, developing and conducting research on cutting-edge technology.

V. Acknowledgement

The authors wish to thank the support to the Arconic Foundation.

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Human movements in virtual reality based on motion capture technology

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***Abstract*— Motion tracking is an important aspect of virtual reality. The motion capture systems are the most famous interfaces to navigate and interact in 3D virtual worlds. Virtual reality is starting to blend into our everyday lives. Thus, the need is emerging to integrate the topic into the education. It is needed to teach the next generation of engineers how to use this tool. The paper introduces a motion capture experimental setup for research, development and educational purposes.**

Keywords*— *motion capture, virtual reality, augmented reality, practical education

I. Introduction

In today's world, technologies of which digital imaging is an important part are gaining importance. It spans every aspect of life, from health, manufacturing, security, space exploration to the entertainment industry. Digital image processing is the process of transforming digitally stored images into mathematical algorithms to obtain the image information we need.

One of the most important paper on the subject of optical motion analysis is an Italian work [1]–[4] which introduces the basic human motion analysis tools with stereo-photogrammetry (multi-sided photographic optical recording) recording, with special emphasis on errors, their causes and ways to eliminate them.

II. Problem description

The subject of this paper is the development of a state-of-the-art motion capture (MoCap) experimental setup that can be used for educational, clinical, academic, and sports research purposes. The primary goal is to develop a framework that will allow the education of this engineering field in informatics and to meet emerging industrial development and research needs. The results of the system created are easy to use and scalable for future improvements.

The purpose of the measurements is to record human motion and to animate it in virtual reality. Time, angle and distance parameters calculated from measurement data can be widely used: athletes' techniques and performance can be analyzed, developed and scientific research performed. Biomechanical studies can be divided into two groups: kinematic measurements, which deal with the description and analysis of motions, and kinetic measurements, which study the forces that create and act on motion. This paper focuses on the first area. As technology advances, the requirements for motion testing are also increasing. A competitive system should enable fast, easy and accurate measurements [5]–[16].

Systems operating on an optical (also known as stereophotogrammetry) basis consist of two or more cameras and computer and software for processing their images that coordinate their operation. The basic principle is that the marker image, knowing the position and orientation of the camera that captures the image, defines a straight line in space that connects the camera center to the marker. If a given marker is on more than two camera images, two or more such lines will be defined that intersect at the spatial position of the marker. From the equations of the two lines the required coordinates can be calculated [2].

Unlike ultrasonic and electromagnetic systems, there are non-rigidly mounted sensors (cameras). Their position relative to one another and to the coordinate system of the measurement shall be determined during a calibration procedure. Calibration is usually easy with MoCap software and calibration tools. At the end of the process, the software gives an instrumental error characteristic of the calibration quality.

The cost of building optical-based systems is high compared to other methods, but in return they are highly accurate. Using the right amount of camera, one can create a measuring volume of any size, even outdoors, which can be important when studying for example animal movements. Coverage problems can be minimized by proper layout. The number of cameras that can be used is determined by the MoCap software and the PC hardware running it. There are several types of cameras, from which the user can choose the one that suits his purpose. Their sampling time, accuracy, field of view and angle of view vary from type to type.

Markers for optical-based motion detection systems do not need to be wired as they do not include sensors. The disadvantage of this is that the individual markers are indistinguishable. This could be done with markers of different shapes or sizes, which in turn would significantly increase the resource requirement of image processing, slow down the process and increase the size of the markers (see Fig. 1).

In order to process the information, it is necessary to know to which anatomical point the given data set belongs. This mapping can be done in the software, but the program can only follow this until the marker is displayed on every frame. If the marker is obscured for some reason and is not visible through one or more frames, it will reappear as a new marker after it has reappeared. As a result, lengthy post-processing is required after testing: a competent person must re-identify the marker at each such break. If three or more markers are rigidly connected to each other as rigid bodies, the system can automatically identify them based on the individual distances between the markers (symmetrical layouts should be avoided). These marker assemblies are commonly referred to as rigid bodies. From the position of the markers on the rigid body, the MoCap system can characterize it with one position and one orientation (a single marker only with a single position). The rigidbody is larger

in size than the single markers and is therefore not capable of directly tracking anatomical points.

Fig. 1: MoCap in movie Ready Player One [17]

III. Simulation Environment

MoCap is the result of the coordinated work of cameras and target points. As a first step, a room with a solid color background should be provided during the recording, which is not essential for digitizing motion, only reducing the error factor. The error factor during recording is when the cameras cannot see a gesture that causes the skeleton and the moving body to fall apart, resulting in an incomplete or distorted gesture. This can also be caused by poorly configured cameras and the transition of moving body and poor background to nearly the same color. This requires manual adjustment of the recorded gesture, resulting in multiple playback adjustments, tuning, which is time consuming.

Fig. 2: PS Eye camera [16]

We used the iPi Recorder software to record the animation of our gestures, with a free version of 6 devices (camera, microphone, sensor). As a first step we surveyed the available cameras on the market, and we found the PS Eye cameras as the most cost-effective solution [18]–[20]. Not all software is capable of capturing images with these cameras, which is the reason of application of this software, which also supports most cameras on the market.

After installation, we connect the cameras, which will first take a picture of the empty room. The program thus creates the virtual space in which the cameras are located. With the application of a moving target point we can define the animator's space of movement. We used a flashlight for this purpose. The illuminating point was the target point we used to draw a cube around us. After processing this, the movement area was defined. Here we have the option of adjusting the virtual plane to the real plane if the program would have incorrectly delimited the space.

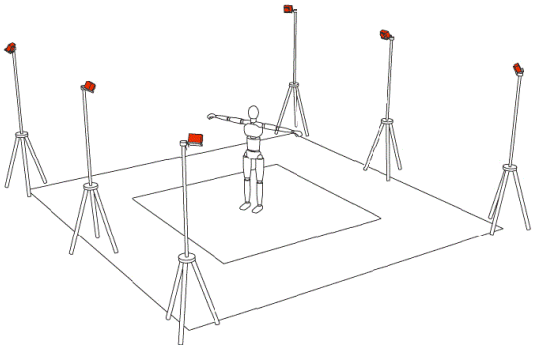

Fig. 3: MoCap room layout [21]

IV. Experimental Setup

After the recording space is calibrated, the animator is calibrated with the T-pose. After a delayed start of the program, the animator picks up the starting position and starts recording the desired movements.

Fig. 4: T-pose

Recording and virtual processing of video image data requires computing capacity on the computer's (VGA) video card module. Even a stable, powerful computer had difficulty processing data with more than three cameras. Thus connecting 6 cameras at the same time to the computer's USB ports failed. Subsequently, two computers were used to record data, where a master and slave were able to create a digitalized motion format using shared synchronized data processing.

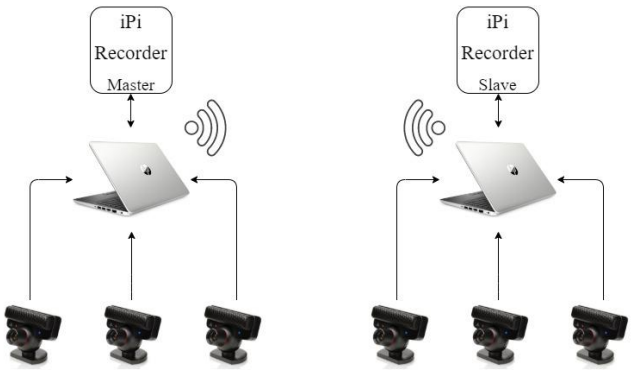

Fig. 5: Hardware architecture

Camera images are processed separately, and the slave sends the finished data to the master which creates a merged version of it. We calibrate the skeleton to the animator with T-pose and then, if possible, look at the results of the first movements at a step by step pace while still being able to adjust the skeleton. We can do this with automatic clean movements as well. Once you've made sure that the skeleton picks up the correct points on the animator and its motion is right for us, then we can start rendering.

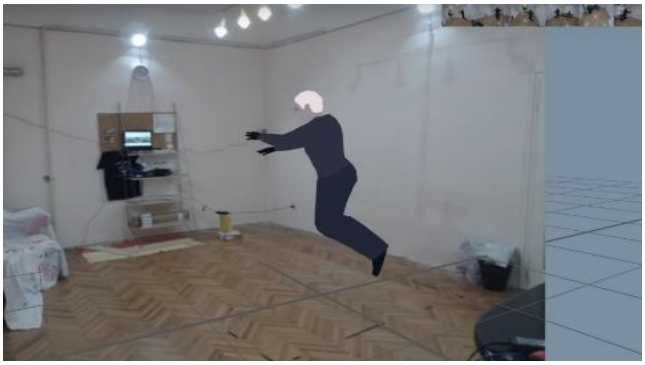

Fig. 6: Animated movement

The resulting animated motion becomes applicable for moving any similar skeleton shape. We integrated the image to move the body created in a 3D graphics program called Autodesk Maya. The resulting animated figure can be placed and controlled in a video game or on the virtual reality training platform we use.

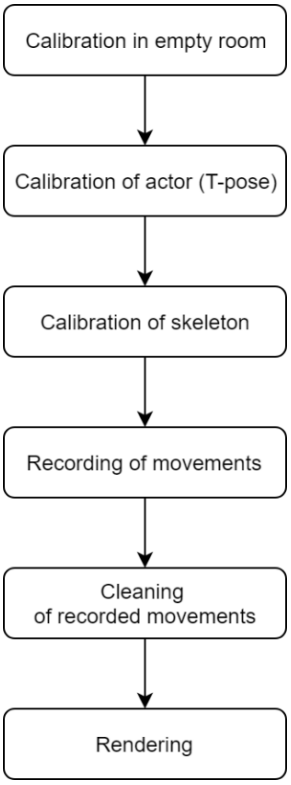

Fig. 7: Process workflow

V. Conclusion

The paper addressed the role of MoCap and VR technology in education. This paper presents a MoCap tool that allows testing and teaching the basic techniques. The measurements are based on six PS Eye cameras and the softwares iPi Recorder and Autodesk Maya. The purpose of our research was to review the area of motion capture technology, to research it and to gain a broad understanding of its depths, how this technology can be applied in healthcare and education. During our research, we built our own MoCap studio to digitize the movements and create an animated character as an educational process for university students.

The technology used in the project enabled us to digitize high-quality movements. Further research is needed to determine the accuracy of the system.

VI. Acknowledgement

The authors wish to thank the support to the Arconic Foundation.

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Collaborative robotics in ROS

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***Abstract*— The paper deals with the usage of ROS middleware (Robot Operating System) in robotic systems. RT-middleware (Robot Technology Middleware) is a technology that implement elements needed to build and operate spatially distributed complex robot systems. In that manner a smart factory model was created based on full duplex communication using TCP Socket and websocket technology which was later integrated in a ROS-based environment. This paper gives an overview of robotic solutions using ROS showing its main features and benefits.**

Keywords—Collaborative robotics, ROS, embedded systems, RT-middleware

I. Introduction

The spark of today's industrial revolution is the advancement of information technology, which enables wireless connectivity between elements of production, through which channels can flow a lot of data. This revolution called Industry 4.0 includes cyber-physical systems, cloud storage, Internet of Things (IoT) and smart machines and cells (Smart Factories) [1]–[5]. Physically present production involves a system for collecting, processing and streaming data in cyberspace. These so-called cyber-physical systems combine all elements (robots, CNC machines, sensors, cameras, user phones, workpieces, etc.) involved in manufacturing into one network. These elements work together to create a 'path' for the machined part, which can be completed at optimum speed. To stabilize such a complex system, highly reliable elements are needed [6]–[8].

This kind of thinking has replaced the former centralized structure and creates a decentralized process in which each component makes its own decisions. Exceptions to this are error handling or higher priority tasks that are controlled by the central control of the system. This is an integrated approach of Industrial Internet of Things (IIoT). Flowing data is easy to read and speaks to people and machines alike. The reason is that you can make both human and machine decisions in the shortest amount of time. It also allows the operator to identify areas of production that can be improved in the knowledge of large amounts of data. The Big Data environment has been developed to collect and manage these statistics [9]. This facilitates processing large volumes of data that would be difficult to use with earlier tools.

II. Problem description

For our current education and future robotics applications, we have developed a ROS-based cyber physical unit for learning and experimental purposes, which consists of a robot arm, a conveyor, and a shape recognition camera [10]–[12]. Such a unit facilitates the presentation of engineering tasks to potential problems encountered in the engineering work and facilitates communication with our industry partners. The design was divided into two parts: one was the selection of a manufacturing process presented and executed by the cell, and the other was the assembly of the cell to accomplish the task.

Selecting such a task was difficult, as Industry 4.0 can best fit into serial production. The chosen task was to perform a quality control: the dimensional correctness and surface quality control of factory-made or supplied parts.

III. Experimental setup

A. Milestones

The main steps are listed below that we focused during the implementation of the experimental setup:

- Assessing, ordering, and purchasing hardware and software needs
- Layout design
- Motor control by microcontroller
- Server for network communication
- Network communication establishing a client-server connection
- Robot programming
- Creating a Graphical User Interface (GUI)
- Modeling, assembly and control of conveyor
- Implementation of camera image processing
- Implementation of the demonstration task

B. Main units

The smart cell is the sum of several units with decision-making power in the spirit of Industry 4.0. The more of such subsystems we have, the harder the task of coordinating communication becomes, but the higher the level of automation can be achieved. The experimental setup can be divided into three larger units, along with other peripheral elements. For example, we put the conveyor in the latter category because the conveyor does not have a control unit on its own, so it cannot make its own decisions on incoming data.

The first separable logic unit demonstrates a collaborative workspace [13]–[15]. It is a group of one robot and two cameras. The robot is a Universal Robots UR3 collaborative robot. The robot is equipped with an RG-2 gripper that allows the robot to manipulate items weighing less than 2 kg. There is a SICK 2D Vision Inspector PIM60 industrial camera mounted on the robot that can perform tasks ranging from shape recognition to size control. We assigned a Keyence camera and its processing unit also to this group (CV-X152 processing unit and CA-LH16 camera with CV-200C lens). They form a group in terms of network connections.

The second unit consists of a Raspberry Pi Model B and two motors controlled by it. Two low-torque (0.4 Nm) stepper motors are controlled by the Raspberry Pi, through a dedicated Adafruit HAT module. This Adafruit PCB is a

Raspberry compatible controller that can control two stepper motors via two TB6612 drivers.

The third logically separable unit is the server that establishes the communication channels and the GUI.

These elements are supplemented by components that are either used as tools or do not have independent decision-making control. There are 3D printed elements that perform various functions, such as the barrier elements introduced later or the prototype parts that attach the motors to the conveyor.

C. Collaborative robot arm and image processing

The robot's job is to signal the arrival of the workpiece and to place it. The states shown in the flowchart (see Fig. 3) are illustrating of the robot's separable functions. Accordingly, this also determines the structure of the robot program. The program is based on a large 'switch case', which means that the robot can be switched between different states. Different inputs cause it to enter a different phase. The process is divided into a total of nine parts (case 0 to case 8), except for the stop button cases. Each is a combination of some kind of movement and network messaging. We have created subroutines for receiving and sending messages, which are called when a robot sends or receives a signal. Programming has revealed that the robot (and the Keyence industrial camera that performs quality control) does not communicate with websocket technology, but with older TCP protocol-based socket communication. Thus, there are two endpoints on the server, one for the websocket and one for the TCP socket connection. The robot program can receive the effects of the stop buttons at any given moment, since we have created a thread to examine the incoming message. If one of the stop buttons is pressed, the robot program switches to the appropriate state within the case structure (case 11 to case 13). The robot program is written in UR Script language. We put the Keyence industrial camera in the logic unit of the robot and the robot-mounted camera.

D. Raspberry Pi and stepper motors

The task of the microcontroller is simple, it must control two stepper motors. This is done by a signal converter driver, the unit referred to as Adafruit HAT. Programming is done in Python. The first program is connected to the websocket server and the second program is responsible for making various motions with the motors as a result of the input parameters.

To transfer workpieces from the conveyor to the image processing site, an arm extends onto the assembly line and rotates the workpiece onto a table. As the performance of the motors is relatively small, we encountered problems caused by the friction [16]–[20].

As the critical surface is the cylindrical side of the workpiece, the workpiece must be rotated for lateral image processing so that it can be examined from all directions. The two motors move two arms which are symmetrically located on both sides of the conveyor belt. When closed, the tongue at the end of one arm slides into the gap formed on the other and closes 90 °. Its function is that when the workpiece is sensed by the websocket message, the arms are locked in an open position and hold current in this position by passing current through their coils. The workpiece strikes the arms and positions itself at the apex of the angle defined by the two arms. The robot then takes the component to the image processing site and the levers reopen after a message from the robot indicates that the component has been removed from its hold. The advantage of this solution is that the image processing can be carried out in a larger space designed for it..

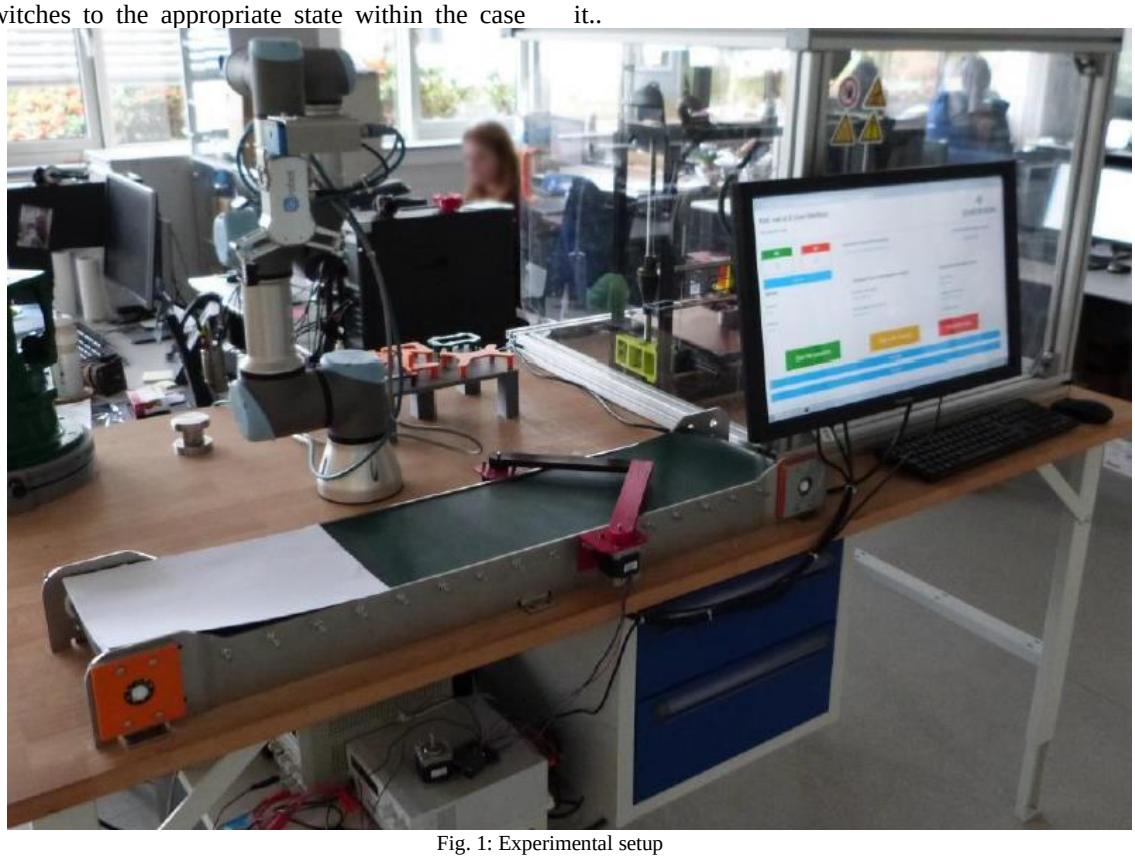

Fig. 1: Experimental setup

E. *Network communication*

One of the most important parts of Industry 4.0 is the communication platform where cell components can send and receive messages. A diagram of network elements (see Fig. 2) shows the color-coded connections. The server for the communication is shown on the right of the diagram. The figure shows two wires of different colors connected to the PC, but in reality, one Ethernet cable connects to the switch. The reason for this is that the robot and the Keyence camera are not capable of websocket technology, but only communicate as TCP sockets. Because of this, the server has two endpoints, which means that the same single server is capable of websocket and TCP socket communication. Since most of the network is capable of websocket messaging, the problem of two types of messaging is solved by converting an incoming TCP socket message into a websocket message and sending it straight away. This is fast and simplifies communication, with no need for two interfaces on each client.

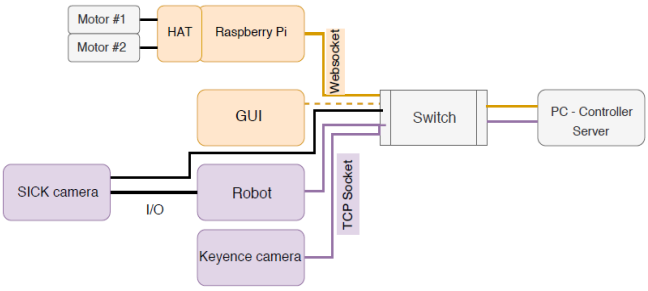

Fig. 2: Communication diagram

The function of the switch is to establish connection between the components. Beside the PC, the robot, Keyence camera, Raspberry and SICK camera are connected to the switch. Indirectly, the graphical user interface is attached to it as a client, but it is directly connected to the server on the PC, but if someone opens the interface in another browser, this connection is made via a switch. The Keyence camera is is not directly connected to the PC. Keyence provides a software option for creating a TCP socket connection point so that it can be connected directly to a robot.

The messages exchanged by the elements are JSON text messages (string). JSON is a language that can be easily transformed into an object in any major programming language, and its structure is easy to read by the human eye. At the beginning, the sender and the nodes to which a given message is intended are recorded. Then there is the message itself, broken down into components. The 'operation' section is a one-word short description that gives the message content to the GUI. In each section, the data to be processed by them. At the end, a 'connection' is a number that indicates whether the message conveys the connection of an element up or down.

The server is designed in a minimal way, only performing tasks that are necessary for the cell to function. An important part, however, is the termination of improperly closed connections, as this may provide false data to the operator. Periodically, the system checks all connected devices and kills the connection if there is no feedback.

Only the robot is connected to the server's TCP socket communication endpoint. The robot has the ability to establish multiple socket connections and has been used to connect to the Keyence camera. The server is also responsible for logging messages. Every message exchanged is also sent to the server and written to a text file using a separate program. By inserting the date, the operator can see at what time the messages were exchanged on the websocket channel. Similarly, the system records the current good and bad workpiece numbers by an interface button.

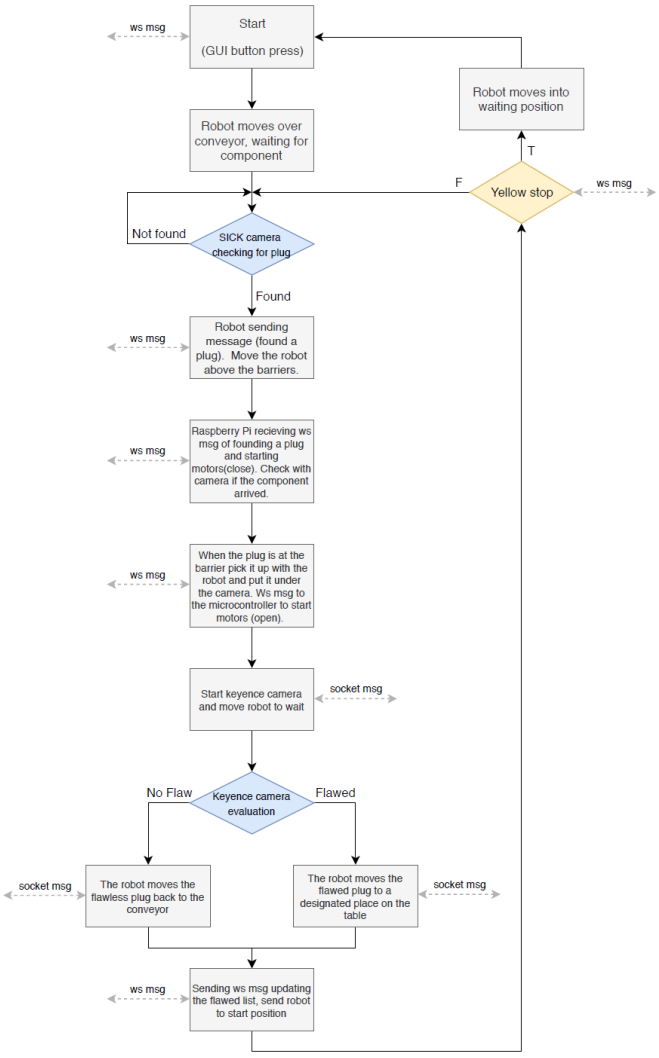

Fig. 3: Flowchart of the experimental setup

F. *Graphical user interface*

The communication interface between the operator and the cell is implemented by the GUI, which is a graphical user interface on the touch screen. The plans for implementing the GUI were minimal enough, the key points we wanted to achieve were start and stop buttons, ease of use, and feedback on message processing.

The web page has HTML structure with CSS and JavaScript elements. The GUI consists of two pages and a third "live" page showing a live image of the camera mounted on the robot. The main page has a brief introduction to the cell. The generic start stop buttons are also located in the

middle of the screen and the navigation buttons for the other two pages.

The second page is a surveillance page ('Data observation page'), where you can find detailed information about the cell. Highlighted and color coded in the upper left corner, the result of the quality control so far, passed and failed. In addition, a brief description of the type of defect in the case of a defective component. This is a development option, and further analysis of the camera image can automatically recommend how to handle a defective component. Highlighted in a slightly larger font at the top right, a description of the type of message processed by the GUI on the last websocket channel. This was a useful feedback during the design process, and the imaginary operator can see what processes are taking place in the background. Below the good and bad counters is a 'Save Data' button, which the operator can use to save the countdown so far. This is to allow multiple users to log their activity. It currently saves the data in a text file with a '.txt' extension but can be expanded with a login system. In the middle of the screen there is general live information about each component. Next to these are the buttons and a status block at the bottom of the screen. The latter is a brief, one-on-one feedback of the current state of the system.

The purpose of the interface is to provide general information and to start and stop the process. In the first plans, we designed two stop buttons. The yellow 'Stop when finished' button only stops the system after the quality-controlled part has finished. The red 'Emergency stop' button, as its name implies, immediately stops the process. This button is split into two parts and after pressing it, one of the following options can be selected: the process resumes from the moment of stopping or the process will cancel the advance of this part so far and will restart.

IV. Experiment

The main task is to demonstrate a surface quality control of a component with an industrial camera. Starting the process on the interface, the robot moves over the conveyor belt and the SICK camera takes a picture at short intervals. In the program that comes with the camera, it runs a round detection to detect the cylindrical part (which, viewed from above, is a circle) passing through the conveyor. The arrival of the workpiece is indicated to the other units and the robot moves over another position on the conveyor. Parallel to this, Raspberry will start the two motors connected to it, with two levers attached. They close in a barrier manner and then hold them in this position, guiding the current flowing through their coils until the component is positioned in the designated position. This is recognized by the SICK camera using another circular recognition algorithm. The component is then moved to the image processing site. After image processing, depending on whether the part was defective, the part is moved to different locations. The good part is returned to the conveyor, while the bad part is placed in a designated location. The interface then updates the number of good and bad parts and restarts the process from the beginning. In the GUI, the operator can stop the process in several ways.

V. Conclusion

In this paper a robot, an industrial camera, a conveyor belt, a microcontroller and a computer have been integrated into one system to perform a quality control demonstration task. The purpose of the cell is not to integrate it into direct production but demonstrate the advancement of information and operational technology. After studying the cell, one becomes familiar with the spirit of Industry 4.0 and the clear benefits of using Smart Factories and RT-middlewares.

VI. Acknowledgement

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Junction Models in OpenDRIVE Standard

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***Abstract*—The development of autonomous vehicles is one of the most dynamically developing areas nowadays and covers wide areas of applied research. The developments are extremely expensive and time-consuming, so to reduce these factors all the available techniques should be used. Analyzes can be performed using simulators, it can accelerate the testing process. Accordingly, the paper has a focus on the use of different junction description method.**

Keywords—junction, OpenX Standards, OpenDRIVE, automotive simulations

I. Introduction

Nowadays different simulations are gaining importance in many areas of life. Therefore, we need information about the real world to make these simulations as complete as possible. This is not different for anyone dealing with transportation issues. I have already dealt with the logical representation of traffic junctions from a security point of view [1]. Due to the increased traffic, improving road safety is one of the major issues in the transportation policies of most countries. Simulation is used in many contexts, there are also several non-professional applications. Simulation is a priority in various automotive development processes as it speeds up and completes development. An automobile simulator provides an opportunity to reproduce the characteristics of real vehicles in a virtual environment. It replicates the external factors and conditions with which a vehicle interacts. Nowadays all major manufacturers use simulators to develop and test new ideas and products [2]. Key issues in simulation include the acquisition of valid information source about the relevant selection of key characteristics and behaviors, the use of simplifying approximations and assumptions within the simulation. The conceptual and feasibility test provides a strong basis for automotive developments, which is carried out with the help of simulators. The relevant road network data have also been extensively utilized to verify and validate the autonomous systems in simulation. The automotive simulators can be grouped into three main categories: vehicular testing applications, driving simulators and traffic simulators. To feed the simulators, data about road geometry and related information is required.

The paper is organized as follows: Section 2 presents the simplified junction description methods. Section 3 gives an overview of the junction and road description in OpenDRIVE format. In Section 4 the obtained conclusion can be read and finally, references can be found.

II. Junction Description Methods

The easiest way to create a digital representation of a junction is to create a simple graph. A graph in this context is made up of nodes that are connected by edges (also called links or lines). A distinction is made between undirected graphs, where edges link two vertices symmetrically and directed graphs. The basic idea is to create an undirected graph first, where the junction branches replaced by simple centerlines. The centerlines can be matched with the nodes. The graph can be defined by a coordinate matrix and an adjacency matrix, and geometry is stored in a separate file. Using this modeling concept, arbitrary complex road junctions can be modeled. Figure 1. shows the simple centerline method to describe a junction.

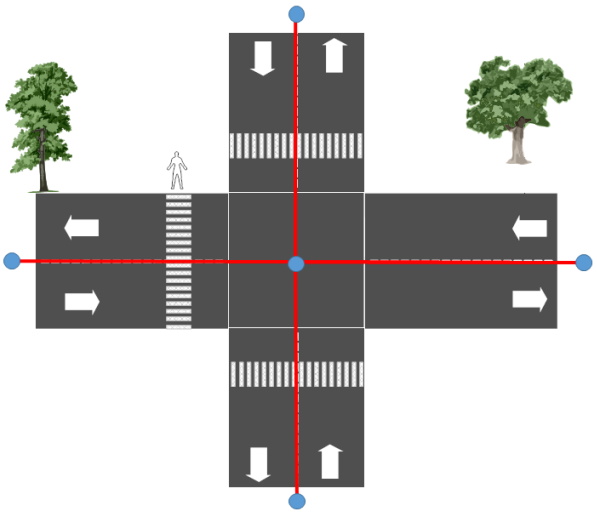
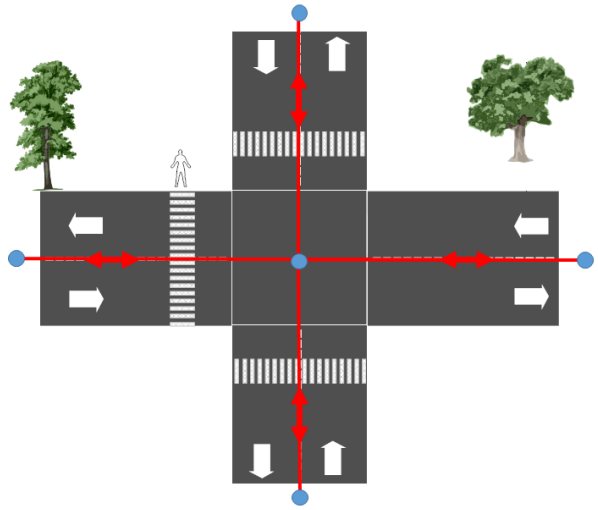


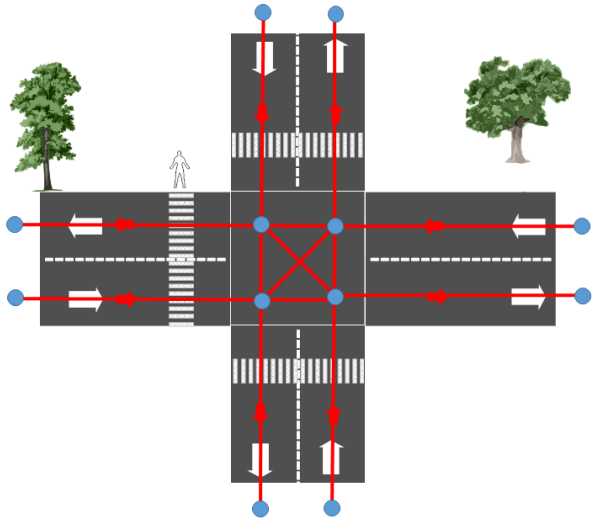
Figure 1. Simple graph representation of the sample junction

In mathematics, a directed graph is a graph in which edges have orientations. In Figure 2. section a) presents a detailed traffic junction information by adding possible traffic directions to the centerlines of the road. The possible driving directions are strictly necessary to run analyses. The number of nodes in the graph does not change compared to the previous version, but the stored matrix is more complex. If

the carriageway contains multiple lanes, lane recording is also required for more realistic analysis. As described above, a simple model of the intersection can be implemented as shown in Figure 2 (b). The number of the nodes is increasing since the lane-level registration requires more information for the nodes than providing a simple centerline. This type of logical description of the traffic junction provides sufficient information for many analyses. In the world of simulators, there is a shift towards open source standardized formats. Such a collection of standards is provided by the OpenX standard package.



a) Graph representation by directions



b) Graph representation by lanes

Figure 2. Detailed graph representation of the sample junction

III. The OpenDRIVE-way for junctions

OpenX standards is a collective term that is used to refer to OpenDRIVE [3], OpenCRG [4] and OpenSCENARIO [5]. These three open-source formats were started to standardize how road data was described and formatted. OpenX began with OpenDRIVE and later evolved to include OpenCRG and OpenSCENARIO to keep pace with industry development. OpenDRIVE was the first open format to prescribe the logical descriptions of roads and road networks in 3D environments. The OpenDRIVE project has been introduced in the market since 2006 as a German company, the VIRES Simulationstechnologie started building visual databases for various driving simulators. Later other big companies joined and the main contributors in designing and developing the standard are Audi Electronics Venture, BMW Group Research and Technology, Daimler, Deutsches Zentrum für Luft- und Raumfahrt, Fraunhofer IVI, Mercedes-Benz Technology, Realtime Technologies, TESIS DYNAware, Technische Universität München, VIRES Simulationstechnologie, VTI – Swedish National Road and Transport Research Institute. OpenDRIVE was managed by VIRES Simulationstechnologie GmbH until November 2018, the assets and maintenance responsibility of OpenX standards were handed over to the Association for Standardization in Automotive and Measuring Systems (ASAM). The OpenDRIVE standard is reviewed and released by a core team of driving simulation experts. Today OpenDRIVE has become an international standard that contains the logical description of the road network. It has an own file format, the OXDR with a hierarchical structure and is available in XML format, which helps the data exchange between different data types. The specified file format contains the precise analytical description of road networks, the main parts are the road segments, the junctions, and the controllers. Roads are described by their centerline. The geometry has three main elements: line, spiral, and arc.

The main purpose of this file format is the use is in simulation applications, which require exact road geometry descriptions, including surface properties, markings, signposting and logical properties such as lane types and directions. Road data may be manually created from road network editors, conversion of map data, or originate from converted scans of real-world roads [6][7][8] [9]. **Hiba! A hivatkozási forrás nem található.** illustrates an example junction created by OpenDRIVE description.

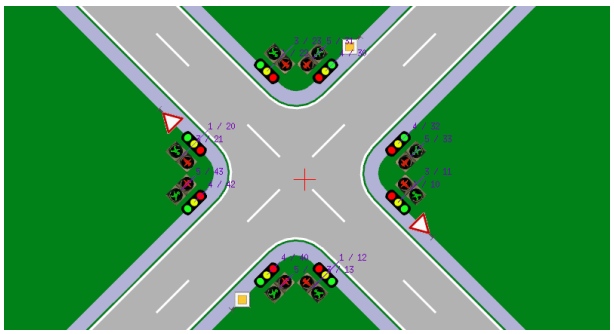


Figure 3. The example junction in OpenDRIVE

In OpenDRIVE format, each road element is described independently. All roads consist of a reference line that defines the basic geometry (arcs, straight lines, and spiral). Along the reference line, various properties of the road can be defined. These are, e.g. elevation profile, lanes, traffic signs. The used layout elements such as reference lines, lanes and other features are illustrated in Figure 4. Roads can be linked to each other either directly when there is only one connection possibility between two given roads. Junctions help to resolve otherwise ambiguous predecessor-successor relationships between the elements when more than one connection is possible from a given road to other roads.

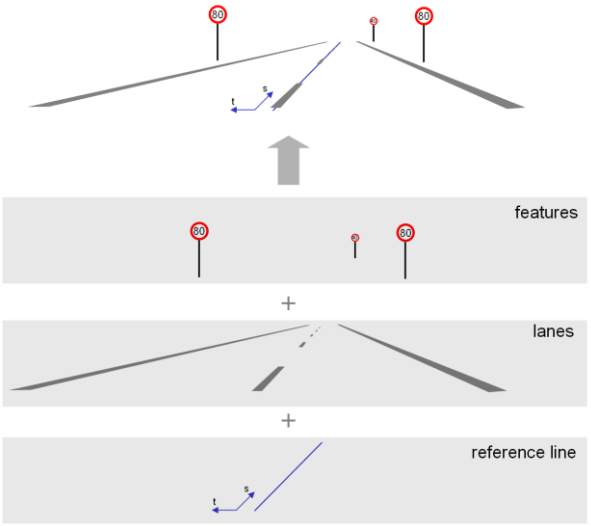
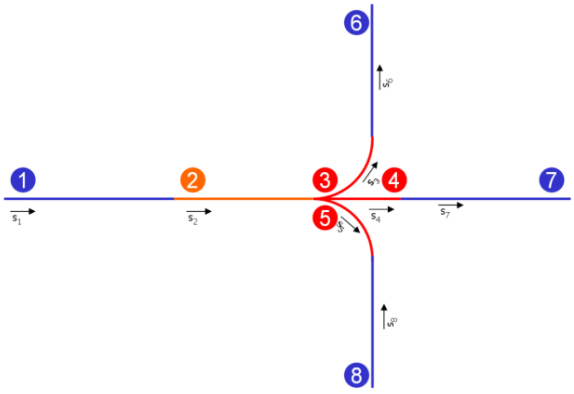


Figure 4. OpenDRIVE layout elements

In order to navigate through a road network, the application must know about the linkage between different roads. Two types of linkage are possible: one is a successor – predecessor linkage or the junctions type. When the linkage between two roads is clear (see Figure 5. road 1 to road 2), a standard linkage information is sufficient. A junction is required when the successor or predecessor relationship of a road is ambiguous. In this case, one of several possibilities must be selected. In the OpenDRIVE standard, the connecting roads could be incoming, outgoing or connecting roads depending on the direction and the number of roads. Figure 5 illustrates some of the possible connections within a junction. The roads No. 3, 4 and 5 are connecting roads. For them, road No. 2 is an incoming road. Roads 6, 7 and 8 are outgoing roads and they could act as incoming roads for other connections.



Road	Predecessor	Successor
1	-	2
2	1	ambiguous
3	2	6
4	2	7
5	2	8
6	3	-
7	4	-
8	-	5

Figure 5. Road linkage in OpenDRIVE

In OpenDRIVE specification, the area of the connecting roads is called the junction area or simple junction (see Figure 6). The basic idea is very simple; the junction links the incoming roads with the outgoing roads. The connecting roads are modeled as roads, so they have reference line with lane sections, etc. (see Figure 7). Junctions consist of a connection matrix which indicates all possibilities to enter a connecting road from a given incoming road. If the traffic junction has U-turn possibilities, it must be modeled as individual connecting roads, in consequence adding one more possibility to the connection matrix. All intended possible connections between roads must be defined via connecting paths; a missing connection means that there is no connection available. In certain situation, several junctions belong to a bigger traffic junction, in this case the traffic rules could be implemented more efficiently, OpenDRIVE standard allows to put junctions into a single group.

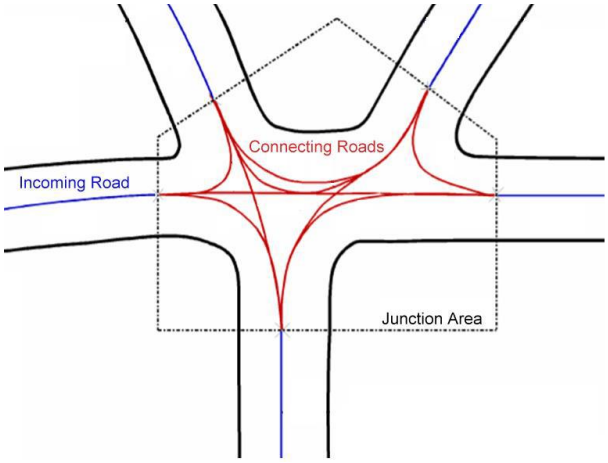


Figure 6. OpenDRIVE junction schema

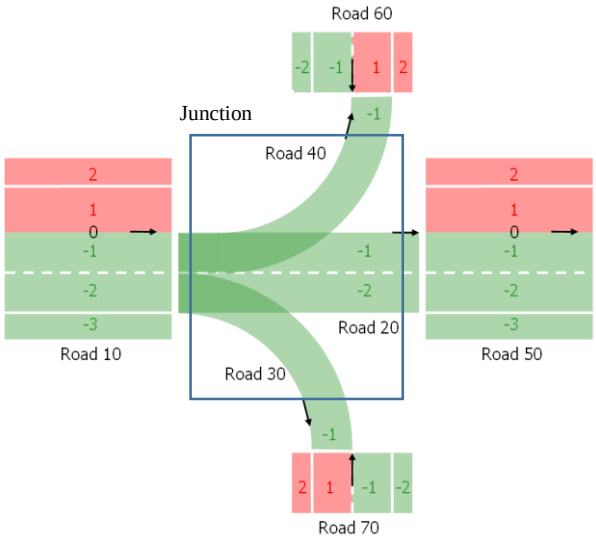


Figure 7. OpenDRIVE road junction model with lanes

Visualization of the OpenDRIVE format data is presented in Figure 8. Detailed information such as lane marking, traffic lights, green vegetation, building, etc. also could be described in a standard way.

Figure 8. Vires, Virtual Test Drive example junction

IV. Conclusions

The simulation is primary in the vehicular development process as it allows time-efficient testing. In autonomous driving, road network data is a necessity. These simulation applications require exact road geometry description that needs to be created and shared in a common format. The need for Open Standards from autonomous car manufacturers is growing. Having industry-wide standards makes it much easier for manufacturers to test and improve the self-driving vehicles. The consistent logical description of road sections based on the OpenDRIVE format allows the use in different simulators, as this format is supported by almost all automotive simulators. The benefits of standardization of road descriptions are clear, one format for many applications allows the exchangeability of information between various user. The OpenDRIVE standard contains exact descriptors about the road environment (road segments, lanes, lane markings, etc.). The standard allows for creating homogeneous road databases which based on the needs of the industry can be used in heterogeneous simulation environments.

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Autonomous Driving Supported by Simulations

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***Abstract*—The automotive industry is largely sensitive to the high quality of the products. This momentum results that huge amount of tests and analyses are required to achieve this goal. The emerged costs and time demand can be decreased by involving computer-based methodologies, like simulations. Simulations imitate the exact characteristics of vehicle parts in fully modeling form. If the whole vehicle stands in the focus of simulations, the system must be supported by highly accurate reality descriptions. The OpenDRIVE standard contains exact descriptors about the road environment (road segments, lanes, lane markings, etc.). Such models can be obtained by surveying and modeling reality. The paper gives an overview of the standard and current implementations in the various automotive simulators. The future perspective awaits massive growth of the importance of the standard.**

Keywords—simulation, autonomous driving, development, OpenDRIVE, digital map

I. INTRODUCTION

Self-driving vehicles are expected as one of the biggest changing factors in our near future life. The road transportation stands in front of a great revolution as the vehicles will be equipped with autonomy. These expectations are implicitly understood together with a very safe operation. The development of vehicles requires a huge amount of resources, manpower, time and money; these efforts are expressed in the price labels. The carmaker industry is therefore interested in effective techniques that can reduce the above-listed items; fewer efforts can establish higher profits at the end. The various computer-based solutions can be used well in this struggle.

Among the plenty of computer-based procedures, we focus on the simulations. “A simulation is an approximate imitation of the operation of a process or system, that represents its operation over time.” [1] after another definition “Simulation is the implementation of a model or models in a specific environment that allows the models’ execution or use over time.” [2] Simulation is used in many contexts, such as simulation of technology for performance optimization, safety engineering, testing, training, education, and video games.[1] Naturally the automotive world profit also from the advantages of the use of simulations in the different production scenarios.

Generally, the purpose of the simulation can be the verification or validation of a proof of concept, the analysis and/or the increase of complexity of a system (architecture) or the analysis and/or the increase of the level of quality (e.g. accuracy). The simulation acts advantageously in error detection, failure localization, effectivity, and performance increase, whereas considers the available resources, manpower and working process. Shortly, it has an excellent, i.e. high added value versus cost ratio. [3]

The modern vehicles contain more and more computing devices: computers, microcontrollers, etc. These hardware components own an adequate software environment, therefor software development has an increasing role in automotive development and production. Simulation can be discussed on various development levels: source code, software component, system component or system levels. These levels have methodologies with sophisticated testing procedures. Experts agree that such a complex development task cannot be managed without permanent feedbacks and continuous testing workflow is mostly desired. Beyond the software world, the hardware is similarly divided into hardware (as a whole), hardware components, etc. levels. All these simulation modules can have inputs and outputs, where the focus is on the System-under-Test (SuT) block.

II. AUTONOMOUS DRIVING DEVELOPMENTS IN GENERAL

The world of the carmakers has the feature of the above-mentioned process. The development of a vehicle starts with conceptual planning, continued by the elaboration of the details and the prototype, then intensive tests are executing with going back to certain planning phases and refining the elements. After long and hopefully overall tests the prototype can be accepted and the series production starts.

Within this process, more and more computers and their software require more and more software tests. Real vehicle testing is only allowed with high mature software. Simulation and the connected virtual testing have a consequently higher importance in nowadays production workflow.

Because software development is tightly coupled to the hardware environment, and this is more crucial in vehicle control, the methods in software development have to consider the hardware specialties. The current hardware components are therefore developed together with their software.

The most important element of a vehicle is its "brain", the Electronic Control Unit (ECU). To be able to test it, a series of vehicle components: the engine, the brake system, the environmental sensors, the wipers, the lighting system, etc. must be connected. There are a series of such units: Engine Control Module (ECM), Powertrain Control Module (PCM), Transmission Control Module (TCM), Brake Control Module (BCM or EBCM), Central Control Module (CCM), Central Timing Module (CTM), General Electronic Module (GEM), Body Control Module (BCM), Suspension Control Module (SCM). Further modules are easy to be mentioned. Some modern motor vehicles have up to 80 ECUs. [4]

In the test procedure, these modules have to be connected to the relevant vehicular subunit, e.g. the engine. As was mentioned, the real tests are preceded by a virtual testing course, where the affected subunit must be substituted by a computational model. This simulation and testing is the Hardware-in-the-loop (HIL) simulation. This is a technique that is used in the development and test of complex real-time embedded systems. [1], [5]

When not only a single vehicular component is under tests, but the car as a whole, the Vehicle-in-the-Loop (ViL) is discussed. The Vehicle-in-the-Loop (ViL) concept, which is already in use, was directly developed to test ADAS functions. In this configuration the vehicle itself is real but all the other elements of traffic are simulated. DAS stands for Driver Assistance System, which is a collection of assistants, i.e. services helping in controlling the driving task. A known example for DAS service is the Cruise Control (CC), or another name "tempomat", which is responsible to ensure a constant prior set cruising speed. ADAS is the abbreviation for Advanced Driving Assistance System. To continue the mentioned example, the Adaptive Cruise Control ("adaptive tempomat") can be revealed, which extends the functionality by permanently measuring the distance to the vehicle driving in front of the ego-vehicle and controlling the speed with respect to a safe distance. The next step is using the Scenario-in-the-Loop (SciL) testing environment, where not just the physical attributes of the vehicle are tested but also its sensors via their virtual twin realization. In this case, the investigated scenario is simulated and fully or partly realized in parallel. [5], [6]

The ViL and mainly the SciL testing tasks have a strong demand for the digital representation of the real environment. The reality has to be captured and represented to support these systems. There several ways to solve that challenge, but the most widely used, nowadays standardized way is the OpenDRIVE representation.

OpenDRIVE is the leading open format and the de-facto standard for the description of road networks in driving simulation applications. The main contributors in designing and developing the standard are Audi Electronics Venture, BMW Group Research and Technology, Daimler, Deutsches Zentrum für Luft- und Raumfahrt, Fraunhofer IVI, Mercedes-Benz Technology, Realtime Technologies, TESIS DYNAware, Technische Universität München, VIRES Simulationstechnologie, VTI – Swedish National Road and Transport Research Institute. The OpenDRIVE standard has the following main components: road geometry (e.g. reference line, elevation, superelevation, lanes), signaling (e.g. signs, signals), road type and speed profile, simplified road surface (e.g. materials, patches), infrastructure (e.g. tunnels, bridges), arbitrary objects, variations (data sets), custom extensions (user data). [7], [8]

Obtaining acceptable results from the different levels of simulations, real-life tests can be conducted. The last phase of this quality control process is the testing with real vehicles on real public roads. Fig. 1 demonstrates the fundamental role of the simulation in the modern vehicle development procedure.

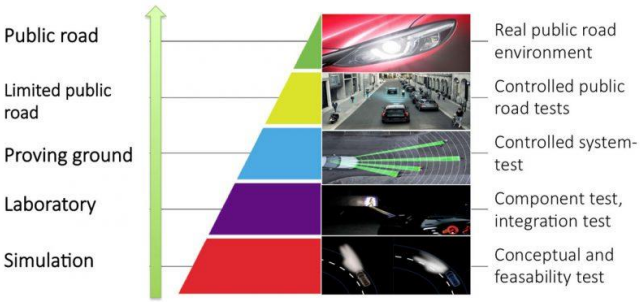

Figure 1. Levels of the tests during the automotive development

III. Simulator environments for AD developments

The previous section might suggest the message, that simulation is a highly appreciated instrumentation in the vehicular development. This is intensively valid for autonomous vehicle development tasks. Because these computer-controlled vehicles are more complicated, have more complex architecture and logic, their software contains more easily bugs, which are also to be discovered and eliminated. The role of simulation gets higher importance.

Because the vehicles are complex systems, their simulators and test environments are similarly complex and various. A rapid survey of automotive simulators having the ability to manage environmental data with OpenDRIVE standard is presented in Fig. 2.

Figure 2. Result of rapid search for automotive simulators with OpenDRIVE – OpenCRG - OpenSCENARIO support [8]–[14]

The common of these solutions is that all of them can consider environmental information with the help of the tools standardized by OpenDRIVE. The simulators expression is building modeling scenario, where the road environment (together with important buildings, rivers, bridges, etc.) is described in a type of map, further elements like vehicles, cycles, pedestrians but other objects as road work components, disturbing elements (wracks, oil slicks, dropped cargo, tree leafs, etc.) extend the scenario. The scenario is then equipped by sensors and controllers and is ready to conduct the test cases (Fig. 3).

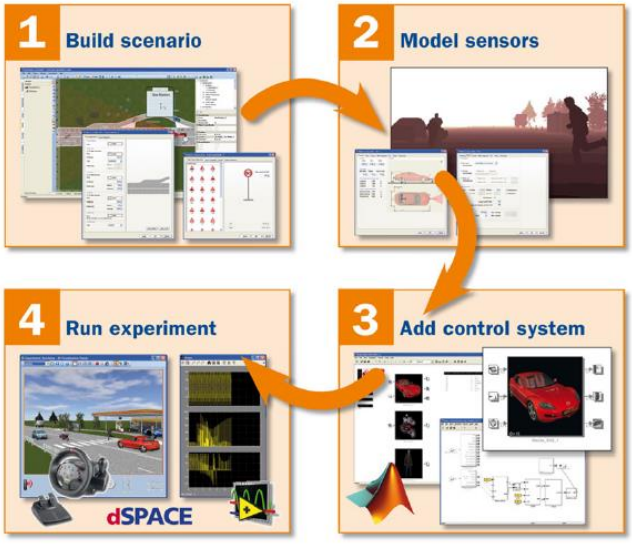

Figure 3. Simulation cycle with scenario definition, sensors and control system, and a running phase [10]

Relevant visualizations in the simulators present the current situation with roads, lanes, traffic signs and signals, as well as the vehicles, or even extended with incidents. The Virtual Test Drive (VTD) system from Vires can be seen in Fig. 4. Similar perspective road visualization is also in TASS PreScan available (Fig. 5) [10].

Figure 4. Vires VTD situation plot

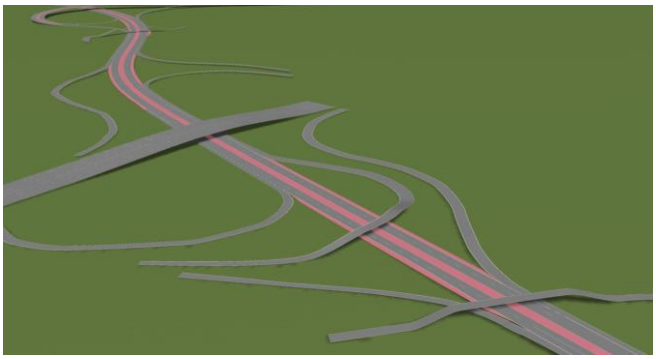

Figure 5. PreScan perspective 3D visualization for roads

Thanks to the achievements in computer graphics, all such simulators are prepared with (quasi) photorealistic environmental visualization power. The graphic engine of those systems can create textured scenarios, where the exact situations are easy to understand, evaluate – even by non-expert users (Fig. 6).

TASS PreScan

Vires VTD

Figure 6. Photorealistic scenario visualizations

The widely known mathematical software package Mathworks Matlab contains also a complete vehicular computation toolbox. Within this toolbox, the OpenDRIVE map models can be imported and for example, safety-critical traffic situations can be evaluated. Fig. 7 demonstrates how a four-arm road junction can be loaded as an OpenDRIVE model, then the behave of a vehicle and a parallel moving cyclist can be analyzed. The presented test case clearly shows also the viewing angle of the onboard camera. Other sensors, like lidars, radars, etc. can similarly be evaluated.

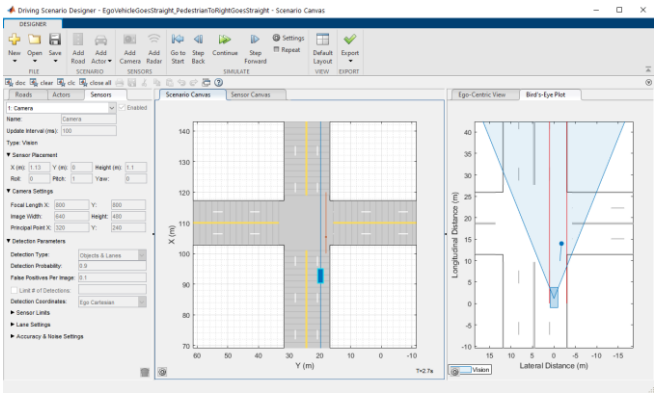

Figure 7. Driving Scenario Designer in Mathworks Matlab with a traffic scenario and vehicle with an onboard camera

IV. Conclusion and outlook

The long and costly development procedure in the vehicle industry welcomes all potential technologies, which can accelerate it and reduce the costs. This moment justifies the rapid increase of the simulations' use. Simulators are computer-based tools, which can imitate reality, in these cases the real components of a new vehicle. Computer simulations require exact models representing the very fine details of the features of the analyzed component. If not just any part of a vehicle is to be analyzed and tested, but the vehicle as a whole, the simulations describe and show the behave of the vehicle in a specific circumstance. The road environment is an elementary part of these simulations. The OpenDRIVE standard is capable to describe all important road elements, like lanes, lane markings, signs, and signals, road furniture etc. OpenDRIVE models can be obtained by surveying the reality and evaluating those measurements. Thanks to this character, OpenDRIVE is implemented in more and more simulators. The bottleneck of the use of OpenDRIVE models is the fact, that it requires exact lane-based road models, where consistency is crucial and the achievement of the necessary quality demands actually quite high efforts and human interactions. There are many improvements expected in the future containing automatic model generation and/or artificial intelligence.

Acknowledgment

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The project has been supported by the European Union, co-financed by the European Social Fund. EFOP-3.6.3-VEKOP-16-2017-00001.

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OpenDRIVE Standard for Road Description

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***Abstract*—The world of autonomous vehicles is developing fast. The best new ideas become new improvements, and later after the testing process, they can be used in the real world. These improvements need countless tests too. Simulation software provide a safer and cheaper alternative to execute them. Simulations are supported with real environment data, which makes the test more reliable and various. The OpenX family is an open format standard family, that provides road data in simulation software. OpenDRIVE was the first project, it gives the basic, the logical road description for simulation software in a standardized way.**

Keywords—OpenDRIVE, standard, autonomous driving, road

I. Introduction

The expression "autonomous vehicle" represents a vehicle, that is capable of transport without human help. SAE International, an automotive expert board has developed the J3016 standard, which defines individual levels for driving automation. According to this standard, there are six levels, numbered from zero to five. Level 0 is the level of no automation when the human driver controls the car completely, perhaps some warning functions can be built-in at this level, e.g.: lane departure warning. The automation starts at level 1 (driver assistance), using lateral or longitudinal support features, such as steering or acceleration. At level 2 (partial automation) lateral and longitudinal control can be used together at the same time in the same vehicle. From level of conditional automation (level 3) the vehicle starts to monitor its surround, and it can activate the right driving task if it is necessary, but the driver has to be ready to take back the control in some special cases. An example of level 3 is the traffic jam chauffeur. From level 4, the level of high automation, the vehicle is capable of transport on the roads, but it can't handle all situations. At level 5 the vehicle can drive itself without human help in all conditions. Figure 1 shows the main features of the automation levels according to SAE. [1]

Nowadays the vehicles on the road are maximum at the level of partial automation. The difference between the lower levels are the numbers and types of driver assistance functions. The new developments are coming continuously, and there is a big competition between the companies. The main factors of the developments are money and time. Both are supported by using simulators for testing the new results. These evaluations become more useful when real

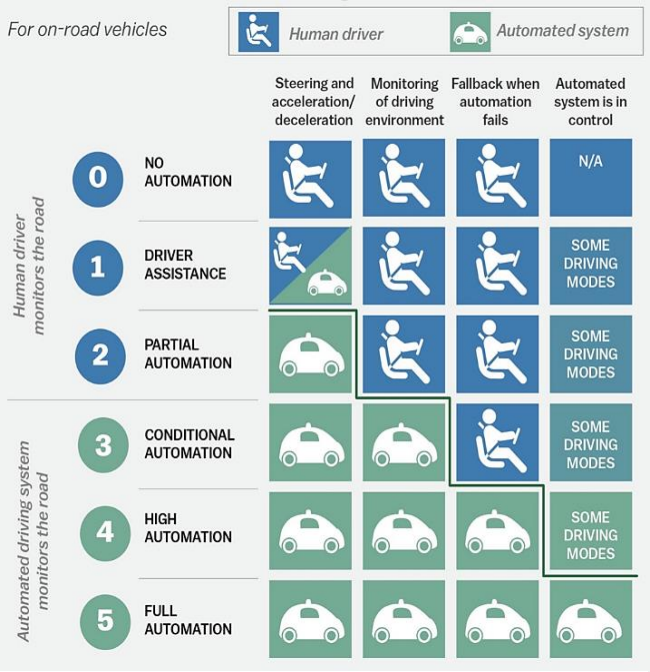


Fig. 1. Levels of automation according to SAE J 3016 [2]

environmental data are used instead of built-in opportunities. The OpenDRIVE, OpenCRG and OpenSCENARIO standards are used in simulation software for modeling the road. They are open projects, and the file structure is based on XML, therefore the creating and using of OpenX data in simulations is advantageous and preferred.

We will introduce the OpenX family and its basic, the OpenDRIVE standard in this paper and a road will be created using the OpenDRIVE standard.

II. The OpenX standard family

A. The OpenDRIVE project

OpenDRIVE is an open solution, project, and format, for describing road geometry and road connections. Its format can be handled by many simulation software, e.g.: Vires, PreScan, and SUMO.

The OpenDRIVE project was initiated by Vires Simulationstechnologie GmbH, when it started to build a visual database for driving simulators. OpenDRIVE meant a

unified platform that is suitable for road description in various simulators. It has started in 2006 with the help of Daimler Driving Simulator company and later more important companies joined this development. From 2018 the ASAM (Association for Standardization of Automation and Measuring Systems) took over and continued the whole project including OpenCRG and OpenSCENARIO, too. [3] [4]

B. *OpenCRG project*

The OpenCRG project deals with the microscopic surface of the road, that is usable in various driving and tire simulations. It was introduced in 2008. In the name, the "CRG" means Curved Regular Grid, which refers to the elevation data in grid frame with curved reference line. There is an example of OpenCRG data from real laser-scanned point cloud in Figure 2. It shows the unevenness of a cobblestone paved road. The blue color shows the deeper and the yellow color shows the higher part of the road. It was made in centimeter resolution. [5]

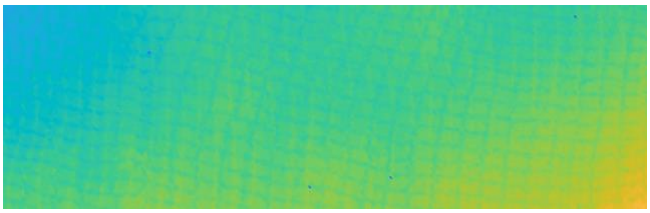


Fig. 2. Microscopic visulization of the road using OpenCRG

C. *Static content of the road*

Road network from OpenDRIVE and road surface description from OpenCRG gives the description of the static content of the road (Figure 3). Figure 4 shows the connection, the origin and the application of the static content. The data come from planning software, real road scans or another way. Later it can be modified or the whole road geometry can be edited manually. It has a surface feature too, that can use various OpenCRG data too, instead of the original basic road surface descriptions, that makes the simulation more efficient. The result, the static environment allows testing of various situations. Traffic simulation is a good way to test the effect of the road network for the traffic, because the parking ways, bus stops, etc. can influence it too. In autonomous simulations, the vehicle dynamics deals with the vehicle's reaction to the input action or data on a given surface. The different road surface data can be studied using the OpenCRG surface model. Various sensors (camera, Lidar, radar...) are tested in

Fig. 3. Static elements of the road [6]

simulations too. The sensing and reaction functions of the vehicle are also investigated. These simulations mean a cheaper and safer way to test the new improvements, this is the biggest advantage of using them. [2]

D. *OpenSCENARIO project*

OpenSCENARIO is the newest member of the standard family. This project started in 2014. It completes the static content with dynamic content. The basics are OpenDRIVE and OpenCRG standards, and OpenSCENARIO helps to simulate moving objects on the road, and test their behavior in various situations. Traffic or pedestrians can be simulated and ADAS functions can be tested in this way. [6]

III. ROAD MODELING BY OPENDRIVE TOOLS

The current stable version of OpenDRIVE is 1.4. H. It came out in November 4, 2015. This version was developed by Vires, which came out with a new 1.5 version in February 17, 2019, but most simulation software works better with the version of 1.4. The new owner, ASAM is working on version 1.6, but it improves a new 2.0 version parallel with 1.6.[4]

A. *XML*

The file name extension of OpenDRIVE is xodr, or xodrz for the zipped files. OpenCRG has crg and OpenSCENARIO uses xosc extension.

OpenDRIVE format is based on XML syntax, which means Extensible Markup Language. It is a describing language that arranges data in hierarchical structure. Tags are used to separate the data. The result can be interpreted by humans and computers too. Because of the good composition the creation, interpretation, and processing are well manageable using this format. There is an example for a road description in xodr format in Notepad++ software in Figure 5.

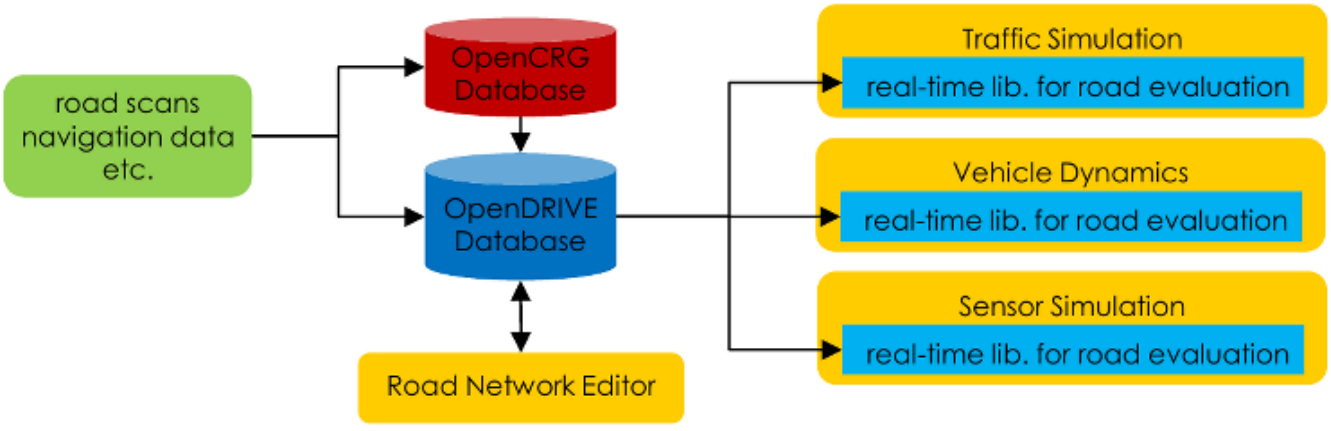


Fig. 4. The connection between OpenDRIVE and OpenCRG [3]

```
<?xml version="1.0" encoding="utf-8"?>
<OpenDRIVE>
    <header revMajor="1" revMinor="4" name="Rome, Italy" version
    </header>
    <road name="Via Biscotti" length="15.71" id="1" junction="-1
        <planView>
            <geometry s="0.00" x="0" y="0" hdg="1.57" length="15
                <arc curvature="-0.10"/>
            </geometry>
        </planView>
        <lanes>
            <laneSection s="0">
                <center>
                    <lane id="0" type="none" level= "0">
                        <width sOffset="0.00" a="0.1" b="0" c="0
                    </lane>
                </center>
                <right>
                    <lane id="-1" type="driving" level= "0">
                        <width sOffset="0.00" a="3.00" b="0.00"
                    </lane>
                </right>
            </laneSection>
        </lanes>
    </road>
    <road name="Piazza Mazzini" length="15.71" id="2" junction="
        <planView>
            <geometry s="0.00" x="0" y="0" hdg="1.57" length="15
                <arc curvature="0.10"/>
```

Fig. 5. Road description in OpenDRIVE in XML schema

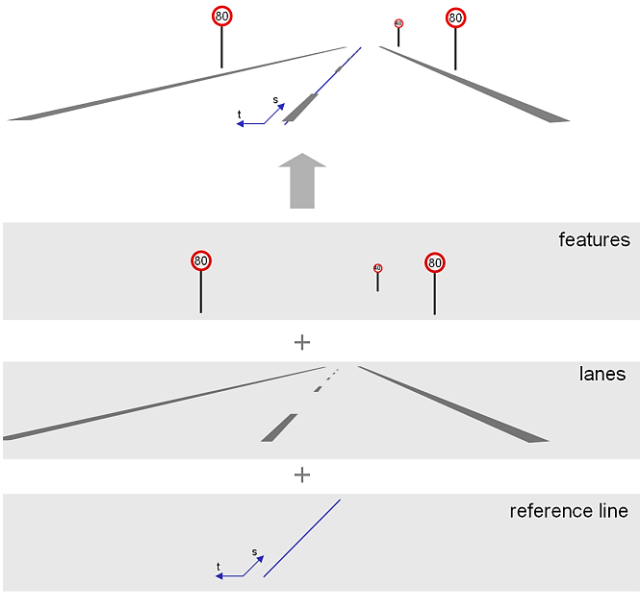


Fig. 6. Main parts of road layout [3]

It starts with a header, that contains some main information. Then the file is divided according to roads and describes the plan view geometry and lane information. [7]

B. *OpenDRIVE description*

Besides the upper example in Figure 5, other information can be defined also in OpenDRIVE format. The first lines contain main information about the OpenDRIVE and XML. The next segment is the header, which describes the data about the road network per road, e.g.: type, plan view, elevation. Signals and signs are defined also for each road. The junctions show the connection between the defined roads, and controllers define the connection between the junctions.

1) Units

The standard contains specifications about the units too. It usually uses SI units, e.g.: position and distance are in meter, angles in radian, time data in secundum; except some special cases, when a given unit has to be used.

2) Coordinate systems

Inertial and track coordinates are used in OpenDRIVE. They are right-handed. The inertial system uses x, y, z coordinates to define the position. The track system is used along the reference line measured the s coordinate from its starting point, the beginning of the road. The lateral position is signed with t, and h is for upward direction. The local system is used for local positioning using u, v, z coordinates, where u is forward, v is left and z is up direction. Curvatures are distinguished according to their direction. The left curve means the positive curvature when the direction of the motion is counter-clockwise. The opposite direction is the negative curvature with the right curve with clockwise motion.

3) Road layout

The road description is divided into three main parts; they are shown in Figure 6. The reference line gives the basis that determines the road geometry. Along the reference line, additional features can be described, e.g.: lanes, traffic signs. Their parameters can be given according to the standard description along the reference line grouped by the properties of the same type in ascending order.

4) Reference line

The reference line is demonstrated in Figure 7. It is a single line, usually a road centerline, that separates the two different moving directions. The s coordinate starts at the beginning of the road and it increases continuously. Geometric primitives are used to describe the geometry. The known types are a straight line, spiral, curve, cubic polynomial, and parametric cubic curves. Arcs and curves are used for modeling the curves of the road, and spirals ensure the continuous transition between the straight lines and arcs.

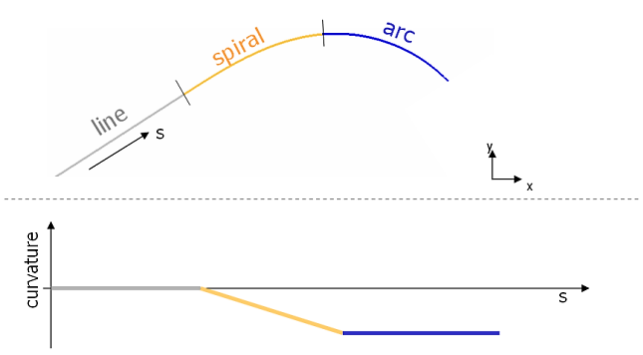


Fig. 7. Reference line [3]

5) Lanes

The road consists of lanes. The lanes have a main transport direction. The reference line is usually in the middle of the road, it has zero width and lane number. The other lanes are numbered relative to the reference line. The numbers increase to the positive t-direction, to the left side, and decrease to negative t-direction, to the right side. The numbers have to be unique in each lane section, and the numbering has to be continuous from the reference line, although the number of lanes can change, as it changes on the roads too. In some cases, the zeroth lane (reference line) has to be offset, e.g. because of a new left-turn lane from the opposite direction lane in the

middle of the road. Then a cubic polynom can be applied to solve the lane offset. Figure 8 presents the lane numbers with the described rules.

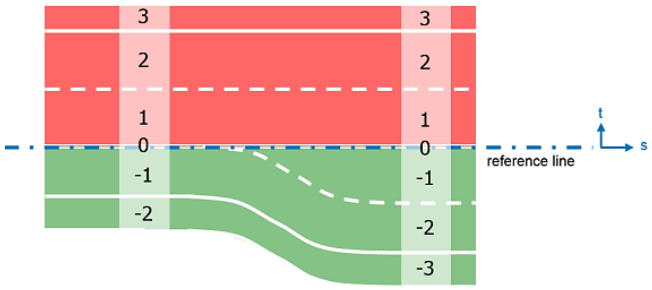


Fig. 8. Lanerepresentation in OpenDRIVE [3]

To handle the changes, the road is divided to lane sections along the reference line. Change in the lane starts a new lane section. It is signed with letters, Figure 9 shows an example of a motorway entry and exit lanes. It shows also, that the lane section is defined only for one side of the road. Lane properties can be assigned to each lane section. Superelevation and crossfall can be defined in OpenDRIVE too when the road is elevated to one side or to the center or other elevation data can be given using surface data or other analytical methods.

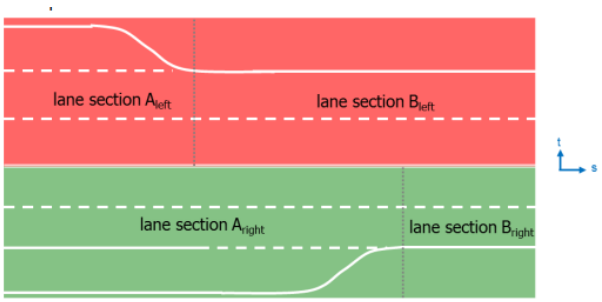
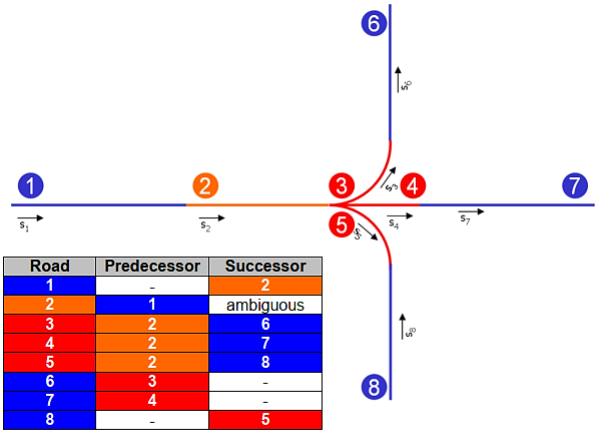


Fig. 9. Lane sections in OpenDRIVE [3]

6) Road Linkage

The individual roads are connected to each other and form a road network. The standard linkage is the continuous connection between two roads, it's type can be a successor or predecessor. Junctions are used in complicated connections. Figure 10 contains an image of a road network and a table with



Road	Predecessor	Successor
1	-	2
2	1	ambiguous
3	2	6
4	2	7
5	2	8
6	3	-
7	4	-
8	-	5

Fig. 10. Linkage types in OpenDRIVE [3]

its connections. Between road 1 and 2 are standard connections. According to the reference line (s coordinate) road 2 comes after road 1, so road 1 has predecessor and road 2 has the successor type. There are more options from road 2, so this connection has to be modeled as a junction. Junction builds the connection between ingoing and outgoing roads. In more complex situations, e.g.: roundabouts, junctions can be organized to junction groups.

7) Neighbors

Other types of road connections are neighbors. Roads can be defined with only one driving direction too. These roads usually have a neighbor parallel with their reference line. Figure 11 shows three roads: a blue, a green and a yellow one. The green road has the maximum, two neighbors, the blue and the yellow has only one. The figure shows the directions of reference line too. The road network editing can be more simplified using neighbors, but the creators of the standard don't suggest to use them.

Fig. 11. Neighbors in OpenDRIVE [3]

8) Surface

The surface can be described in OpenDRIVE using standard or extended description. Standard description means a simple description of surface material code, roughness and friction data per lanes. The extended description uses OpenCRG data.

In some cases, roads can meet with railroads, therefore railroads can be described in OpenDRIVE too.

C. OpenDRIVE in practice

OpenDRIVE files can be viewed in OpenDRIVE Viewer simulation software, or e.g. Matlab too. The OpenDRIVE Viewer can be downloaded from the OpenDRIVE webpage under the Downloads tab. It runs under Linux operation system.

A simple road network was created and it is shown in OpenDRIVE Viewer in Figure 12. The OpenDRIVE Viewer was chosen as test software to eliminate the accidental

simulation software problems. Figure 5 contains a description of one of these roads. It represents a curvature, so it follows the geometry of Figure 7. It begins with a line and it turns into an arc using a short spiral (clothoid), and then it turns to straight line applying another spiral. The grey color refers to the straight segment, the darker blue color shows the spirals, and the light blue presents the arc.

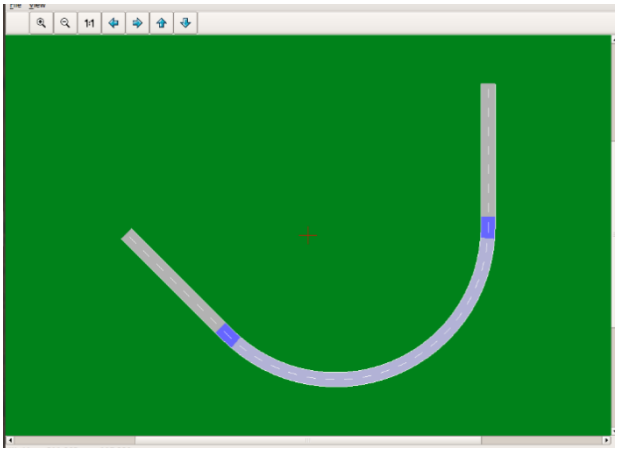


Fig. 12. Created OpenDRIVE road in Viewer

IV. Conclusions

OpenDRIVE is a good choice to describe the road geometry. Its big advantage is the open file format, and the widespread usability in simulation software. ASAM is working on OpenDRIVE 1.6 and 2.0 parallel. It indicates further improvements and features, that supports further success to this standard.

The test road was created successfully in OpenDRIVE file and shown in OpenDRIVE Viewer. The manually editing works well. The examples from the webpage can be used in the Viewer program. The future plan is to test the result in simulation software and create and test complex road geometry in OpenDRIVE.

Acknowledgment

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Mesh Generation for Laser Scanned Point Clouds

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***Abstract*— For autonomous vehicles, environmental information is extremely important. While we can generate data quickly and efficiently, but research for processing is still have a lot of opportunities to develop. Mesh generation from the point cloud is one area where development is possible.**

Keywords—mesh generation, autonomous vehicles, point clouds

I. INTRODUCTION

The mesh generation has been around for a very long time. One of the first applications comes from the second half of the 5th century when Zu Chongzhi used it to determine the value of π, which was considered the most accurate result for about 900 years. With the mesh applications, they have been used to simplify the complex (and under the circumstances the impossible) tasks. The problem solving by mesh generation is very fast and we can make a simplified model from the object or the road very fast. The different parameters and settings generate different meshes. With different mesh parameters, they are suitable for different tasks. One of the most important steps in the mesh generation step is to add parameters. Here we determine the type, shape, and quality of the resulting mesh. Subsequently, we will process, refine, and verify that the resulting mesh is of the desired quality.

The main test aspect of the created mesh is whether it is structured or unstructured. A structured mesh is that if there are two sets of lines and a line belongs to one intersect all the lines belong to the other set of lines, but each line only once. The advantage of this method is that it can write very fast and efficient solving algorithms, many methods are known for their solution and the quality of the elements can be well controlled. In the case of an unstructured or free mesh, there is no restriction on the shape of the elements and no specific pattern is used. In this case, the mesh is made up of a multitude of disorganized polygons.

The advantage of structured mesh is that connection information can be clearly deduced only from cell numbering. Any existing mesh is easy to be stored and managed on a computer. [1] However, it has the disadvantage that the orthogonality and slenderness of the cells must be within

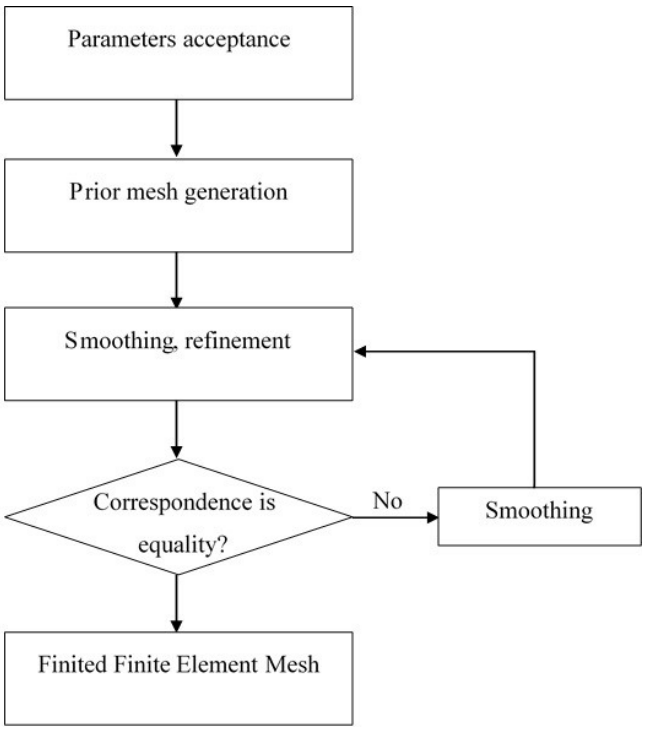

Fig. 1. Mesh generation steps

certain limits, which makes a mesh of complex geometries more difficult and less effective in locally fine meshes.

The advantages of unstructured meshing are that they are easy to network with complex geometries and are very effective for locally fine meshes. The disadvantage is that the connection information must be stored and retrieved separately for each cell, and it is more difficult to be stored and manipulated by the computer. [2]

II. MESH TYPES IN ENGINEERING PRACTICE

We have a lot of types of mesh methods. The triangle and the quadrilateral are the most common methods, but the triangle is much more popular in computer graphics than quadrilateral. One of the best-known subdivision types is the Voronoi cell. Producing a Voronoi cell is a simple but at the same time slow process. If we connect the starting points of

the adjacent convex polygons thus obtained, we get the Delaunay triangles.

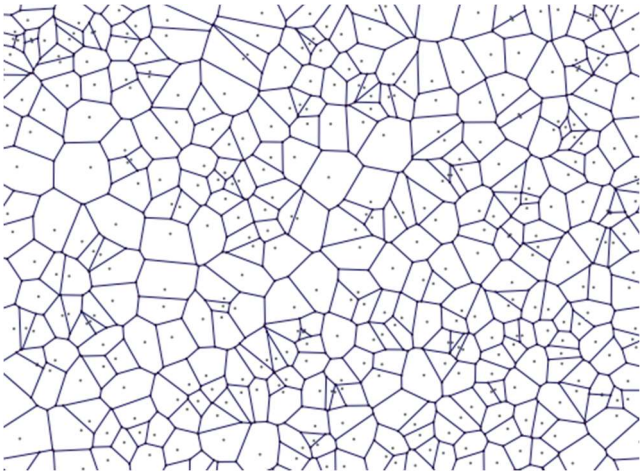

Fig. 2. Voronoi cells

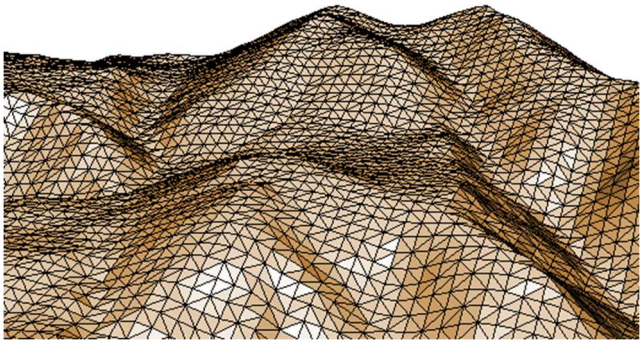

Fig. 3. Delaunay triangulation

Centroidal Voronoi tessellation is a special type of Voronoi mesh where Voronoi cells are centered on the center of gravity of each element. This road is well suited for cloud computing, with the disadvantage that it requires global parameterization and can be used on a limited surface. The other basic method of subdivision is the quadrilateral mesh. In terms of applications and speed, this method can provide a better solution than the Voronoi triangle, although the debate and results in the scientific community are fairly divided. By using this, it can more easily follow the features of the lines of the represented shape and also better adapt to deformations. [3]

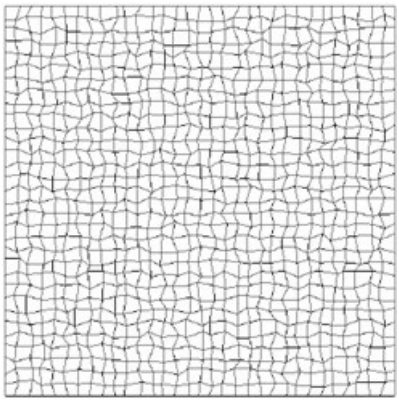

Figure 4. Quadrilateral mesh

In addition to basic meshing methods, there are many newer methods. Newer meshes include the Blossom-Quad mesh. This is a non-uniform quadrilateral mesh method, mixing triangular meshes with quadrilateral meshes, so the mesh created by this method is better for the shape of the element and also for the efficiency of the size of each field.

It needs a little longer time; first a pure triangle mesh is created, and after a quadrilateral transformation happens from the triangle when it is possible. [4]

Another solution examines the use of hexagons when processing point clouds. As a 3D scanners and imaging tools evolve at a faster rate, programs that can process them need to evolve, or a different solution must be found so that higher quality clouds with higher storage requirements and more computing can be processed with the same or even better solution than other programs. This hexagonal mesh method is used to represent surfaces constructed with flat glass or metal panels. The basis of this method is also based on triangulation, first the algorithm calculates the regular triangulation of the surface, and then converts it into a specific shaped P-Hex mesh, which fits the surface much better than a triangular mesh of the same size would have been generated.

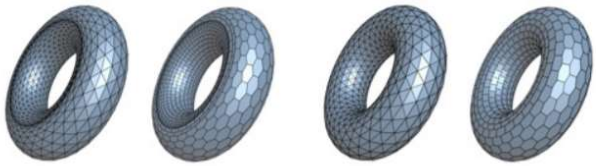

Fig. 4. P-hex

It has a lot of variation, and requires further research to find a better way to make a mesh model. [5]

III. Pilot site for mesh research

The sample was made in a section of Budafoki Road in Budapest. The survey was conducted with a car, and we wanted to test what a self-driving vehicle could see if it had a suitable sensor. The original measured point cloud contained more than 6 million points, which was cleaned down to 4 million.

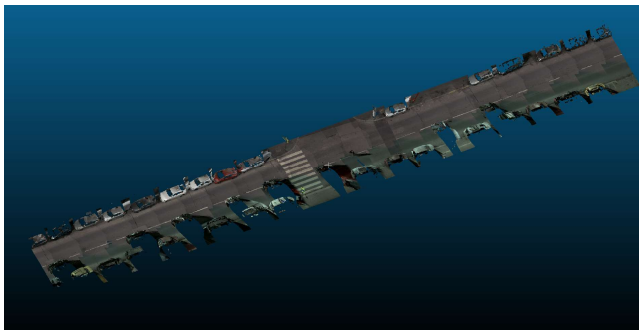

Fig. 5. Sample road

One of the major drawbacks of the remaining point cloud is that there had coverage of cars and pedestrians crossing the road. In this way, it is possible to hide details that could be important in the future.

That is why it is important to use a corresponding meshing method to add details that have not been surveyed and to link them with topological information that can be used later.

In order to find the best-fitting mesh method that produces an acceptable quality mesh and an acceptable processing speed, we examined several programs and compared the results obtained depending on their configuration.

IV. Methods and results

First, we used the CloudCompare to create a mesh. It has a very few settings, only three types; two used the Delaunay triangles with height (2.5D), and the third one is the Poisson Recon method. The first two methods are very similar, and they don't have a big difference in the results. It is very fast, and normal quality, unfortunately it cannot be used on hilly terrain or smaller radius bend. It is perfect for flat roads. The third method is the Poisson Recon. It is applicable only to closed surfaces, but we didn't have here. The other mistake was if we don't know any details about the methods of the mesh generation, but most of them are unstructured.

The second software was MeshLab. This is an open-source software, focuses on handling and processing unstructured meshes and provides a toolbox for editing, cleaning, checking, rendering and transforming this type of mesh. The major disadvantage of the program is that it only creates a triangular mesh and can use color data, but it takes longer to process than some similar programs. If the existing point cloud is first sampled and then the Ball-Pivoting method is performed, the result will be an almost good mesh, sometimes with gaps. But the obscured objects have still not been taken in, and the running time is much, so it is not suitable.

The third application was the GMSH. In this application, the mesh always will be unstructured, even so if we made a structured method. The main option is the Delaunay method, both triangular and quadrilateral, and the Advanced Front method. It has the great advantage of being able to smooth in contrast to other programs. It is also possible to change the size of the elements in the mesh, from 10 m up to 0.01 mm. The coverings were no problem either, making the mesh easy and very fast; a mesh produced using the Advanced Front method with a 3 cm element size in less than 0.07 seconds.

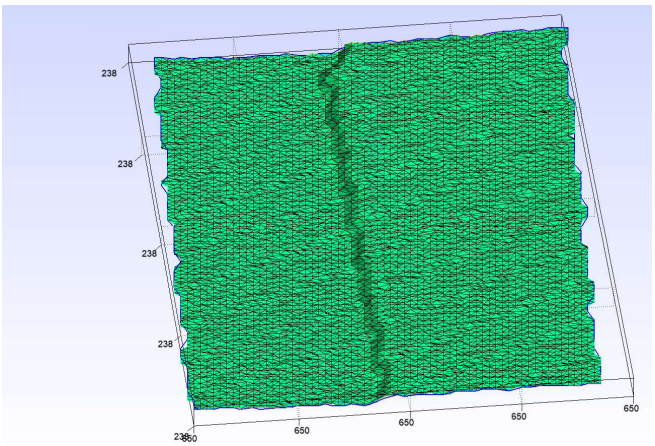

Fig. 6. Example for triangle mesh (road and sidewalk)

The deceleration time for the complete road section with the appropriate parameters is less than 2 seconds. This is a good result at such a distance.

The fourth application was the GiD. This software is capable of producing a structured and unstructured mesh. You can specify where to place the nodes in the completed mesh, generate a triangle, a rectangle, or even for a very specific examination, generate a circular mesh. The main consideration was the speed of the mesh generation it was 0.5s. Thus, the quality of the mesh and the speed of its preparation can be considered optimal.

TABLE I. Versions of the mesh generation

Version of the mesh methods			
Version	***Structured/Unstructured***	***Type***	***Element type***
1	Unstructured	Triangle	Linear
2	Unstructured	Triangle	Quadratic
3	Unstructured	Triangle	Quadratic9
4	Unstructured	Quadrilateral	Linear
5	Unstructured	Quadrilateral	Quadratic
6	Unstructured	Quadrilateral	Quadratic9
7	Structured	Triangle	Linear
8	Structured	Triangle	Quadratic
9	Structured	Triangle	Quadratic9
10	Structured	Quadrilateral	Linear
11	Structured	Quadrilateral	Quadratic
12	Structured	Quadrilateral	Quadratic9

Here, high processing speeds are quite significant at the expense of item size. There are several solutions available to keep the item size at the desired value. The simplest one is a better-performing computing tool. If this is not available, increase the time or reduce the size of the working area.

TABLE II. MESH GENERATION PARAMETERS (10M × 7M)

Details of the versions:				
Version	***Item size (m)***	***Node***	***Item number***	***Production time (s)***
1	0.35	78498	19472	0.5
2	0.35	109358	19502	0.5
3	0.35	109358	19502	0.5
4	0.45	85374	16612	0.5
5	0.5	119926	16524	0.5
6	0.5	136450	16524	0.5
7	0.4	78422	19320	0.5
8	0.5	108710	19178	0.5
9	0.5	108710	19178	0.5
10	0.7	85279	16517	0.5
11	1	120427	16691	0.5
12	1	137118	16691	0.5

Taking the sample into account, the time spent on the fastest triangle (version 1) and quadrilateral (version 5) for the complete road section and other data:

The quadrilateral mesh had a size of 0.2 m and contained 57 976 elements, while 688 013 nodes had a generation time of 61 seconds, the triangular mesh had a size of 0.1 m, 395 841 elements and 829 238 nodes. This generation took 200 seconds.

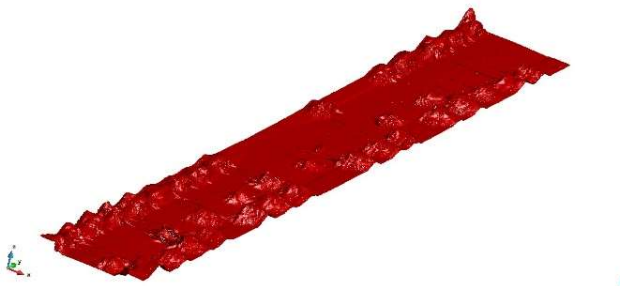

Fig. 8. Quadrilateral mesh generation

V. CONCLUSION

Each software used different methodologies, so it's hard to compare these different methods. The first and the second was used mainly for scanning a large number of point clouds, and reliably and accurately for small sections. Its disadvantage is that it uses only one method, it only works with the triangle method, and it is not clear viewing the mesh what method it came from. In the second method, the processing speed was also inadequate and it contains a lot of little holes. The third method has the advantage of adding numerous parameters, all are to be set manually. The downside is that any point cloud is impossible to use, and must be shared with another application. The fourth application has more settings than the previous ones; it works great for creating a mesh, and can be used for fast and good quality mesh. The main aspects include how we generate point clouds and define parameters in relation to the environment.

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An Overview of the most Important Implementations of IPv4aaS Technologies

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Abstract **This paper discusses the need to use IPv4-as-a-service (IPv4aaS) technologies in an ISP/enterprise network where both IPv4 and IPv6 can co-exist together efficiently, considering also their performance, operations and properties. There are currently many IPv6 transition technologies, but in this paper the most prominent ones are being discussed, moreover, the deployment and implementations of the theses technologies are also addressed.**

Keyword **IPv4 as a service, IPv6 transition technologies 464XLAT, DS-Lite, LW4o6, MAP-E, MAP-T.**

I. INTRODUCTION

As expected years ago, the world is now running out of IPv4 addresses. In February 2011, IANA, the global body responsible for managing Internet addresses, distributed the last five "/8" sets of IPv4 Internet addresses to the five global Internet address registries [1]. IPv4 uses a 32-bit addressing scheme, which was thought to be enough supporting billion of devices, yet the more devices connected within the 4th industrial revolution and the internet of things, IPv6 was the solution of the dilemma that many were predicting.

The deployment of the IPv6 protocol around the world is relatively slow, as the problem lies in the following:

1. Service providers do not want to activate IPv6, because there is no demand from subscribers, and subscribers do not request IPv6 because of the lack of content that works on it, and content providers do not want to activate IPv6, until it becomes a demand from users.
2. IPv6 hosting provides many features for users of the built-in protection of the protocol, a greater number of available Internet addresses in addition to navigation and many other features.
3. If one wants to deploy something new into the network, there is an impact on the stability of the network, routers have to be upgraded, sometimes firmware has to be changed and the code of IPv6 in the routers and switches is brand new, so an upgrade is needed more often, debugging this software is necessary and it costs extra effort. IPv6 and IPv4 are incompatible protocols meaning that if one have at least one application that does not support it, then both protocols have to be run.

IPv6 is the new generation of IP addressing for the Internet, which solves many of the limitations of IPv4 and the main one is that IPv4 is running out of addresses, IPv6 is more efficient and secure; that's why it's a necessity to deploy it.

IPv6 activation is the main solution to the problem of lack of IPv4 addresses. IPv6 is the next generation of network environment needs to be converted from IPv4 to IPv6, it may take a long time because of some factors, such as the inability of the IPv4 network device to be completely replaced.

There are a high number of IPv6 technologies have been developed to facilitate the co-operation of the two incompatible versions of IP (IPv4 and IPv6) for different scenarios [2]. One important scenario is, when IPv4 addresses ran out and only IPv6 is being distributed to the clients, but there are still many old servers, which have only IPv4 addresses. A suitable solution for this scenario is the combination of NAT64 [3] and DNS64 [4]. This technology works well with the majority of the generally used client-server network applications [5], however there are some applications such as skype which can't use IPv6. For this reason, many providers, who would like to forget about IPv4 in the access and core network, still have to provide IPv4 to the customers. It is called "IPv4 as a service" (IPv4aaS) and there are several new solutions were developed for this purpose. The advantages and disadvantages of the five most important IPv4aaS technologies are discussed in the following active Internet Draft [6].

The remainder of this paper is organized as follows. Section II introduces the five most important IPv4aaS technologies. Section III deals with their implementations. Section IV is about plans for future work.

II. THE FIVE IPV4AAS TECHNOLOGIES

A. 464XLAT

IPv6 hosts cannot communicate directly with IPv4 hosts and for this reason, several transitions methods have been developed; 464XLAT [7] technology provides the IPv4 access by combining stateful (RFC 6146) and Stateless translation (RFC 6145).

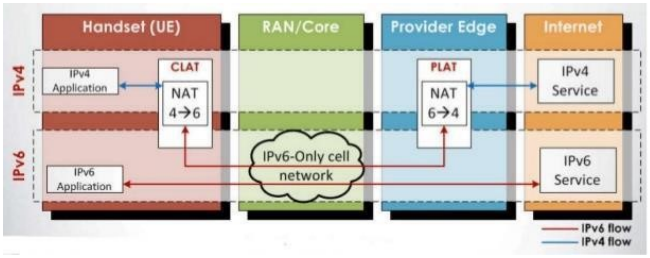

Figure 1: 464XLAT mechanism [8]

According to [9], 464XLAT is essentially an extension to NAT64, if there is an IPv6-only connection; sometimes it's not possible to access IPv4 only content. 464XLAT solves this problem. With 464XLAT, a client application uses a stateless IP/ICMP translation algorithm, which is a

translator) [7], the IPv4 address comes from a specially reserved prefix. On the provider side, PLAT [7] translates statefully IPv6 to IPv4 using stateful NAT64, (see figure 1). This solution is similar to NAT64, but the main difference is that the CLAT service needs to be installed on the mobile equipment. For example: Skype is an IPv4 only application so it does not work with IPv6, the CLAT is used to translate skype clients IPv4 packets into IPv6 packets, the packets are then sent over an IPv6 only network to a NAT64 translator which translates them back into IPv4 and sends the packets to an IPv4 only server (Skype server). 464XLAT helps a lot of mobile providers with the IPv6 implementations, because customers with 464XLAT can have an IPv6 only connection and still access all IPv4 only applications and content.

B. Dual Stack Lite or DS-Lite:

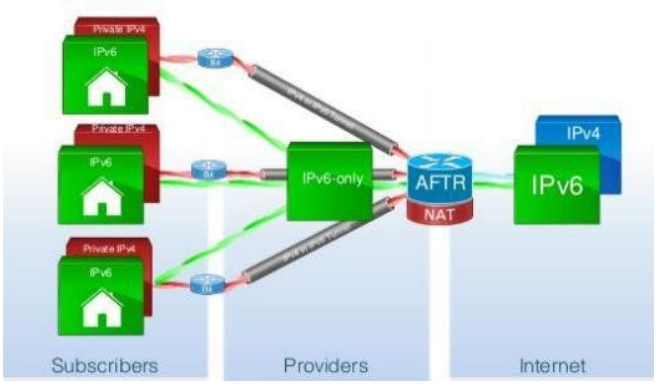

Figure 2: DS-Lite mechanism [9]

According to [9], DS-Lite enables service providers to deploy IPv4 services over an IPv6 infrastructure. It's a transition mechanism based on native IPv6 tunneling and Network Address Translation. DS-Lite (see Figure 2) allows an ISP to give access to IPv4 only services for customers that have only native IPv6. As it becomes impossible to provide customers with public IPv4 addresses to connect to the Internet, ISP has to make sure that all customers can access the Internet whether they are IPv4 only IPv6 only or dual-stack. When a customer has only public IPv6 addresses, DS-Lite is the way to let this customer reach IPv4 only services by giving this customer native public IPv6 addresses and private NAT-ted IPv4 addresses. The customer needs a native IPv6 connection with DS-Lite capable CPE supporting IPv6 tunneling and IPv4 as well as a private IPv4 address to be able to connect to the IPv4 Internet. The ISP sends the customer one private IPv4 through a tunnel over the IPv6 connection between the customer network and the providers network. Because the customer is given private IPv4 address that is non-routable on the Internet, the ISP must do network address translation on behalf of the customer. The problem is that the ISP keeps several customers behind one public IPv4 address. In DS-Lite, the translator box records the public IPv6 address the private IPv4 address and TCP/UDP port number of the customer to keep track of who uses which connection. This mechanism is very useful for DSL or cable provider as the client has public IPv6 address and can still use all the home devices as they do today. In most cases, DS-Lite deployment requires zero involvements from the customer, while the fully automated configuration is possible on the service provider side.

C. Lightweight 4over6

Lightweight 4over6 [9], while remaining the stateful nature of DS-Lite, it relies on two network functions: the B4 is called Lightweight Basic Bridging Broadband "lwB4" that represents client's gateway and the AFTR called Lightweight Address Family Transition Router "LwAFTR", and represents provider's side, the main task of the first one is to do the NAT-ting and the encapsulation, where the LwAFTR is doing the de-capsulation as well as the software lookup.

The way Lightweight 4over6 (see figure 3) shares the addresses among clients is different, where it gives a portion to port space to each client, the CPE is going to do a NAT and encapsulates the packets into IPv6, the packets get through the border router. Here it comes the task of LwAFTR. The LwAFTR is doing a lookup in the binding table which is a static table, once there is a match, LwAFTR de-capsulates the packets and forwards it to the Internet.

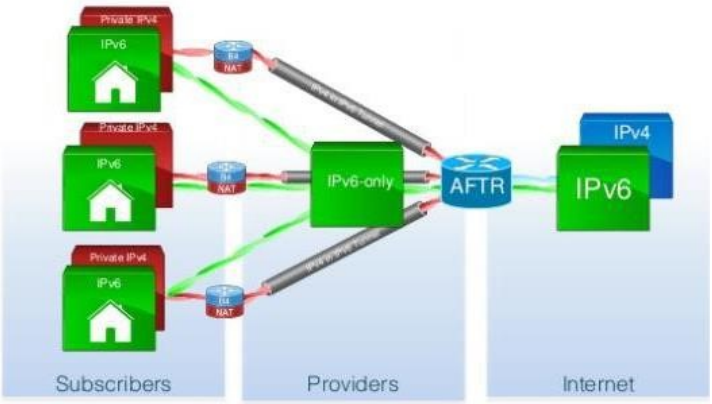

Figure 3: Lightweight 4over6 mechanism [9]

Lightweight 4over6 is a technology that flips the complexity of the dynamic address translation (between the LAN interface and the given public address) back to the client, where every CPE does the address translation and port-based NAT-ting, the difference in lightweight AFTR is that customer shares the public IP address and each client gets the same IP address over limited port range to use, which makes this function stateless, where they all share the same binding table.

Lightweight 4over6 is a scalable solution where all routers are configured equally to load balance the traffic, for single flow packets can be distributed, and once the routing updates don't get through an instance fails then it's quickly picked up as another negligible hop and the traffic gets distributed to the other one.

D. MAP

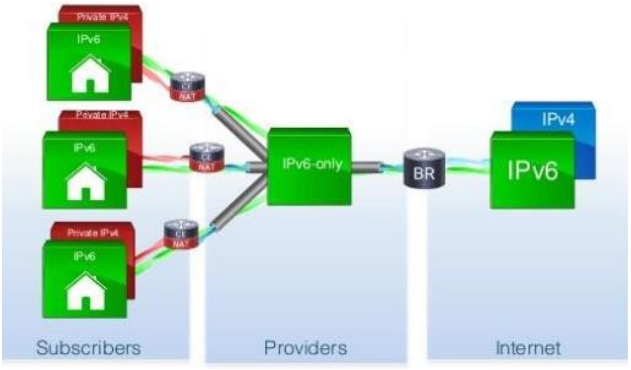

Figure 4: MAP mechanism [9]

MAP stands for mapping address and port, it's another transition mechanism; it basically maps the addresses and ports of IPv4 into the IPv6 addresses in order to serve IPv4 traffic, where IPv4aaS on top of IPv6 is being delivered using this stateless technology. MAP (see figure 4) is targeted access customer of broadband service providers, where it allows them to deploy an IPv6 infrastructure for the dominant type of traffic such as Google, Facebook, Yahoo and all serving IPv6 content.

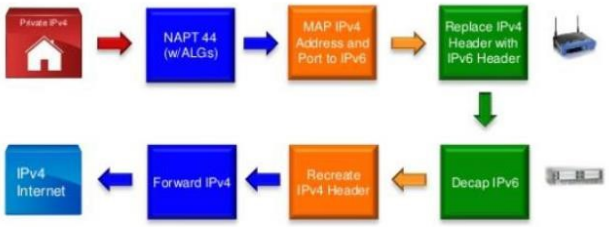

Figure 5: MAP-T mechanism [9]

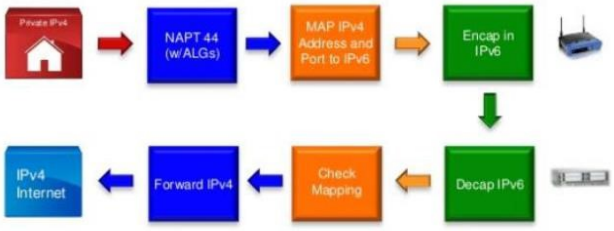

Figure 6: MAP-E mechanism [9]

The main benefit of this technology is that it's stateless, where no additional hardware is required even with the growth of the traffic. MAP-T [10] (see figure 5) is one of two transform modes of the parent technology MAP, which aims to transport IPv4 over an IPv6 domain, while MAP-E [11] (see figure 6) uses encapsulation, similarly to DS-Lite, where an IPv4 Packet is prepended with an IPv6 header and transported across the network, MAP-T uses IPv4 and IPv6 stateless translation, so the header translation as opposed to encapsulation. With MAP-T, the IPv4 addresses are embedded within the corresponding IPv6 address.

III. IMPLEMENTATIONS

The following are some implementation cases for the most IPv4-as-a-service (IPv4aaS) developed technologies:

1. CLATD :

CLATD [12]- a CLAT / SIIT-DC Edge Relay implementation for Linux is free software available to implement the CLAT components of the 464XLAT stateful NAT64 network where it allows IPv6 content only to have IPv4 content across the network by translating from to IPv6.

2. Android CLAT

Android CLAT [13] is an open -source application already Installed for any Android OS 4.3 jellybean or above. This solution relies on the routing table in order to separate traffic, this implementation does not support IPv6 content only; it was mainly designed to offer CLAT services through Wi-Fi connection.

3. Cisco CGv6:

Cisco CGv6 [14] supports stateless MAP technology to deliver both IPv4 and IPv6 services more efficiently on a high scale at a lower cost and less latency. Machine to Machine services is an advantage of this technology, while IPv4 is still supported, unlike DS-lite, which is a stateful tunneling of IPv4 over IPv6 where both information must be maintained, CGv6 gets rid of that by reducing the cost of additional carrier grade network address translation appliances for handling IPv4, with this technology gateway maps IPv4 into IPv6 using a v6 header before sending it over the v6 network, while at the boundary router the IPv4 traffic is stripped and forwarded to the v4 internet, that makes MAP easy to deploy, this technology is built into hardware and software, making it ideal and better solution for a better internet experiences, traffic is delivered more efficiently , IPv4 addresses are easily traceable without state sessions at the boundary router which lowers the cost and enhances geo-location and geo-proximity identification, optimizing network content delivery.

4. Map:

Map [15] is an open source repository supports both MAP-T and MAP-E and can be configured with or without NAPT44 function. This software is also compatible with AFTR of DS-Lite and NAT64 (stateful and stateless), this CPE implementation runs on Linux and Openwrt.

5. SNABB

SNABB [16] is fully compatible open source software with Lightweight 4o6 that has a large binding table with high performance, it consists mainly three elements: APP (Filter, LwAFTR), Programs and links to connect

applications together. The 3rd version of SNABB supports YANF IETF. The 4-th version of SNABB supports RSS (Receive Side Scaling) ,multiprocess and YANG Alarm Module.

6. *AFTR*

AFTR [17] two sources for these implementations were needed: a licensed software tunneling IPv6 through a tunnel broker and an open source one from ISC, in this implementation CGN (DS-Lite AFTR) must be available..

IV. Plans for Future Research

By carefully studying the most five prominent IPv4aas technologies, collecting the available software implementations; my next step is a comprehensive comparative analysis according to some aspects such as security, performance efficiency, which will be done through experiments. I will be trying out those technologies for a better understanding by measuring the performances of their most important implementations according to RFC 8219 [18].

Conclusion

I came across the necessity of deploying IPv6 technologies, have given an overview of the five IPv4aas technologies, their mechanism advantages and disadvantages and their most important implementation cases.

Acknowledgment

I would like to acknowledge the support from my supervisor, Dr. Gábor LENCSE.

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Industry 4.0 Case Study
Big Data Analysis on an Industrial Database

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***Abstract*— A pilot project on an existing production line was accomplished to help to join to industry 4.0 objectives. The essential of the project is a big data analysis, which tries to find new information in the collected complex dataset and find correlation between the product quality inspection data and the data of the production line. Our final mission is to discover the cause of size and figure deviancies of a cylindrical product. One unit of a whole complex production line was investigated with statistical and intelligent data analysis methods. All the products are labelled with a unique identifier, but these were not included in the manufacturing data. The connection of the production line and the quality inspection was established by using the timestamp values. During this research classic statistical methods and smart data analysis methods, SOM data analysis were used. In the examination we could extract some interesting information. The results in the following step are utilizable by an automatic evaluation system, after that the information could be tracked back to the production line.**

I.INTRODUCTION

Industry 4.0 is today's important endeavor, which tries to change the industrial production in the direction of more intelligent, cost-efficient, flexible, adaptive and robust enough. In this system the collection and processing of information is the key element [1]. There is a continuous information gathering at the work place, the generated dataflow is integrating with the information of the corporation and the surroundings of the corporation, and the analysis of the created dataset is executed and results a loopback to the production [1],[2], [3].

With this structure of such system almost all experts agrees [3],[4]. The implementation of this process starts with the creation of the IT background. This is followed generally by form of data analysis pilot projects and primary data strategy forming, which are followed by the automation of the system with continuous data gathering, evaluation, and formation of intervention pipeline [5], [6]. The first and third steps of the process can be easily generalized, but the second is harder[5]. In every situation the involvement of an expert is mandatory to ask the appropriate questions from the system, to define the information to be processed and the way of this process and evaluation.

In this paper we will present a case study about a practical application of this concept from the gathered data to the practical decision making support via data cleaning and analyzing and concluding. The main questions are: can we extract any interesting information from the collected quality control and manufacturing data, and can we combine the quality management data and manufacturing data to get closer to the targeted predictive maintenance?

II.DATA

A. Manufacturing data from PLC

The data collected from the PLC was stored in an MS-SQL database. Data records between 2018.01.01 and 2018.06.30 were processed in this research. It contains the name of a particular workstation and its parameter (e.g. feed, rpm), the timestamp and value of the given parameter. The time values are recorded when a significant changes happen. This MS-SQL compatible backup contains approx. 3 million data records, with 27 variable (each recorded with timestamp). But only one workstation's five parameters - namely a lathe- were selected for the data analysis.

B. Quality inspection data of the production line

On the production line cylindrical product is produced. Every product is inspected and checked during the manufacturing process. The measured dataset contains 1-7 data record per product (depending on the measurement protocol). Each product is identified with a virtual unique product ID.

C. Unique product identifiers and the corresponding timestamp

This dataset contains the time value of the beginning and endings of a manufacturing process of a corresponding product on every machine queried from the robotic arms. This was recorded in an SQL database, so it is possible that there are some delay compared to the rough PLC data. By the investigations, the beginning of a product is differ from the PLC data, but the recorded endings have generally 1-2 second delay in a 50 s long production period.

III. METHODS

In the project MS-SQL database, R 3.5.0 statistical software, R studio Version 1.1.453 environment and MS Power BI were used [7].

A cleaned and homogenous dataset has to be involved in the investigation. The quality inspection features and production line data were processed according to this concept. The second goal was to link the manufacturing data to the quality inspection data, so the correlation between them can be evaluated.

In the first phase one workstation, which is a lathe, was investigated, its data were separated and in the future we can make similar examinations for the other workstations.

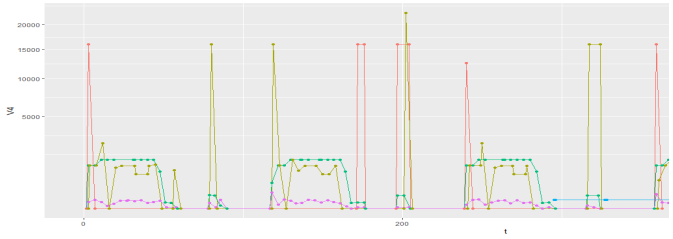

Figure 1 Raw data from PLC

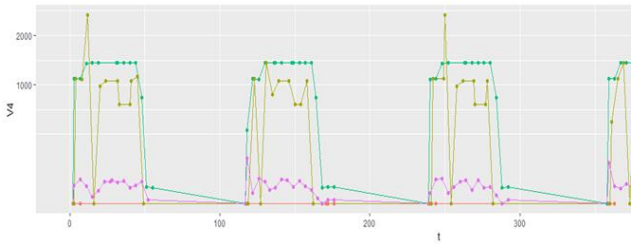

Figure 2. Data after the cleaning algorithm

Preparation of the production line data

The production line data was processed with the upcoming methods during the preparation

- Separation of the parameters connected to different workstations
- Data cleaning. On figure 1 we can see a section of data from the PLC. On the image we can see the rapid movements of the nonworking tool. While it is not relevant for the manufacturing process, it can be taken out from the dataset. The other disturbing factor is the spin up and down of the spindle between manufacturing of different products for the automatic cleaning of the workspace, so these should be taken out as well. The data cleaning was built upon the rotation of the spindle, because the manufacturing starts when the product starts spinning and it stops, when the spin stops. The identification of the manufacturing of one product is trivial on Figure 2.
- For each products (from the graphs on Figure 2) each parameter's maximum, average, integral value, biggest steepness of up going phase and down going phase were calculated. To sum up: For every workstation in case of 5 characteristics of the totally 25 variable was calculated. These data was take into the upcoming statistical analysis.

Preparation of quality control data

- Quality control data were separated by the workstation which is responsible for the given parameter.
- Values were standardized and normalized by the next method. Actual values of all parameters were subtracted from the optimal value and normalized with the tolerance of the given parameter, so the majority of data is in the [-1,+1] interval.

$$E_{norm} = \frac{K_{value} - Kta_{rget}}{K_{bound} - Kta_{rget}} \quad (1)$$

- If a radially symmetric attribute had more measured values on one product, the average and the most different from the targeted value was calculated. So totally 14 characteristics were gained.

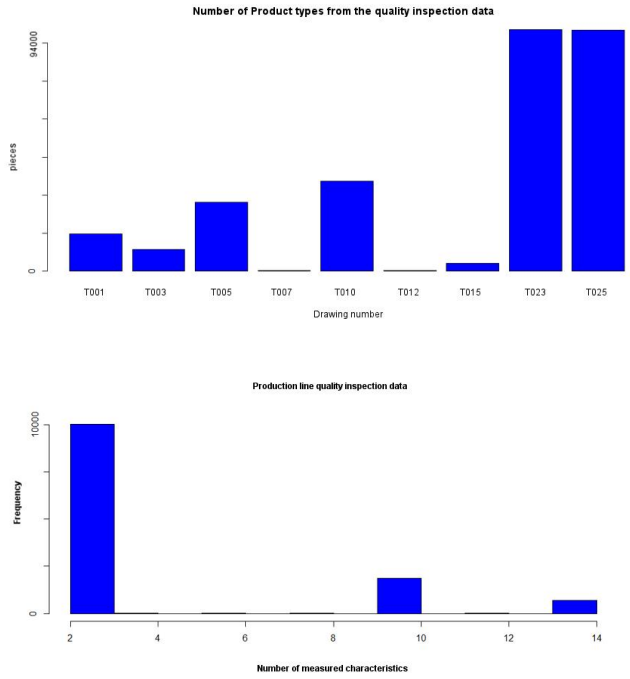

Figure 3 A. Number of product types from the quality management database. The most frequent product dataset was selected for further analysis. B. Distribution of the measured quality features of the selected product. All of the products have one measured feature, and according to the quality management policy some selected products took part in a more detailed investigation.

Fitting the product IDs to the manufacturing data

To this fitting data from section 'A' and 'C' were used, so the PLC data was possible extended with the product ID, which makes possible to track every product during the manufacturing, and makes the finding of correlations available. Fitting is possible, if we try to fit the calculated end of the manufacturing from PLC data to the manufacturing timetable. Because the database processes could have a 1-2 second latency in the records which have to take into account in the data processing.

It is very important to supply the statistical investigations with homogeneous data. To reach it, the most relevant product type and the most relevant characteristics were selected after a distribution calculation (fig. 3). Most of the products have only 1-2 measured features, which is later appropriate for time series investigations, the smaller part have 10-14 measured features which was involved in the correlation hunting statistics.

The prepared dataset were used for traditional statistics and for smart statistical methods. These were histogram calculation and visualization with R script and Self Organizing Map investigations. Finally ~5000 pieces of the products were investigated in the statistical analysis. The distribution of the characteristics is normal but some characteristics have no variance. These are excluded from the statistical investigations (fig 4).

SOM analysis were made with R Kohonen package [8][9][10]. Data were centered and scaled for the calculations. The map size was 20*25, type is hexagonal, the length of the training was 1000 epoch, the supersom method was used to avoid the problems of missing data [8][10].

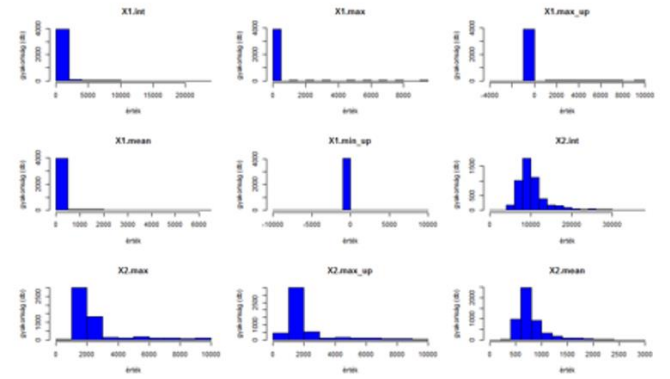

Figure 3. Histograms of PLC data of one workstations in the production line

IV. Results and Discussion

On figure 3 and 4 the histograms of the production line data and the quality inspection data can be seen. The production line data has minimal variance, however few extremely different values are in the histograms. The quality management data's histograms show larger variance. It can be presumable that the variance of the product does not show a direct correlation with one or few features of the production line, but the consequence of the accumulation of bit differences. However the extreme values that were measured on the workstation could be interesting. It is important to investigate if these are some artificial products of the data recording or cleaning algorithms or real extreme values. Furthermore the extreme process data and the connected product attributes have to be queried and investigated.

The distribution of the product quality data (fig 4.) was accepted to be normal by the Shapiro-Wilk normality test and the q-q test. However few histogram's maximum values have on offset from 0, which means that the largest part of the product is not optimal. It could be a normal consequence of the technological decisions if the variance is low enough. However some histograms are too wide - large variance -, which means that few products are out of the tolerance. In this case the narrowing of the histogram very likely need a technological change, but change of the offset needs only the setting of the workstation, which can cause the decrease of the number of rejected products. Some histograms have a local minimum in the middle of the graph instead of a global maximum. It suggest that the setting is often made ad hoc instead of deeper consideration, or might not accessible a correct model for the settings.

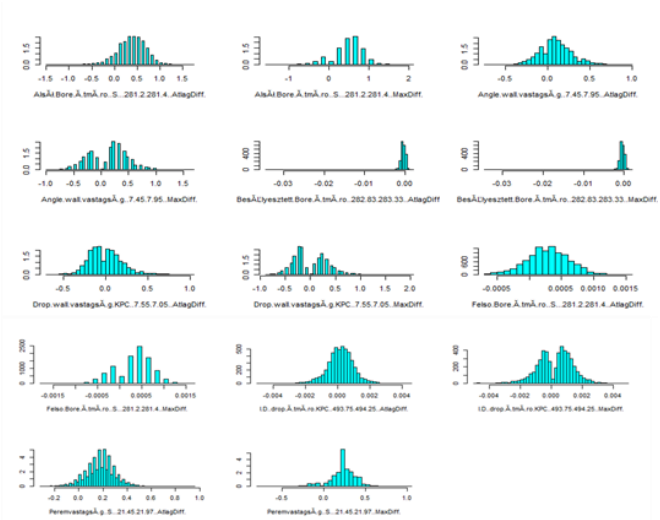

Figure 4. Histograms of quality inspection data measured during the manufacturing process

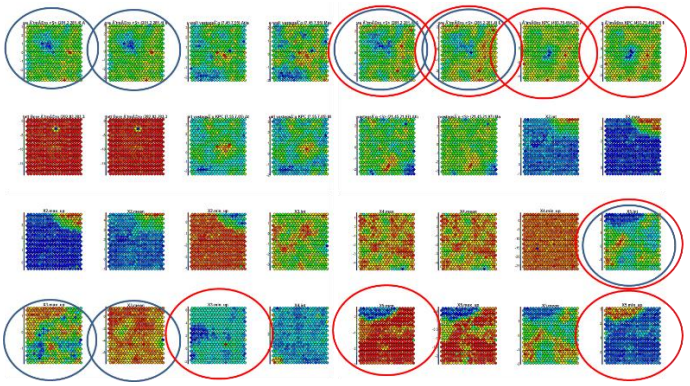

Figure 5. SOM feature maps of the quality inspection data and the relevant production line PLC data.

Self Organizing Map is a smart data analyzing method for medium or large size of dataset of which dimension number is smaller than 150. In this feed forward type neural network the neurons learn the dataset and create a map which is fitting to the dataset. The distance of the neurons shows the grouping property and clustering of the data, moreover each feature can be seen on a feature map, which makes possible the visual correlation hunting. Every single neuron has got weight vector, what is possible to reflect the processed data value, thus the SOM map characteristic planar for the purpose of the values of the different features, such as a topographic map can be evaluated visually. The akin map elements show the correlation between different characteristics. On fig 5 two correlation groups are signed with blue and red circles. However not the whole feature maps are similar, but only parts of them. Two interesting groups are in the map line. There is a group In the top left third section of the blue circled map is being depicted recurrently in more characteristic plane and the same groups can be found in characteristic of production line process, which would justify a conclusion that occurrence of certain deviation accompanied, at the same time it can be related to the characteristic of production line. It anticipates a correlation between the adjusted rotational speed of the spindle (main axle may reach the expected rotational speed slower) and the speed of stoppage next to the different values of the engine characteristics.

The other correlation can be observed in the red surrounding map by a line running from top right corner towards to two-thirds of the left down corner. The pattern is a characteristic occurred recurring in more maps which coinciding with more production characteristics. These are the cut- off speed of spindle speed rotation (rev), in addition to this there is a correlation between this pattern and different engine characteristics. It makes difficult to analysis of data that the same deviation of cutting off at the spindle, implies in one case positive in another case negative differences in size, combined with other production data. This occurrence due to the fact, that we try to analyze a complex system, and in many cases several reason can explain the same phenomena. It should analyze the statistical methods due diligence separating them properly.

V. Conclusion

The goal was to statistically analyze the 2018-year data of the products of a company. The task was to find a correlation between the quality characteristics of the products, most importantly the surface and size characteristics and the production line processes. On the production line the production process is quite complicated moreover, multiple products were made on the line which makes data analysis even further complicated. The statistic examinations must be executed on homogeneous data in order to avoid any statistical error. For this reason, the data of certain workstations and product types must be analyzed separately. From the histograms it is possible to determine that in case of some characteristics the maximum of the normal distribution is not at the optimal value. The correction of this is worth considering, because probably it would lead to the improvement of the quality without additional costs. Create histogram from quality control data could be a daily routine and could be easily achieved, because the data for this are online available at this moment.

Using the data of production line, quality inspection laboratory and the attached production line process, SOM analysis have been made. During the analysis a conclusion was formed, which includes that some of the quality characteristic and the production line data could be correlated by the lathe spindle load and lathe spindle rotation speed. This question was used to create a null hypothesis. To analyze the null hypothesis PCA, LDA, Boxplot diagrams can be performed on the data structures. For the first step only a few well-understood characteristic and production line characteristics as description values have been analyzed. Every statistics showed the possible correlation between the subset of the describer and the description values. The problem is that most of the variance of the description characteristics cannot be explained, these are under complex environmental control. Using other kind of interpretation, the describer values are not forming bordered clusters, which would make possible the very reliable, robust prediction that can be used in an industrial environment.

There are two options to get closer by executing future examinations. At the of time series analysis, the variance of the base noise and the autocorrelation can be distributed. If the analysis of the other product types will give a similar result, then it will be possible to combine them for the analysis of the

Time Series using proper precautions. The other possible method is the analysis of the combination of the described factors, which would probably return a good result as well. If the number of correlations reaches the required amount, then a simple decision tree can make the result applicable in industrial environment. All in all, a statistic null hypothesis has been created and in the next step the professional background must be clarified by involving company's employees.

Further research is required using the mentioned methods in order to prove the statement in the results. To ensure full investigation of the production line the other workstations are to be examined as well by using similar methods as before.

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The Testing of the Secondary School Model of Problem Based Learning at Székesfehérvári SZC Jáky József Construction-Oriented Vocational Secondary School

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***Abstract*— A new type of workforce is needed to meet the changing needs of the economy: to be able to acquire, transfer and integrate new knowledge independently. The transfer of useful knowledge comes to the fore, which includes not only up-to-date knowledge but also the competences necessary for working. To do this, students need to develop a complex professional mindset that is specific to their profession and focuses on professional problem and problem-solving thinking. The aim of the action research is to explore the possibilities and the tendency for the development of complex professional thinking through problem-based learning (PBL). Classical PBL is commonly used in higher education, where flexible frameworks allow for its application. Purpose of the study: 1. Summarize the experience of pre-research among high-tech engineering students between 2014 and 2016. 2. Presentation of the experience-based PBL model that can be used in vocational secondary schools, which was introduced in September 2016 at the Székesfehérvár SZC Jákyf József Vocational Grammar and Vocational Secondary School among the students of the then 9th grade construction and surveying sector. 3. Presentation of the main experiences of the period 2016-2019.**

Key words – PBL, problem solving thinking, vocational education, action research, complex vocational thinking

I. THE RESEARCH PROBLEM AND PURPOSE OF THE RESEARCH

Vocational grammar schools have a multitasking role: they prepare students to meet the criteria-oriented examination requirements, equip them with useful knowledge to be able to cope with real-world working conditions, and establish vocational upper secondary education for their students. These three requirements are contradictory in several respects. Preparation for further education and examination focuses more on the transfer of theoretical knowledge, but on the job, practical experience is required. This contradiction can only be resolved if secondary schools not only convey the curriculum, but also develop knowledge transfer and thinking skills independently of the profession they are learning. The need to teach thinking skills is made necessary by a rapidly changing world [13]. Learners expect vocational training to provide them with useful knowledge that will enable them to work independently [4].

The problem-based learning (PBL) method seems to be suitable for the effective solution of professional problems and the development of the necessary thinking in the field of construction and surveying sector training in addition to the traditional learning methods. PBL as a learning method has already been proven in higher education (Maastricht, Aalborg, York, Delaware, Debrecen), where its flexible educational arrangements ensure the application of the classic version of the method. On the other hand, the educational organization of vocational secondary school education is very strict: the teaching day is divided into lessons, which are usually forty-five minutes, and the subjects of vocational and general education are not block scheduled, but alternate. This routine is only hard to modify to fit the PBL schedule. The grammar school schedule is bound by the number of hours required by the syllabus, but the issues of class division and timetable are not negligible. The aim of the research is to develop and test a version of PBL that fits the organizational and educational characteristics of vocational secondary schools.

II. CONCEPTS OF RESEARCH

A technical activity is a series of decision-making processes in which engineers apply basic scientific knowledge to transform the resources available for a specific purpose through the steps of synthesis, analysis, construction, testing and implementation. Engineering tasks are technical problems that cannot be clearly identified, and the information available is incomplete or misleading. All professional problems are open-ended and there are many possible solutions. Therefore, engineers have always considered themselves problem solvers [14].

Solving professional problems requires problem-solvers to have a comprehensive repertoire of thinking methodologies and to apply diverse and flexible ways of thinking. In solving professional problems, problem-solving thinking should be defined as a self-generating process that returns to each stage of thinking [5]. Recognizing the problem, choosing the appropriate method, deciding upon and implementing the options, and then checking the work done is the result of a complex thinking process that focuses on problem-solving and problem-solving thinking. These processes together can be called complex professional thinking.

In this research, problem-based learning should be understood as a method of applying existing knowledge, acquiring new knowledge and developing collaborative skills aimed at preparing the learner to solve workplace problems in the context of dynamically changing working conditions. All of this occurs in a learner-centred learning

environment where useful knowledge is generated through active learning to solve a vague, poorly defined problem.

III. EXPERIENCES OF PROBLEM-BASED LEARNING IN VOCATIOAL EDUCATION AND TRAINIG

The aim of the small-scale pre-research conducted between September 2014 and April 2016 was to test problem-based learning as a learning method in secondary education. Using the results of the research, it is possible to develop a problem-based learning method that enables vocational training of the 14-20 year olds within the framework of vocational secondary school. The sample of the pre-research was made by 18 persons participating in the training of high-tech technicians at the Jáky József Vocational Grammar School of Székesfehérvár OKJ 54 582 03. In addition to traditional learning methods, the technical training participants also acquired professional skills through problem-based learning. To measure students' existing problem-solving abilities in October 2014, their progress was monitored in January 2015 and May 2015, October 2016, January and April 2017 with a real-life, professional-contextual measurement toolkit. The typical method of data collection was to observe the pupils spontaneously during problem solving and then by highlighting identities using a simple set of criteria. Aspects: student use of tools, student interactions, applied problem solving strategies, what is a problem for the learner. A secondary method of data collection was the analysis of the technical documentation prepared by the students.

From the observation of students during problem solving, the following conclusions can be drawn:

Promoting the development of thinking is possible through a variety of learning methods. It is crucial for the development of thinking that students are fully familiar with the basic concepts since an everyday expression can have a specific meaning when placed in a given professional context. In the case of classical PBL described in the literature, the conceptual framework related to the topic develops simultaneously with the problem solving. Within the framework of a vocational secondary school, students do not yet have sufficient prior professional knowledge to be able to integrate new knowledge independently into existing knowledge. Therefore, at the beginning of each subject, it is necessary to develop a professional conceptual framework and to present various subject-related relationships with teacher guidance in the number of hours corresponding to the size of the course unit. The method encourages students to develop knowledge transfer between subject and subject. During the initial phase of the training, the problem-solving process was difficult for the students to transfer knowledge even between topics.

The problem-solving thinking of the learners when applying the first PBL was characterized by uncertainty due to the lack of routine problem-based learning. To overcome this, several smaller problem-based learning blocks should be developed at the beginning of the training. This was not done during the pre-research, which prevented the learners from applying this learning method in the early stages of training. Another reason for the problem-solving problem is that students in vocational training have learned to use the knowledge through well-defined tasks, so they also expected a problem-solving algorithm during problem-based learning. At the time of the first measurements they were unable to develop a solution plan to solve the problem. It is important to gain experience in solving tasks that can be solved in several ways. This experience was largely missed in their earlier study. Preliminary experience gained in this area can reduce uncertainty in the solution and the solution variants, and will help to solve problems. In students, the problem-solving approach should be strengthened before starting VET.

In the problem-solving process, students need to recognize the problem, perform various thinking and action operations, and develop information seeking and problem-solving alternatives. The application of the method requires the presence of certain cognitive abilities (information identification, systematization, selection) that the learner should already possess when applying the method. In the first year, students' ability to search and process information fell short of the level required for successful PBL application. They were not able to deal flexibly with different ways of thinking; typically, they chose to solve problems by analogy. Thus only one solution could be developed.

The role of the teacher is significantly transformed, shifting the focus from curriculum delivery to teacher guidance and formative assessment. This was also unusual for the students. Contrary to the tutoring role described in the literature, one weekly group discussion and consultation are not enough for students of vocational secondary schools. Continuous teacher presence and multiple interventions are needed to discuss type errors and to set boundaries for further problem solving. Teacher reinforcement is crucial to problem-solving decision-making milestones, as their critical thinking has not yet reached the required level to self-test during problem-solving. Without confirmation, students were stuck in the solution process. Students' insecurity also manifested itself in the fact that in nearly ¾ of the training, the groups did not divide the tasks needed to solve the problem, but solved each part of the task together. The division of labor between the two was only completed by the end of the training. It is also probable that in the final phase of the training students were able to integrate the knowledge of different subjects and to integrate the knowledge safely into the design or implementation workflow.

Reference [16] focused on students' motivation. They found that PBL learners are more motivated, more likely to interact with group members, and to seek information more effectively. In order to maintain learning motivation, it is important that students consider the problem solvable, preferably within a reasonable time. Preliminary research shows that students have the necessary level of motivation only if they have already used the learning method safely. The interaction between the group members also increased in the case of the examined group, but only when they were developing the plan for solving a partial problem. One of the disadvantages of PBL was a significant reduction in motivation: in their self-search, students encountered a number of misleading information, which was time consuming to interpret and correct. Prolonged problem solving has a particularly negative effect on student motivation, especially if the student is stuck in the process of

solving it and does not receive useful help that only the teacher can provide. Because of the misleading conclusions, students were less able to take proactive steps in problem solving, more people made mistaken conclusions, and were uncertain about the decisions needed to move forward with a solution. Students' motivation has increased dramatically with PBL, as evidenced by the preparation of lessons (with tools, knowledge), classroom activity and interaction between students. This is because they have become routine in problem solving and based on their professional experience, they have been able to determine the workflow of design and construction and their order more easily, as well as the relationship between their structural and technological knowledge.

A key element of problem-based learning is the activation of prior knowledge, a context-dependent context where the focus of learning is on the problem. Therefore, the method cannot be applied indefinitely to all ages. Students should always be given a level of experience appropriate to their age and experience [10]. According to the literature, a real life, poorly defined open-ended problem is ideal for PBL. This kind of problem puts the beginner problem solver into an almost insoluble task. The students were able to solve problems that covered a given knowledge or a thematic unit of the curriculum with good results. At the end of the training, they were only able to solve problems in a cross-curricular topic. Vocational training should progressively lead from the school example to the real-life problem situation. The professional content of the problems should be gradually expanded from the curriculum to the multidisciplinary topic.

In problem-based learning, conscious problem-planning is crucial: from the learner's point of view, it is necessary to work out the problem because the novice problem-solver perceives something else as a problem than the practicing engineer, the tutor. In most cases, solving the problem units required for problem solving can be a complex problem for students. It is also difficult for students to unite the components of the problem. The results of the observation show that at lower levels of knowledge, students focus on solving spatial problems because without them they cannot move towards solving professional problems. At a higher level of knowledge, the main difficulty in solving professional problems can be related to the difficulties in combining subject or discipline knowledge and recognizing relationships.

Students with PBL are better at applying knowledge and have better problem-solving abilities, better remembering and more effective recall of prior knowledge. The processing of the information is more extensive and better prepared for application. However, they have performed poorly in the knowledge tests, and the acquisition of knowledge is inadequate. Research among medical students using PBL has found that the process of knowledge and retrieval was effective in the higher grades in an unusual situation. Students' grades were also decisive in the selection of information relevant to problem solving and in the development of existing knowledge [3]. Therefore, the class of students and their professional experience play an important role in managing and applying the information. This phenomenon was also observed in the case of pre-research technician students. In the second year of training, subjects with a purely PBL method learned less about the professional examination requirements of the subjects when the conventional and PBL methods were used together. A major disadvantage of the method is that it does not always produce the right knowledge [12] or that it does not effectuate sufficient knowledge. Therefore, PBL cannot be used as a sole learning method within a vocational school.

During the pre-research it was observed that the development of thinking and other abilities is hindered by the students' backward thinking. This thinking technique also hinders the recognition and the likelihood of learning about the relationship between problem conditions and appropriate actions [9]. There are two typical ways of thinking in the literature: top-down and bottom-up. During the pre-research, students typically used a top-down thinking approach to problem solving. The automatic application of the top-down method of thinking stems from the peculiarity of PBL. When solving a problem, students first look at what data they need directly to solve it. By gathering the missing knowledge, you will recognize what additional information the problem solving requires. With this method, the solution time is delayed and student motivation is reduced. It would be desirable for students to use inductive thinking first to examine what useful data is already available and what parts of the work can be drawn from it. The parts that are prepared also carry new information that will advance them in solving the problem. However, the transition to the bottom-up method is mentioned in only a little literature.

Adequate learning environment must be provided to apply the method. According to the literature, the ideal group size is 3-9 people. In the case of engineering tasks, based on the experience of pre-research, groups of 3-4 people are more suitable, but paired work is also effective in problem-based learning. For smaller groups, it is possible to ensure that students have an overview of the whole process, even when subtasks are allocated. This also ensures that each student has all the knowledge needed to solve the problem, not just the part that is relevant to the task. Due to the educational organization constraints of the secondary school, it is not possible for the tutor to focus on only one group per class. In the first year of the pre-research 18, in the second year 15 people participated. This means that 5-7 groups were formed in the problem-based learning blocks who took part in the lessons at the same time. Therefore, the class had a block where, after checking progress in problem solving, class errors were discussed in class work. The advantage of this is that each group learns from the mistakes of others from which they can benefit. From this point of view, the literature has not examined possible methods of problem-based learning.

The time frame for solving the problem is also a determining factor in the PBL method. There is a wide range of such periods in the literature. Based on experience, high school students are able to stay motivated for two to three weeks, depending on the number of hours per week. Prolonged problem solving results in a drastic decrease in student motivation and negatively affects the quality of problem solving. Students simply get tired of the task. The final issue of the training was to cover several subjects, giving students the opportunity to deal with the curriculum in ten lessons per

week. In this case, student motivation was sustained for two weeks. For lower grades, the maximum recommended duration is two weeks, taking the age-specific characteristics of the students into account.

IV. PBL METHOD FOR THE APPLICATION AT VOCATIONAL GRAMMAR SCHOOLS

However, in order to develop a vocational school model, it is not enough to analyze the experience of pre-research, but it is also necessary to learn about good practices already in place. To this end, the practices of the above-mentioned higher education institutions also had to be examined. From the description of their different methods, it can be stated that the lack of developing a conceptual framework for the syllabus in the students subsequently caused difficulties for the students as well as the methodological shortcomings of the teachers and the students. The use of assessment techniques that do not fit the methodology can also lead to failure. Several examples show that universities have developed their own examination system to measure PBL students' knowledge. By comparing the PBL models used by engineering training institutes, a specific set of properties of the method that are only suited to technical training can be established. Guided learning of the conceptual framework and short problem solving cycles, as well as increased tutor guidance during problem solving, are prominent. These characteristics became the main features of the elaborated vocational school model [6]. In other respects, there is a need for institutional leadership, the funding bodies and teachers to be receptive to the method. In order to successfully implement the learning method, it is also advisable to examine the institutional environment by SWOT analysis [7].

Based on the experience of pre-research and the advantages and disadvantages described in the literature, the PBL method should be developed, which is adapted to the students' problem-solving abilities, professional knowledge and organizational structure of secondary education. Due to the advantages and disadvantages described, it cannot be used as the only method in secondary technical education. PBL learners do not develop a cognitive basis for acquiring knowledge, but they are also at a disadvantage in learning logical thinking [11]. Therefore, in the vocational sector, the primary focus is to understand the technical context, to develop basic knowledge and to develop general and job-specific skills (spatial competence in technical VET), and to recognize basic relationships, largely through traditional methods. In addition to the foundation of knowledge, it is necessary to develop students' self-regulated learning and problem-solving, which can subsequently be based on problem-based learning. Putting students in early problem situations carries a great deal of risk of failure and delusion, which in later studies hinders effective problem solving and diminishes students' intrinsic motivation.

The aforementioned disadvantages of problem-based learning prevent the PBL from being used in its original form throughout the technical training process. The biggest disadvantage, if the learner has to meet criteria-oriented requirements, is that the PBL is not able to accurately determine what students will learn during problem solving. Therefore, in secondary vocational training, the teacher has a great responsibility in applying PBL. The roles are reinterpreted: the teacher becomes a tutor rather than a supervisor; manages, regulates, limits time and content, provides resources, provides guidance in finding new resources, and ultimately reflects upon lessons learned from the problem solving that has been accomplished. The solution to the hidden problems resulting from the disadvantages of the PBL method is the constant presence of the tutor in problem solving or the use of a controlled version of the PBL, which is rarely mentioned in the literature and is not mentioned in Hungarian studies at all. Managed PBL is well adapted to the specifics of technical training. When using a guided version of the method, problem descriptions also include questions that help students solve the problem in their decision-making steps. In addition, programmed instructions help with lifelike troubleshooting. The learner and teacher become part of the learning process, with opportunities for teacher guidance and feedback. Feedback informs the learner whether he or she has provided the correct answer to the problem. If the answer is correct, it receives confirmation in independent thinking, and if it is wrong, it receives information for correction [15]. The degree of control is influenced by the students' prior knowledge and experience in problem solving. Management is more important for beginner problem solvers, where understanding the professional content of the problem is more difficult than just identifying and solving it. Knowledge tests were better performed by PBL students who preferred a controlled version of the method [2]. Bearing the professional maturity and complex professional exam requirements in mind, only the managed PBL model can be successfully used in vocational secondary schools.

In the first year of vocational training, the foundation of professional knowledge and skills should be achieved through traditional learning organization methods. This is when students become acquainted with the basic concepts, the professional language and the elementary relationships between the basic concepts. In this phase of learning, demonstration plays a key role while professional problem solving is not feasible. Pupils also learn to apply the knowledge through traditional school practices in a conventional way, and learn basic solution routines.

In the upper grades, the conceptual framework of the topic and the problem solving are intertwined. In the next three years of the course, the subject matter knowledge will be processed through traditional or guided class level problem-based learning. With the increase of professional knowledge and experience, the professional problems are also increasing in volume, adapting to the course unit and then to the subject.

In the final year of training, students already have the prior knowledge to integrate new knowledge with existing knowledge. Thus, the focus of management shifts to the interpretation of new knowledge, the recognition of relationships between knowledge and the problem-solving process. This is also an opportunity to practice inter-subject knowledge transfer through complex problems. Knowledge transfer can take place only in the final years of training, due to the anomalies inherent in the curriculum of the vocational secondary school: coordination between knowledge of the individual subjects and parts of knowledge from different subjects is required to acquire it.

The key to successful application of problem-based learning is for students to become familiar with the characteristics and rules of the method. In addition to the philosophy of the method, they need to understand how to create useful knowledge and what work processes they need to acquire to do so. Students should be introduced to the sources of knowledge, the requirements for authentic data sources, and the methods of analyzing, organizing and using information. This is done in the first semester of VET through mini-problem solving in one lesson so that students can become routine in applying problem-based learning.

The emphasis should be on improving the interpretation of professional texts and illustrations. In the construction and land survey sector training, the interpretation and solution of spatial problems, which is the first step in solving professional problems, comes to the forefront. Documenting the result of problem solving also appears as a spatial problem. Therefore, the development of spatial skills is a priority for the first year of training. Problem-based learning can only take place once the students have mastered and applied the basic knowledge of the subject.

The formation of the number of groups depends on the topic and sector. The possible variants are:

• Group of 12 people - solving the problem together in one class.

• Groups of 3 people - working out a common solution.

• Groups of 3 - joint execution but with individual documentation.

• Pair work - work out a common solution.

• Pair work - create custom solutions.

• Individual work

The problem encountered by the learners must be adapted to the students' routine of problem solving and professional experience. Professional problem-solving should be designed in a way that it can be traced back to the knowledge learnt from common subjects. Problem-solving thinking and the exploration of causation must be supported by teacher demonstration in the first year of vocational training. Students will imitate this approach during initial problem solving. Within the given subject, you have to proceed gradually from solving basic tasks to the solving of professional problems. This can be accomplished by first adding professional content to the core task and then putting it in a realistic context. A real-life problem occurs when students have to solve a problem in different situations, overloaded with additional information, linked to another professional problem, or embedded in a complex problem.

A common feature of the problem-based learning variants presented in this study is the continuous teacher formal assessment in group discussions, based on the observation of students during problem solving. Students are monitored in a structured way. Key points:

• students' reaction to the problem, motivation,

• pupils' problem solving activities: work sharing, data collection, analysis, interaction with each other,

• what tools and data students are using to solve the problem,

• what causes the difficulty,

• if they deviate from the thought process leading to the solution, how delusions are handled during the solution,

• the thinking strategy used by the students,

• the ability to make the decisions needed to solve the problem and how to make it,

• what parts of the work are being made.

During the formal assessment, students receive feedback on whether the problem is moving in the right direction, whether there are aspects to consider and guidance on self-monitoring. An important aspect of any professional meeting is that students have their own ideas. This requires a great deal of preparation and adaptability from the teacher, but in this way, students can develop their creativity and really interpret the problem as their own. In this way the motivation can be sustained and increased.

Even in the case of a time-frame for solving problems, gradual approach must be followed. In the first year of training, where students are still learning how to use problem-based learning, the time it takes to solve a problem usually takes one lesson. Depending on the student's problem-solving routine, it may be possible to complete two to three lessons at the end of the first year of study. For further training years, it is not possible to clearly determine how many lessons a problem should take. Experiences from pre-exploration suggest that problems should be planned for up to two weeks. In the upper grades, the time spent on problem solving can be increased by combining multiple subjects in a two-week cycle, and by providing individual home preparation.

V. MAIN FINDINGS OF TRYING THE VOCATIONAL GRAMMAR SCHOOL MODEL

The high school model was first applied to students in the 9th grade surveying and construction sector who started their professional studies in 2016 in the framework of an on-going action research project at the above mentioned institution. As previously only students who already had professional knowledge had been tested, it became obvious to students starting their professional studies that much more time than planned was needed to develop the basic conceptual framework and the spatial skills required [8] to reach the level that enables students to acquire knowledge of guided PBL on their own.

Applying this method, it was also evident that students received mainly frontal education during their previous studies, but were not prepared to active learning, although this trend is increasingly common in primary education. The difficulty was that the students were expecting to acquire professional skills but did not want to be actively involved. Therefore, I believe that PBL at this age, after having experienced multiple school failures and thus being under-motivated, is not only a learning method but also an educational principle that not only develops the ability to think independently, but also develops the ability to think in parallel, and to increase students' self-esteem and confidence.

According to the model, the action research groups have reached the level of their ability to recognize problems by their last year, the 12th grade, solving them using PBL method based on their existing knowledge, but they still lack the ability to search and process information independently. Students have moved beyond the level of knowledge transfer within the subject to the level of knowledge transfer between subjects, which exceeds the expectations of the 12th grade. This is probably also due to the guided problem solving process, as questions or tutor discussions confirm that students need to move in that direction. Often, however, they are still uncertain about their own solution to a new topic, so it may take longer than necessary to resolve the issue. I think that the most important step forward is that the students are able to raise other possible problem situations and propose solutions to them. This indicates that they will be able to develop more than one solution strategy for the problem during the final year of training, with a well-informed decision to select a solution and implement it as planned.

As mentioned in the presentation of pre-research experience, the role of the teacher is significantly transformed. Teachers' prestige is becoming more and more prominent, and is no longer automatically associated with the role of the teacher, but must be achieved through the expertise of the teacher. Applying this method requires the tutor not only to convey the curriculum, but also to be an active participant in the learning process and to be able to exit frames. I consider it fortunate that professional subjects are taught by only a few teachers so that there is a need for alignment between the teacher and the students for PBL.

VI. Summary

Problem-based learning is a widely used learning method and teaching strategy. Its great advantage is that it can be flexibly adapted to the characteristics of the profession being taught and to the educational organization. By analyzing hybrid variations in educational practice, new models can be developed to meet educational needs and the age characteristics of students.

The literature on PBL is very extensive. The action research is based on the essays that specifically describe the PBL model used in engineering education. However, no aspect is mentioned in any study: what students' input abilities are, what levels of knowledge they use to start their problem-based learning, and how problems are adapted to students' input abilities. This shortcoming can only be filled by the pre-research conducted in 2014-2016 and the experience of the mentioned action research. The experience gained from pre-exploration agrees with the advantages and disadvantages detailed in the literature. The most important finding of the pre-research is that there is a big difference between the pre-qualification and the learning attitude of the students attending higher education and the students of the vocational secondary school. Therefore, self-regulated learning and independent information search and processing should be encouraged much more in these students.

Applying PBL to the new grade has shown that although the method developed needs to be refined and probably the milestones need to be tailored to the student group, it has been proven that problem-based learning can be applied within a strictly vocational education system.

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Mistakes that can be Made During Thermographic Measurements and How to Avoid them

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***Abstract* — Thermal imaging or thermography is an extremely versatile measurement procedure. The user-friendly handling of modern thermal cameras is comparable to the widespread digital camcorders. In order to make thermal images that are accurate from the point of view of measurement, adequate theoretical, professional knowledge, experience and, in addition, measurement preparation are required. This article details the most important metrological requirements and practical knowledge of thermographic testing of electrical equipment. The effects of some common thermal camera operator errors, the accuracy and credibility of the measurements are also presented.**

Keywords—thermal imager, heat camera, heat emission, thermal reflection, IR camera, frame rate, depth of field, temperature measurement

I. Measurement difficulties and suggestions for solutions

The biggest problem arises from the object of measurement itself, from its material [1]. One of the common defects of electrical equipment is the inadequate conductivity of the wires and rails, which are based on screw, spring or crimped contacts [2]. Increased contact resistance – for any reason – leads to heating of the contact in proportion to the load. But because of the low emissivity of metallic, mostly polished surfaces, there is only minimal heat emission [3]. Thus, with the help of thermographic instruments, it is possible to detect contact heat, but it is almost impossible to accurately measure it.

The low emissivity of the surface of the object has a high reflection factor, so our measurement activity must be organized so that the measurement error is minimized [4]. The ambient temperature measurement should be as homogeneous as possible [5]. During the measurement, do not operate a strong heat source such as a radiator, radiant heating, high temperature technology, or other point or line interfering radiation sources in the angular direction of the object's reflected radiation. What cannot be temporarily decommissioned should be avoided using a different angle of observation. If this is not possible, cover it with a screen or other shielding surface, but without touching the interfering heat source.

Both the person carrying out the measurement and his / her attendant as well as the spectators watching the measurement are all sources of interfering radiation, causing reflection. In order to eliminate the heat radiation caused by the heat of our body, it is advisable not to measure at 90° to the object surfaces. It is recommended to measure the object surface at an angle of 70-80°.

If moving the thermal camera changes the position of the projected reflection, it is an actual reflection. If the motion of the thermal camera does not change the position of the reflection, it is a real heat effect. Figure 1 and 2 shows that there is reflection, not a material heat effect. Misleading reflections cause problems with the perception of true object temperatures. There is usually some labeled, painted or insulated surface which, due to the heat of the fault location, will also heat up – due to the good thermal conductivity of the electric conductors.

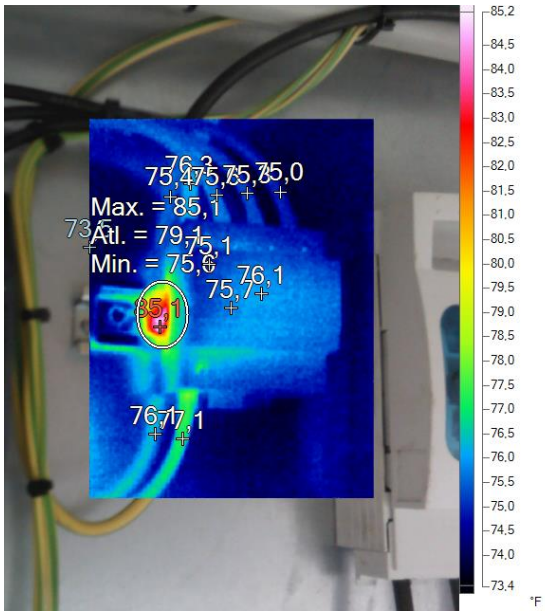

Fig. 1. Reflection of a thermal object

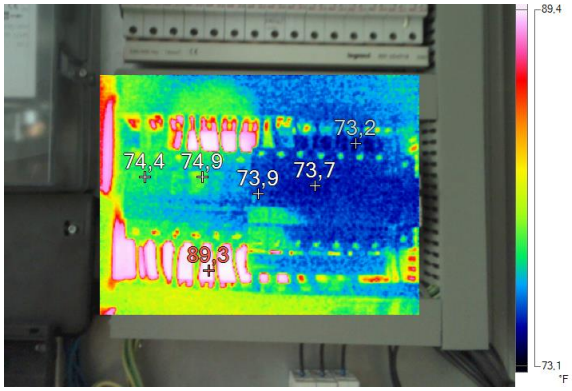

Fig. 2. Reflection of the person carrying out the measurement

II. Thermal imager adjustment

A. *Geometric resolution*

Thermographic status survey is an effective way of working, but this is true only if we have met the geometric

resolution requirement when reviewing. Failure to do so will cause the thermal effects of smaller wires and contacts to go unnoticed (see Fig. 3 and 4). A pre-validation calculation shall be performed with the IFOV (Individual Field Of View or Instantaneous Field Of View) parameter valid for the data thermal camera and the lens combination:

$$p_{x,y} = d\ IFOV \tag{1}$$

where $p_{x,y}$ is the pixel size in [mm], d is the measuring distance in [m], and IFOV is in [mrad].

The sensor matrix has gaps due to manufacturing technology and the optical system also has imperfections, so in practice multiplying the above pixel size by three to determine the minimum size of the object to be measured.

$$p_{min} = 3\ d\ IFOV \tag{2}$$

where p_{min} is the minimum size of the object to be measured in [mm]. [6]

It must be guaranteed that the measuring spot is completely cover the measured object. If this is not observed, the measurement spot also includes the temperature of the objects in the vicinity of the measured object. As the measurement spot is averaged, the measurement result may be lower or higher than the actual temperature of the object. The greater the difference in temperature, the greater the error of the measurement.

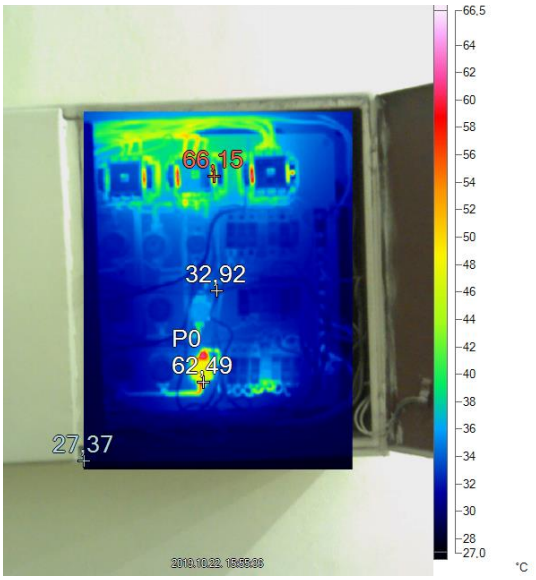

Fig. 3. Overview image with invalid resolution

B. *Overheating lose connection*

All plastic covers covering the elements to be measured must be removed before the thermal measurements. In most cases, the error of the encapsulated device or contact can be clearly linked to the temperature of the outgoing wire, which decreases with distance from the device in question (see Fig. 5).

C. *Frame rate*

The integration time for the lower refresh rate (around 9 Hz) is 110ms. The integration time for the average refresh rate

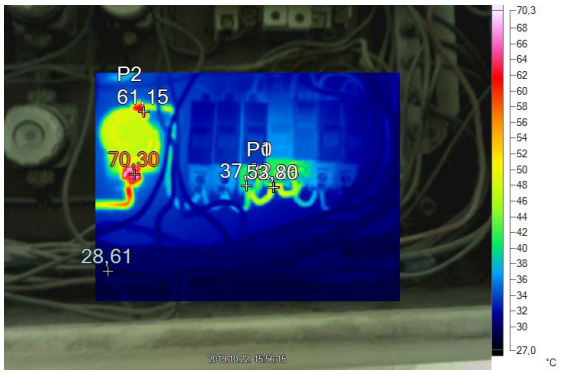

Fig. 4. Overheating lose connection

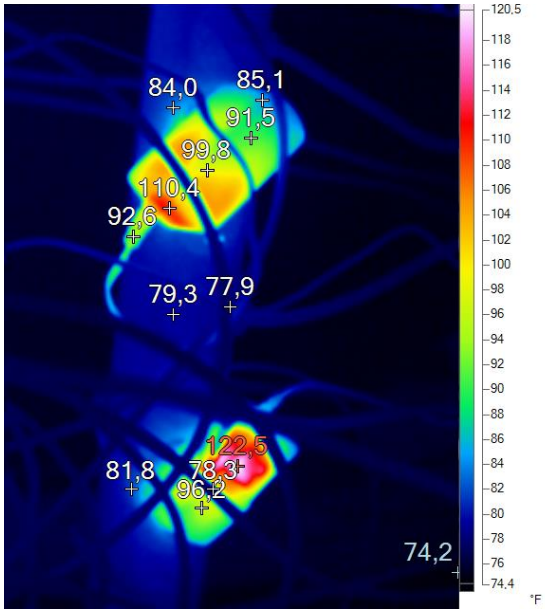

Fig. 5. Thermal conductivity of electric cables

(around 50 Hz) is 20ms. In photography, an amateur's insecure hand can occasionally produce blurry images at 1/125th shutter speed, it means 8ms integration time. A tripod is required to take thermal images that utilize the resolution of the thermal camera, or a thermal imaging camera with a refresh rate of 60 Hz or more.

D. *Focusing*

Inadequate Focusing not only results in blurred thermal images but also causes serious measurement errors. In case of incorrect focusing, only a part of the actual amount of radiation falls on the sensor surface, the rest are projected around it. This results in the measured temperature being lower than real local maximum and higher than real local minimum. The worse the focus setting, the greater the deviation from the true value.

E. *Depth of field*

The degree of error also depends on the depth of field related to the measurement distance. The shorter the distance (and hence the smaller the depth of field), the more critical the focus is. And as the local minimum and maximum geometric sizes of the object increase, the amount of value falsification decreases.

The depth of field range depends on the following parameters:

- the smaller the focal length of the lens, the greater the depth of field,
- the smaller the aperture window, the greater the depth of field range,
- the greater the subject distance, the greater the depth of field.

Therefore, the problem is most common with low-sensitivity microbolometer thermal cameras, especially at short range distances (for example, working with macro lenses or microscope lenses).

The hyperfocal distance (the distance to which the depth of field focuses to infinity when focused) can be calculated as follows:

$$H = f^2 k / r_p \quad (3)$$

where f is the focal length in [mm], k is the aperture, and r_p is the detector pixel size in [µm].

The sharpness of the thermal image extends from the half of the hyperfocal distance to infinity.

III. Practical Temperature Limits

Electrical equipment thermographic surveys shall be carried out only when at least 50% of the rated load is present (see Fig. 6 and 7). With a minimum load of 75%, and in case of a 20-40 degrees in Celsius (or Kelvin) warming relative to the ambient temperature, a revision is required; in case of a 40-60 degrees difference, an urgent revision is required; and in case of a higher than 60 degrees difference, the situation is critical. [7] [8] [9]

With a minimum load of 75%, in temperature limit difference between phases: in case of a 5-20 degrees difference, a revision is required; in case of a 20-40 degrees difference, an urgent revision is required (see Fig. 8); and in case of a higher than 40 degrees difference, the situation is critical. [10] [11] [12]

With a minimum load of 75%, the limits vary depending on the insulation material: in case of rubber insulated cables, it is 60 degrees in Celsius; in case of PVC insulated cables, it is 70 degrees in Celsius; and in case of silicon insulated cables, it is 180 degrees in Celsius. [13]

With a minimum load of 75%, other limit values: in case of plastic casings (depending on the material) max. 50-75 °C; in case of contactors, max. 85 °C; in case of transformers, max. 85 °C; inside electrical cabinets, max. 35°C; power rails, max. 65 °C. For lower load measurements, lower limits apply. [14] [15] [16] [17] [18] [19] [20] [21] [22]

Conclusion

The article attempts to introduce some typical mistakes that can be made during thermographic measurements and how to eliminate them. This paper proposes some further useful measuring recommendations for reducing measurement errors in the area of thermal imaging diagnostics. The proposes techniques are makes more reliable measurements. The author believes the high industrial usability of the shown adjustments.

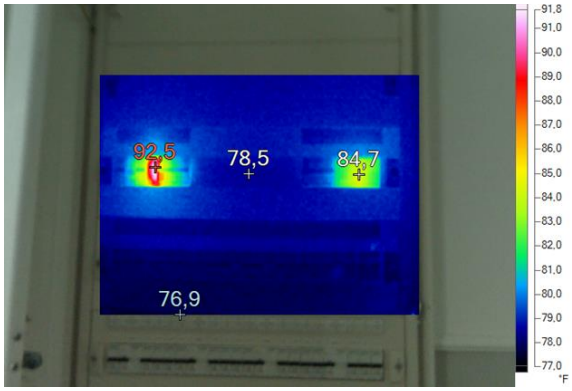

Fig. 6. Loaded circuit breaker board

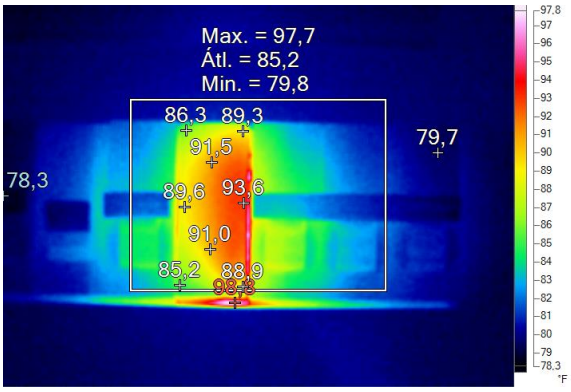

Fig. 7. Loaded circuit breaker

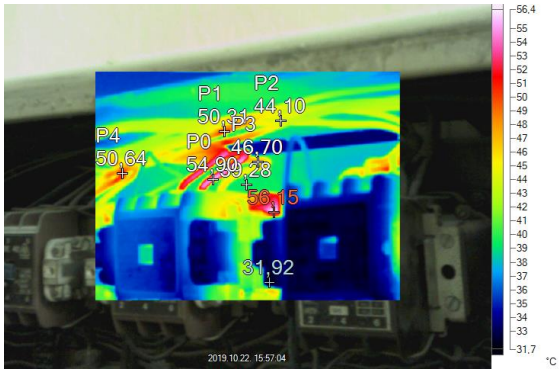

Fig. 8. Overloaded wires

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Educational Aspects of a Modular Power Management System

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***Abstract* — A redundant, modular, off-grid power supply unit is an often-used component in high reliability system. It makes it more fault tolerant and increase maintainability. With self-monitoring functions it can predict malfunctions and component lifetime. This system can also be used as a task for higher education projects. The students can expert their team working, problem solving, designing, building, testing skills with this kind of task.**

I. INTRODUCTION

The ongoing research development project offers many opportunities for university education and training. Students can explore their own research and development topics. It is a good opportunity to learn individual, independent work. The next level, however, is the acquisition of creative, constructive activities in the team. As university professors, we have methodologically identified the following path for our students. The personalized, knit work has helped with the trainer, but it should be largely through a self-contained solution, for more dynamic and distributed, pro-active, flexible teamwork. It may also be possible for different grades or programs to work on a particular project. In the middle of the training, a scientific conference material can be used as a useful side-effect and even a thesis on well-documented developments can be created for graduate students. Of course, to achieve higher grades, these activities and documented materials can also help you gain access to the scientific degree. The implementation of a longer project solution into education and the use of modern technologies used will greatly contribute to the training of high-value graduate students. This also enhances the quality of training, improves satisfaction with industrial partners, as they are more willing to use fresh graduates with useful and up-to-date knowledge.

Each project can be implemented in a variety of courses that are taught and recorded. Measurements (test measurements) that can be connected to the developments in the measurement technology class can play an important role [1]. A project detail can also be used to form the electronics measurement labs [2]. It is a good opportunity to get to know the digital components of the electronics to be designed or being operated, i.e. to deepen the knowledge of digital electronics and to apply them in practice [3]. It is an excellent opportunity to learn the programming of digital circuits and microcontrollers [4]. Thinking in the system, you can learn how embedded systems work [5]. In addition to foundation objects, new professional differentiated courses can be launched in higher grades [6].

II. IN PRACTICE

Let us look at how it is built, an R&D project is being built into our university level training.

Let us throw out a technological problem to solve. Define your needs. Give students the choice of the problems to be solved. If more than one group or course or course of study has the same function, introduce the "bidding" method. This basically means that for the given task the students are increasing the bar on the solution and make offers. The team that promises the highest quality, most useful solution will win the task. Of course, this can never mean that the solution cannot be further developed. A separate chapter should be devoted to the options for improvement.

Educational research projects can be co-operative, competitive or different. The solutions should aim to ensure that the problem solved is consistent with the problem that has been issued and has a well-defined output. So, it is important to define the tasks accurately, to develop a correct theoretical solution, to create a proper system plan, to perform preliminary simulations [7]. In case of wrong conclusions, step back into the planning in the right steps [8]. If the simulations are correct, they can only capture the students for circuit design and re-check the completed schematic plans with simulations. [9]

The next corner is also an important opportunity for further training. Real Circuit Designs (PCBs) must be

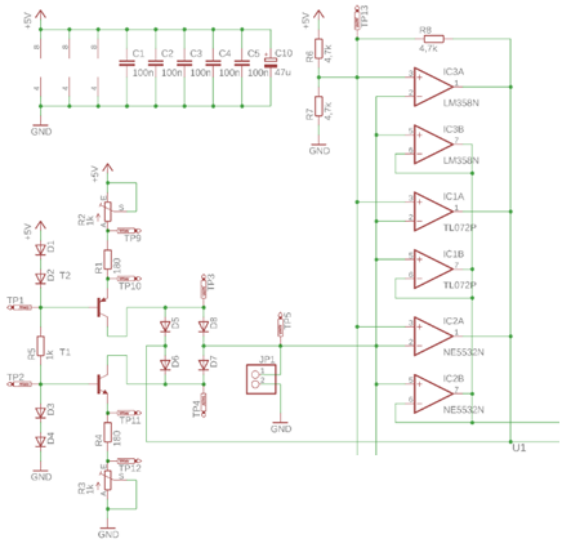

Figure 1. Schematic design example

made with the help of some authentic software (Fig. 1 and 2). [10] The modern equipment at our institute allows us to design printed circuit boards for 0-series equipment and to cut them off in an automated production line (Fig. 3 and 4). In a microcontroller environment, it is also possible to create firmware [11]. This requires proper hardware close and system knowledge [12]. The finished cards must also be measured by the students [13]. The measurements also can be automated (Fig. 5 and 6). [14]

Performing evaluations (evaluation) in one of the last steps and documenting the results. It is important to note that any development carried out in school conditions must not lead to the production of continuous and detailed work documentation, thus preparing our students for industrial work and approach. [15]

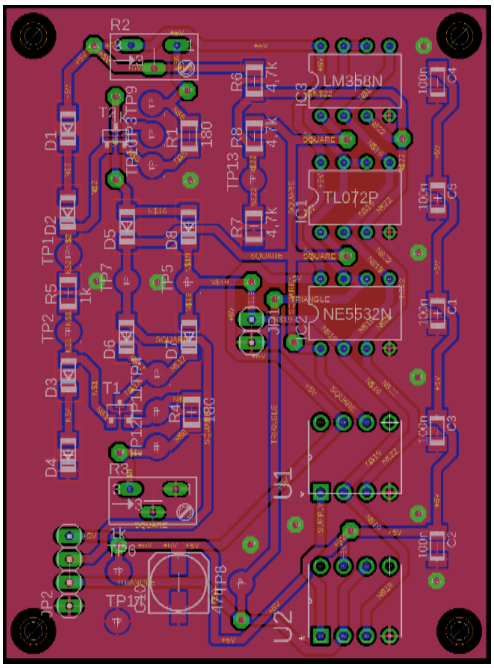

Figure 2. PCB design example

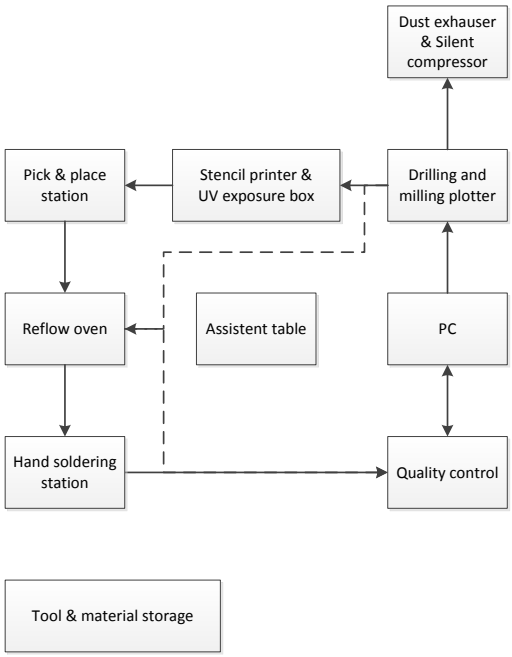

Figure 4. Prototype labor block diagram

III. REALIZATION

As an example project, the architecture of an off-grid redundant power supply system can be seen in Fig. 7.

The energy that feeds the system comes from the photovoltaic cells. The two redundant solar panel module can be compared to each other and can be selected one of them as an input of the next stage.

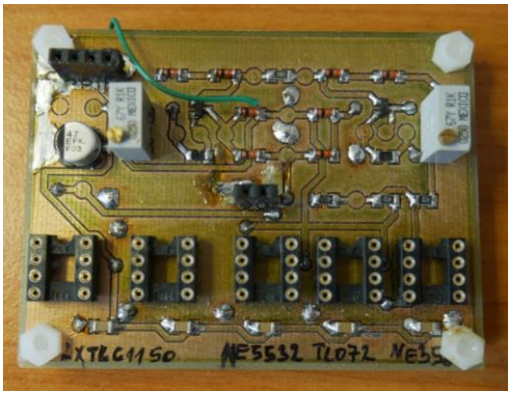

Figure 3. Milled and hand soldered PCB example

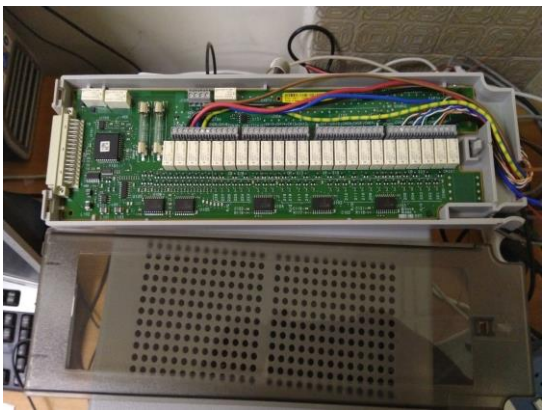

Figure 5. Digital multimeter multiplexer card

Figure 6. Automated measurement for validation purposes

The DC/DC converter module is also monitored (see Fig. 8) by the microcontroller unit (MCU). The input and output current and voltage are measured, and an efficiency is calculated. For further lifetime prediction the switching semiconductors (MOSFET's) drain-source voltage is measured, whet the element is open and under load. These modules will charge the accumulators and feed the system with stabilized DC voltage.

The accumulators are also used as redundant elements. The measured flowing in and flowing out charge can be measured and an efficiency, inner resistance can be calculated, a lifetime can be predicted.

The test loads can be used for short time, periodic module measurements with constant load. The task of the switching and measuring matrices is to connect, cross connect the different modules. The capacitor module will feed the inner controlling microcontroller, the connected load and other optional modules, if the power flow is temporarily disconnected due to switching.

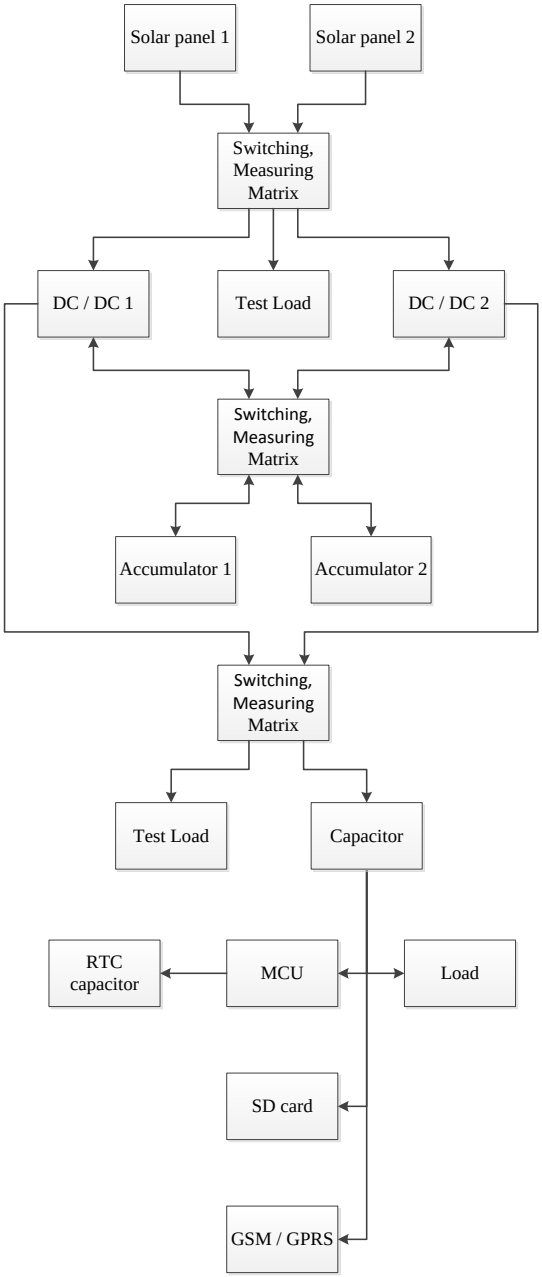

Figure 7. Redundant modular PSU structure

All these mentioned modules can be a development [16], construction [17], programming [18] and measurement tasks [19] for a whole semester. Students or student groups need to work together both in hardware and in firmware levels [20]. There are tasks to make a schedule, manage time, find the right solution, assign subtasks, find the connection interfaces and protocols between modules, and so on. [21] [22] [23] [24] [25] [26] [27] [28] [29] [30] [31]

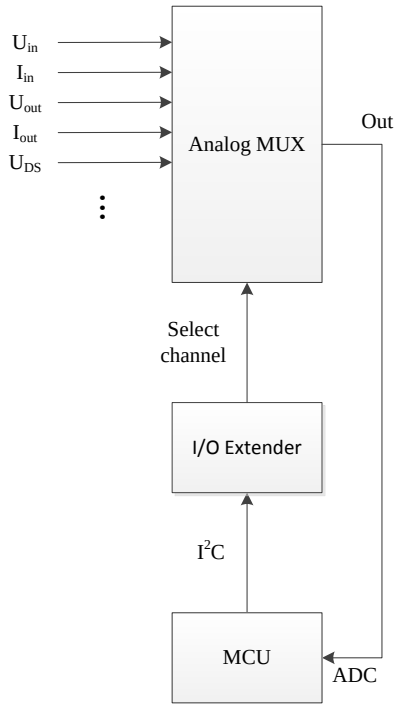

Figure 8. Module measuring architecture

CONCLUSION

In this paper a useful real-life application about a modular redundant power supply unit has been presented. The cooperation between the modules is endured by a microcontroller based embedded system. It had been showed, how to implement the mentioned solution to educational environment. Students also can learn and practice a lot of important competences with this method.

The authors believe that the proposed solution can be useful for civilian and industrial applications, where reliability is hardly required, even if it is needs some extra hardware and software redundancy.

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A Uniform Distribution Theorem Concerning Intersections of Finite Sets

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Abstract— **Families of finite sets with restricted intersections stood always in the centre of mathematical researches. Yet in the sixties there were papers which treated this topic. In this paper we will solve a Kürschák problem of 2019 of this topic, and we will write about its possible generalizations. The aspect is something new in respect of the former research work.**

I. Introduction

Families of finite sets that can intersect each other only in some prescribed ways have been investigated for a very long time. Throughout a problem of the Kürschák competition held in 2019 we will raise some research problems that are worth being investigated.

II. Some Problems in Extremal Set Theory

First of all, we want to give a survey about the former research work concerning the topic of restricted intersections. The first result about extremal sets was published in 1928, this was Sperner's theorem (see [4]):

Sperner's Theorem: *Let n be a positive integer, and let H be the set H={1,2,...,n}. If F is a family of sets consisiting of some subsets of H such that none of the sets in F is a subset of another set in F, then F contains at most* $\binom{n}{[n/2]}$ *sets, and this bound is the best possible.*

One of the most important results about intersecting sets was the Erdős-Ko-Rado theorem, published in 1961 (see [2]).

Erdős-Ko-Rado Theorem: *Let n and k be positive integers, k ≤ n, and let H be H={1,2,...,n}. If F is a family of sets consisiting of some k-element subsets of H, and every two sets in F intersect each other (i.e. they have at least one common element), then there are at most* $\binom{n-1}{k-1}$ *sets in F, and this bound is the best possible.*

Later a lot of problems were raised, in which one gives some restrictions concerning the intersections of the sets modulo a prime number. Perhaps the most classic examples are the Oddtown and Eventown type theorems.

The famous Oddtown theorem was published by Berlekamp in 1969 (see [1]).

Oddtown Theorem: *Let n be positive integer, and let H be H = {1,2,...,n}. Assume that* $\boldsymbol{H_1}$, $\boldsymbol{H_2}$, ..., $\boldsymbol{H_m}$ *are distinct subsets of H such that for every index 1≤j≤n the number* $|\boldsymbol{H_j}|$ *is odd, and for every pair of indices*

$1 \le k < l \le n$ *the number* $|\boldsymbol{H_k} \cap \boldsymbol{H_l}|$ *is even. Then* $m \le n$*, and this estimate is the best possible.*

The Eventown theorem was published independently by Berlekamp and Graver (see [1] and [3]).

Eventown Theorem: *Let n be positive integer, and let H be H = {1,2,...,n}. Assume that* $\boldsymbol{H_1}$, $\boldsymbol{H_2}$, ..., $\boldsymbol{H_m}$ *are distinct subsets of H such that for every index 1≤j≤n the number* $|\boldsymbol{H_j}|$ *is even, and for every pair of indices*

$1 \leq k < l \leq n$ *the number* $|\boldsymbol{H_k} \cap \boldsymbol{H_l}|$ *is even. Then* $m \leq \boldsymbol{2^{[n/2]}}$*, and this estimate is the best possible.*

Since there were a lot of other results concerning the size of intersections modulo a prime number. Here we mention a last one, which without doubt merits attention. Xin, Wei and Ge recently published the following result, which verifies an older conjecture of Babai, Alon and Suzuki in a stronger form (see [5]).

Theorem (Xin, Wei, Ge): *Let p be a prime number and* $L=\{\boldsymbol{l_1}, \boldsymbol{l_2}, ..., \boldsymbol{l_s}\}$ *and* $K=\{\boldsymbol{k_1}, \boldsymbol{k_2}, ..., \boldsymbol{k_r}\}$ *two disjoint subsets of {0, 1, 2, ..., p-1}. Suppose that F is a family of subsets of {1, 2,..., n} such that the number of elements in every set of F is congruent to some* $\boldsymbol{l_i}$*, and the size of the intersection of every two sets in F is congruent to some* $\boldsymbol{k_j}$*. If* $n \geq s + max\{\boldsymbol{k_1}, \boldsymbol{k_2}, ..., \boldsymbol{k_r}\}$*, then F contains at most*

$\sum_{t=0}^{2r-1} \binom{n-1}{s-t}$ *sets.*

III. Our Main Theorem

We formulate the second problem of the Kürschák competition held in 2019 as our main theorem:

Main Theorem : *Let n be positive integer, and let H be the set H={1,2,...,n}. If F is a family of subsets of H such that for every fixed nonempty subset X of H, exactly half of the values $|X \cap A|$ is odd, whenever A runs through all of the sets of F, then F contains of all of the subsets of H.*

Proof of the Main Theorem:

First of all we will prove that choosing all subsets of H as the family F, we get an appropriate construction. Let X be a subset of H that contains the integer number k ($1 \leq k \leq n$) as an element. Let A be a subset of H that does not contain the integer number k as an element.

In this case one of the two numbers $|X \cap A|$ and $|X \cap A \cup \{k\}|$ is even, and the other is odd. Thus ordering all subsets of

H in pairs in the manner such that such an A is a pair of the subset $A \cup \{k\}$, then one can see that the conditions of the theorem are fulfilled.

Now we have to prove that there is not any other possibility to choose such a family F. We will prove this statement by induction on n. For n=1 it is easy to check, that the statement is true. Let us assume that we

proved the statement of the theorem for all positive integers less than m. Now we have to prove it for n=m.

In this case $H=\{1,2,...,m\}$. Let X be a nonempty subset of H, that does not contain the element m. Let us consider all of the values $|X \cap A|$, if A runs through all of the sets of F that does not contain m as an element.

Let us assume that a_1 of these values are odd, and a_2 of them are even numbers.

Now let us consider the numbers $|X \cap B|$, if B runs through all of the sets of F that contain m as an element. Let us assume that b_1 of these values are odd, and b_2 of them are even numbers.

Using the conditions of the theorem, $a_1+b_1 = a_2 + b_2$.

Now let us consider all of the values $|(X \cup \{m\}) \cap A|$, if A runs through all of the sets of F that does not contain m as an element.

Exactly a_1 of these values are odd, and a_2 of them are even numbers.

Similary, taking the numbers $|(X \cup \{m\}) \cap B|$, if B runs through all of the sets of F that contain m as an element, one can easily see, that b_2 of these numbers are odd, and b_1 of them are even numbers.

Using the condition of the theorem we get

$a_1+b_2 = a_2 + b_1$.

Thus we have to solve the sytem of equations

$a_1+b_1 = a_2 + b_2$

$a_1+b_2 = a_2 + b_1$

From the first equation we get $a_1 - a_2 = b_2 - b_1$, from the second one we get $a_1 - a_2 = b_1 - b_2$. This implies that $b_1=b_2$, and $a_1=a_2$.

Thus half of the values $|X \cap A|$ is odd, if X is a fixed nonempty subset of H, that does not contain the element m, and A runs through all of the sets of F that does not contain m as an element. Using the induction hypothesis, we get that all of the subsets of the set H-{m} must be present in F.

Now let us choose X as X={m}. Using the conditions we get, that half of the sets in F contain m as an element, thus $|F| \geq 2 \cdot 2^{m-1} = 2^m$, which means that F must contain all subsets of H.

IV. A Linear Algebraic Consequence of the Main Theorem

Let us identify every subset of {1, 2, ..., n} with an n-dimensional vector in the standard way, which means that for every index $1 \leq i \leq n$, the ith coordinate of the vector equals one, if i is an element of the subset, otherwise this coordinate will be zero. Now let us prepare the matrix I with (2^n-1) rows and n columns, where each row corresponds to exactly one nonempty subset of H. Let M be a matrix with (2^n-1) rows and k columns such that in every row of M exactly half of the elements is one, the other elements are zeros, and the rows of M are distinct vectors (the condition implies that k must be even). If we can find a matrix F* such that IF*=M over the field F_2, then F* has n rows and k columns. The columns of F* represent the sets of a good family F, as prescribed in our main theorem. But we proved that this is only possible if $k = 2^n$, which means that for $0 \leq k < 2^n$ we cannot solve the equation IF*=M over the field F_2 for the unknown matrix F*. If $k = 2^n$, then the rows of M are uniquely determined, they must be the distinct n-dimensional 0-1 vectors in some order.

V. Some Research Problems

First we will reformulate our main theorem in order to be able to some generalization ideas.

Main Theorem Revisited: *Let n be positive integer, and let H be the set H={1,2,...,n}. If F is a family of subsets of H such that for every fixed nonempty subset X of H, the number $|X \cap A|$ is even exactly with probability 1 / 2 (where A denotes a random set of F), then F contains of all of the subsets of H.*

A natural way to extend our investigation is to replace H by an infinite set (which can be countable or not), and one could try to choose an appropriate family F from the finite subsets of H. The problem could be the following (or one can search for any other similar variants):

Problem 1: *Let H be an infinite set, and let F be a family of sets containing some finite subsets of H. Assume that for every X fixed finite subset of H, the number $|X \cap A|$ is even with probabillity 1 / 2, where A is a random set of F. Are there any families F that correspond to these requirements? If there are any, can we describe all of them?*

Here appeared the term probability, which can lead to new research problems concerning this topic. We could replace the modulus two by any other number. In a general form, we can raise the following questions:

Problem 2: *Let n be positive integer, and let H be the set H={1,2,...,n}, and let F be a family of distinct subsets of H. Let m be a positive integer greater than 1, and let $0<p<q<1$. Assume that for every X fixed subset of H, the number $|X \cap A|$ is divisible by m with a probabillity greater than p, but less than q, where A is a random set of F (this probability can vary, if we choose different sets A of F). Are there any families F that correspond to these requirements? If there are any, can we describe all of them?*

Problem 3: *Let H be an infinite set, and let F be a family of sets containing some finite subsets of H. Let m be a positive integer greater than 1, and let $0<p<q<1$. Assume that for every X fixed finite subset of H, the number $|X \cap A|$ is divisible by m with a probabillity greater than p but less than q, where A is a random set of F (this probability can vary, if we choose different sets A of F). Are there any families F that correspond to these requirements? If there are any, can we describe all of them?*

Unfortunately, our ideas applied in the proof of the main theorem do not seem to work in the general cases.

If we shift an element modulo 2 by one, then we can be sure that we will get the other element of the field F_2.

But if we want to make calculations modulo m, where m is greater than 1, then this will not work. It seems probable that these problems can we solved (at least partially) using some linear algebraic methods, as for example in the case of Oddtown and Eventown type theorems.

Thus it seems impossible that these problems have a purely elementary solution like our main theorem. But even that is why these slight modifications can be good research problems in the future.

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5 S at a large enterprise

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***Abstract*— The authors expound the 5S method which defines the success of any other productivity improvement technique at an enterprise. 5S is applicable in any area of the work-process. However it primarily used at the operational level to maintain order, cleanliness and supports continues improvements, even so the use of 5S can produce similarly significant results in office areas. This paper underlines the advantages of 5S mainly at the operational level through the example of a large enterprise. This paper gives an overview of 5S solutions in the practice showing its main features and benefits for the enterprise.**

Keywords*— *Kaizen, 5S, quality management, productivity, improvement

I. INTRODUCTION

Other Kaizen activities based on 5S. It creates a culture (behavior) and configures a system in the operational level. Improves process transparency, helps maintain order and explores and solves process issues. People pay attention to their work-environment, maintain and develop it consciously. The 5S system improves employee proprietary, discipline and image of the company [4]. Productivity accession is also possible orderly because in a well-structured workstation can be eliminated a lot of unnecessary losses (searching, unnecessary movements, repackaging, product injury, machine failures, unnecessary transportation).

5S is not just about tidying up and cleaning, it is a process organizing tool that creates the operating framework and conditions of the process not on paper but in physical reality [9]. With the introduction of 5S, we are working with workers together to design for the efficient layout and safe work environment and workflow [10], [11] . The clue is to work with the employees to create a system that is accepted and adhered to in the future.

II. THE ESSENCE OF 5S METHOD

The 5S method is a simple, easy-to-understand technique that underlies the success of any other productivity improvement technique.

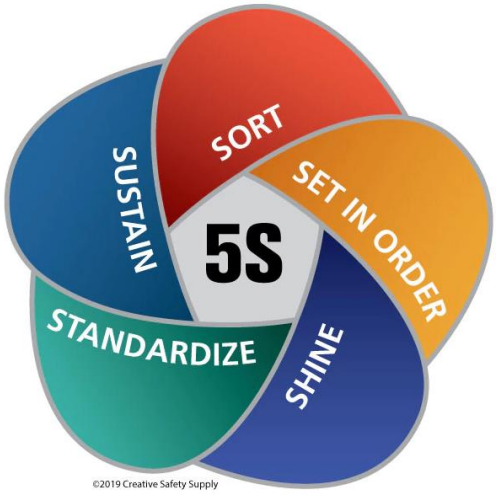

Fig.1. 5S Elements

Source: What are some examples of 5S strategies? https://www.creativesafetysupply.com/qa/5s/what-are-examples-of-5s-strategies (10.09.2019.)

The 5S method follows Kaizen's 3 steps: Eliminate, Decrease, and Change.

Target: Creating and maintaining an effective work environment that is safe and of good quality. To create a state in which the company can continuously promote Kaizen (continuous improvement).

The kernel of method: Creating a quality work environment. 5S is an abbreviation for five Japanese words. The first three are practical steps and the last two supports system sustainability.

Sort (Seiri): Remove the unnecessary - Keeping only what is used and red tag the rest. You should enquire from the workers whether defective tools and equipment, outdated items, and other non-essential materials on site. Items must be stored that are difficult to classify.

Fig.2. “Sorting” [8]

Set in order (Seiton): A place for everything and everything its place – Fixed locations and clear visualisation. Allocate and store items in accessible spots. Tools and items should be grouped based on use and function. Heavy materials should be placed where the employee is able to pick them easily.

Fig.3. "Setting in order" .[8]

Shine (Seiso): Everyday clean – Regular cleaning and checking to set the standard. Activities and items that cause dirt, contamination are traced and actioned. After the shift ends the work area must be cleaned. Tools and other equipment should be ready for use all the time.

Fig.4. "Shining" [8]

Standardise (Seiketsu): Same standard, every time for everybody – Optimising the standard across all shifts. Expectations of workers' responsibility to maintain the culture of cleanliness must be set.

Fig.5. "Standardising" [8]

Sustain (Shitsuke): Maintain Discipline – Sustaining the habit of properly maintaining and improving the standards.[1] Sustaining helps workers contributing to maintaining a healthy and safe working environment.

Fig.6. "Sustaining good practising and improvements" [8]

Figure 7 and 8 shows the effects of introduction of 5S by an enterprise.

Fig. 7. shows:

- Inventory stacked far out of reach
- Unused older inventory
- Safety hazard; boxes stacked in aisles
- No discernable organization such as barcoding, inventory dating, color coding, or naming convention
- Trash and debris allowed to accumulate

Fig.7. Before 5S .[7]

After the introduction of 5S, the view of the work-area is very different. The materials and products are put in systematic order.

Fig. 8. shows:

- Uniform bins and racking
- Date tracking of inventory
- Bin contents are labeled
- Bins, racks, and floors are kept clean and in good repair
- Lighting in facility is sufficient
- Racks are low enough that ladders are not required to access inventory

Fig. 8. After 5S .[7]

III. APPLICATION OF 5S IN THE PRACTICE

5S is applicable in any area where you work. We use it primarily at the operational level to maintain order, cleanliness and it supports continues improvements, but the use of 5S can produce similarly significant results in office areas. [2]

Henceforward the authors submit the practical implementation of 5S. Managers are committed to configure call and inspiration, the engineer insure the tools the operator is responsible for their use and compliance. The process begins to create a list of items needed which describes exactly which tool should be at the station and which is unnecessary. Then the placement, naming and labeling of their place will follow. If something is out of place or disappears or it will be ruined, we already know what needs to be replaced. So the main point of 5S is to maintain order and cleanliness. To verify this, there is a 30-point series of questions that measure the status of the state in 5S. The certification system expects a result above 80%.

However in practice not only manual workers can use 5S, but also office workers in their own environment. We can't work without the tools we need is there or the space to do our work. Now the 80% requirement is not perform every month at the area, and the area's 5S policing needs to be reconsidered. The first thing we did to improve it was to ask the workers about the system. We were primarily concerned with the auditor about the recurring problems in each line and area. The first problem that could be eliminated was the lack of feedback. The area competent received the percentage, but they did not know what the difference was. To eliminate this, we turned to the IT team to report any discrepancies we found after each audit.

When this e-mail system was created, many things could be solved immediately, such as the lack of individual 5S cards, marking labels, required documents (including the list of items needed), or paintings. We solved the missing 5S cards and documents. Paintings and labels were the responsibility of the area. Replacing the list of items needed took the most time. This document contains a list of the equipment that is regularly used at a given station. It includes their quantity, and the identifier that the storage can use to replace the missing item.

Identify applicable funding agency here. If none, delete this text box.

These includes tools, additives, cleaning tools. This list may be drawn up with the operators and engineers help, and will be subject to periodic monitoring. But at that time, we noticed another opportunity for improvement: they can't just look back at e-mail. If it were collected in a database and could be queried at any time, Pareto analysis1 could be made from it, which would lead to further increase in results. Before start this new development, we consulted with area assign to inquire about the effectiveness and shortcomings of the current system. At this point, questions that were too broad to be interpreted were revealed, ie the items in the question list do not necessarily indicate the cause of the problem. Therefore, we thought that not only would it be serve or not to select at the audit, but that the cause could be commented on. Even with the differences posted, the operating level 5S results increased 4%. The IT team has committed to improve the application. The result is spectacular, and this month there hasn't been a single line below the expected level. The efficiency analysis go on 60-90 days, which in this case is rather 3 months due to the rarity of the audit. So our next step will be to keep an eye out for further support, questions, or comments.

1Pareto: “80% of the problems are behind 20% of the root causes. It is essential to distinguish little and insignificant much. ”[3]

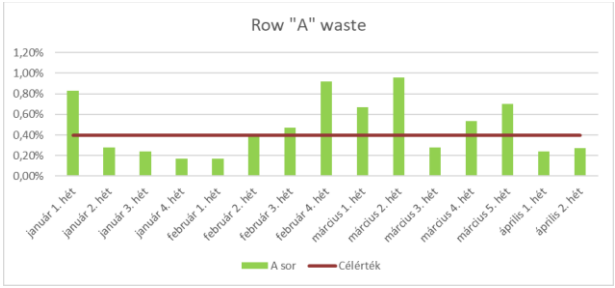

Fig.9. Percentage of rejects by week (self-edited)

Figure 9 shows the scraps rates for one of the line since January. This was calculated by looking at the total number of pieces produced and the number of scrap, and calculated the percentages from each week. The target is 0.4% (or lower) as shown in the chart, which is a company-defined index. It is a requirement of the Certification System that, wherever possible, the maximum should be at the target value. We suggest that if the line does not reach the result, it should be mandatory to start A3 for the problem. This gives us a much better chance of finding out the cause of the problem and eliminating it, so we can achieve better results in the future.

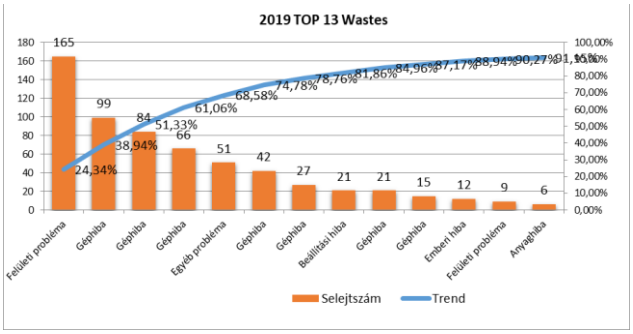

Fig.10. 2019 Top 13 wastes (scraps), (self-edited)

Fig. 10. shows a Pareto diagram of the main causes of scrap. Starting in January, these were the reasons that caused the most scraps. This also shows that the Pareto principle applies, ie that 20% of errors cause 80% of problems. Above the columns is the number of scraps, and for the trend, the percentages are calculated by dividing the number of the first scraps case by the total number of scraps, then dividing the second by the sum of the first two, and so on. We recommend that you open the A3 for the first 3 most scraps case and investigate the problem to prevent such a large number.

IV. CONCLUSION

The 5S system improves employee proprietary, discipline and image of the company. Improvements in productivity and quality have long-term effects on the success of business. Productivity accession is also possible orderly because in a well-structured workstation can be eliminated a lot of unnecessary losses. The introduction of the measurements of 5S method in the chosen enterprise saved lots of losses, also. There must be a sincere belief by employees from top management to operating employees that the enterprise is able to achieve higher productivity and quality with 5S method. The commitment to quality among the work force within the organization is essential. It can be obtained with motivational programs, job enrichments, goal setting, positive reinforcement, team development [5], [6]. Participative management which involves employees in important management decisions is a good method to improve productivity and to reach higher quality.

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Teaching implementation of sustainable and innovative reporting approaches by means of embedded SAP GUI technologies

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***Abstract*— Various methods and techniques are available in SAP reporting. New approaches, however, rarely replace old and robust techniques immediately. Depending on the environment, business requirements, organizational and personal best practices, multiple solutions might be adequate. This paper presents an embedded SAP List Viewer technique by means of using shortened expression, the ALV Object Model. This case study demonstrates how to use old and new approaches in parallel, enabling both sustainability and innovation.**

Keywords*— *SAP List Viewer, Sustainability, Innovation

INTRODUCTION

Enterprise Resource Planning, *ERP*, Systems [1-2] play an important role at company level worldwide. A huge number of employees carry out their daily work applying business functions. One can find numerous techniques and methodologies for executing business processes. It is important, therefore, to differentiate between, reliable and novice solutions. Development of reports is one of the most common requests when easy-to-use, enhanced and complex programs are being created.

SAP, a famous, popular and widely used ERP System [3], offers different ways for reporting. SAP ALV List is a tool, which enables business users applying smart features, e.g. sorting, downloading, reacting on users' activities, etc. Developers have various options for creating ALV Lists. SAP applies its own programming, the Advanced Business Application, ABAP language. Modularity is a clear development approach that makes possible the reuse of building blocks, such as subroutines, functions, methods and so on.

A business environment requires reliable solutions for sustainability. It means that the chosen development technique should be valid for long term, applied in different business areas and supported easily. This paper compares three different ALV developments, applying SAP REUSE functions, CONTROL framework and the class based SALV model.

ALV SOLUTIONS

Reusability is available by using the REUSE_ALV_LIST_DISPLAY function module. There are a couple of standard demo programs in the System, introducing the functionalities of ALV lists. One of the simplest one, the BALVSD02 report consists of a simple array of Flight data displayed by the DISPLAY function.

The code extract and the resulting list is displayed on Figure 1.a and 1.b.

```
DATA: GT_SFLIGHT TYPE TABLE OF SFLIGHT.
*---------------------------------------------
* Selection
SELECT * FROM SFLIGHT INTO TABLE GT_SFLIGHT.
* Call ABAP List Viewer (ALV)
CALL FUNCTION 'REUSE_ALV_LIST_DISPLAY'
     EXPORTING
          I_STRUCTURE_NAME   = 'SFLIGHT'
     TABLES
          T_OUTTAB           = GT_SFLIGHT.
```

Fig. 1.a. Output flights program, ©SAP

ID	No.	Date	Airfare	Curr.	Plane Type	Capacity
AA	17	07.10.2015	422,94	USD	747-400	385
AA	17	14.10.2015	422,94	USD	747-400	385
AA	17	21.10.2015	422,94	USD	747-400	385
AA	17	28.10.2015	422,94	USD	747-400	385
AA	17	04.11.2015	422,94	USD	747-400	385
AA	17	11.11.2015	422,94	USD	747-400	385
AA	17	18.11.2015	422,94	USD	747-400	385
AA	17	25.11.2015	422,94	USD	747-400	385
AA	17	02.12.2015	422,94	USD	747-400	385
AA	17	09.12.2015	422,94	USD	747-400	385
AA	17	16.12.2015	422,94	USD	747-400	385
AA	17	23.12.2015	422,94	USD	747-400	385
AA	17	30.12.2015	422,94	USD	747-400	385

Fig. 1.b. Simple ALV functions, ©SAP

Even though only a few functions are handled by clicking on the application toolbar icons displayed above the list, general reporting requirements are covered:

- A line can be selected to display details.
- Records can be sorted ascending or descending.
- Contents can be filtered.
- Totals and subtotals can be added.
- The list can be printed and transferred to different document formats.
- The layout can be changed.

List output can be chosen as List, Fullscreen Grid or Grid. A fullscreen grid list is displayed in Figure 2, where enhanced features, like colors, symbols and icons are added.

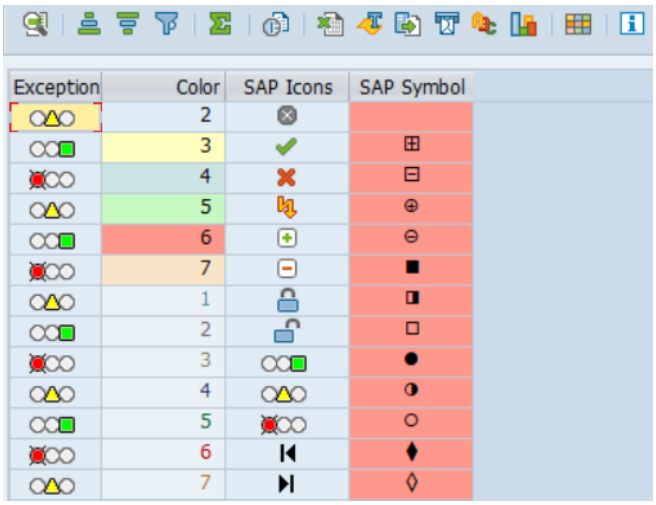


Fig. 2. Fullscreen Grid List, © SAP

SAP introduced then the Control techniques, supporting Custom Container, Dialog Box Container, Docking Box Container, Splitter Container and Easy Splitter Container Controls, respectively.

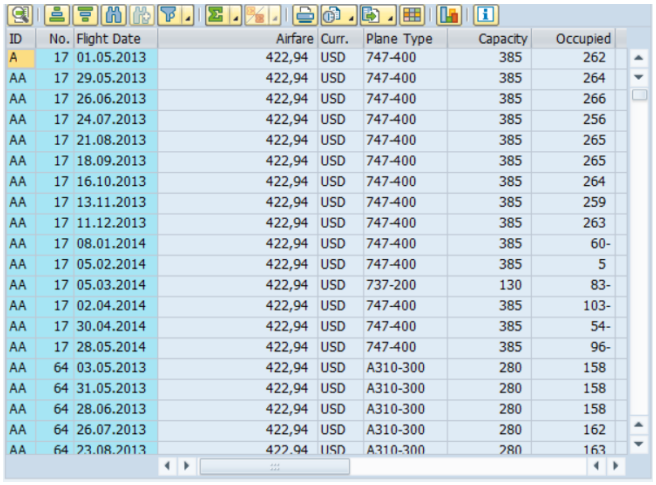
Displaying list data as a table on the screen, SAP Grid Control Tool enables print and display non-hierarchical list.

The calling program transports data in a table format. A special class, an instance of the standard cl_gui_alv_grid includes necessary communication details.

A filed catalog is the formatting description of displaying data.

Two methods of the instance class inherited from cl_gui_alv_display, the set_table_for_first_display and the refresh_table_display ones.

Figure 3.a and 3.b. display a simple SAP Grid list with extended toolbar.



ID	No.	Flight Date	Airfare	Curr.	Plane Type	Capacity	Occupied
A	17	01.05.2013	422,94	USD	747-400	385	262
AA	17	29.05.2013	422,94	USD	747-400	385	264
AA	17	26.06.2013	422,94	USD	747-400	385	266
AA	17	24.07.2013	422,94	USD	747-400	385	256
AA	17	21.08.2013	422,94	USD	747-400	385	265
AA	17	18.09.2013	422,94	USD	747-400	385	265
AA	17	16.10.2013	422,94	USD	747-400	385	264
AA	17	13.11.2013	422,94	USD	747-400	385	259
AA	17	11.12.2013	422,94	USD	747-400	385	263
AA	17	08.01.2014	422,94	USD	747-400	385	60-
AA	17	05.02.2014	422,94	USD	747-400	385	5
AA	17	05.03.2014	422,94	USD	737-200	130	83-
AA	17	02.04.2014	422,94	USD	747-400	385	103-
AA	17	30.04.2014	422,94	USD	747-400	385	54-
AA	17	28.05.2014	422,94	USD	747-400	385	96-
AA	64	03.05.2013	422,94	USD	A310-300	280	158
AA	64	31.05.2013	422,94	USD	A310-300	280	158
AA	64	28.06.2013	422,94	USD	A310-300	280	158
AA	64	26.07.2013	422,94	USD	A310-300	280	162
AA	64	23.08.2013	422,94	USD	A310-300	280	163

Fig. 3 SAP Grid, © SAP

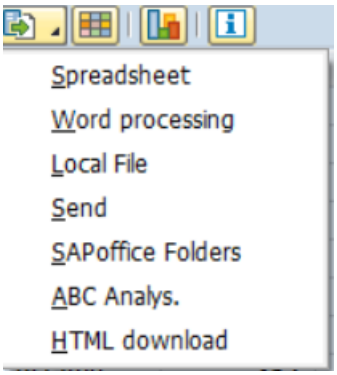


Fig. 3.b. Export, © SAP

Transporting data in different format lets the business users to process information easily.

The ALV Graphic button displays more information, as shown in Figure 4.

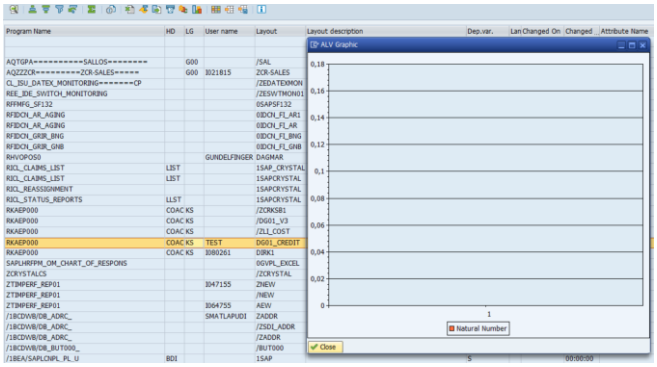


Fig. 4. ALV Graphic, © SAP

Drag&Drop is a comfortable tool in GRID list. Figure 5 a and b demonstrates if one selects a coloumn, and then moves that one to a new position.

ID	No.	Flight Date	Book. no.	Cust. No.	B/	Sr	Lug.weight	Unit	In	Cl	Amount (for.currency)	Curr.
AA	17	01.05.2013	1	1552	P		17,4000	KG		C	875,90	EUR
AA	17	01.05.2013	2	560	P		13,4000	KG		C	803,58	USD
AA	17	01.05.2013	3	3080	P		9,8000	KG		C	845,88	USD
AA	17	01.05.2013	4	710	P		23,9000	KG		C	829,82	EUR
AA	17	01.05.2013	5	583	P		25	KG	X	C	922,01	EUR
AA	17	01.05.2013	6	669	P		19,8000	KG		C	543,36	GBP
AA	17	01.05.2013	7	180	B		18,9000	KG		C	845,88	USD
AA	17	01.05.2013	8	3871	P		10,9000	KG		C	922,01	EUR
AA	17	01.05.2013	9	4482	P		15,3000	KG	X	C	543,36	GBP

Figure 5.a. Select two coloumn in the GRID List

ID	No.	Flight Date	Book. no.	Cust. No.	B/	Sr	Amount (for.currency)	Curr.	Lug.weight	Unit	In	Cl
AA	17	01.05.2013	1	1552	P		875,90	EUR	17,4000	KG		C
AA	17	01.05.2013	2	560	P		803,58	USD	13,4000	KG		C
AA	17	01.05.2013	3	3080	P		845,88	USD	9,8000	KG		C
AA	17	01.05.2013	4	710	P		829,82	EUR	23,9000	KG		C
AA	17	01.05.2013	5	583	P		922,01	EUR	25	KG	X	C
AA	17	01.05.2013	6	669	P		543,36	GBP	19,8000	KG		C
AA	17	01.05.2013	7	180	B		845,88	USD	18,9000	KG		C
AA	17	01.05.2013	8	3871	P		922,01	EUR	10,9000	KG		C
AA	17	01.05.2013	9	4482	P		543,36	GBP	15,3000	KG	X	C

Fig. 5.b. New Coloumn positions after Drag&Drop

A further interactive option is also possible when using ALV GRID. Double-clicking on a row of the basic list, a dialog box appear that includes a detailed list, shown is Figure 6-. The content of the secondary screen is retrieved according to the program code being developed in the corresponding screen (so-called module pool) program.

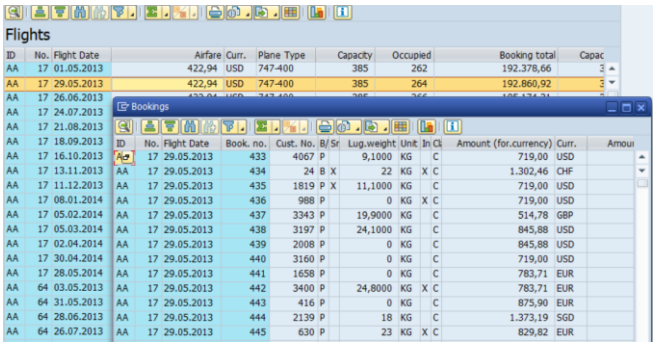


Fig.6. Detail List in SAP Grid Popup Window, © SAP

A user-specific function can be added to the Toolbar with a simple pushbutton or icon. A program code is executed when the user selects a custom function. If the user selects one or more lines, an addition detailed list can be displayed, as shown in Figure 7 after pressing the 'Detail' pushbutton.

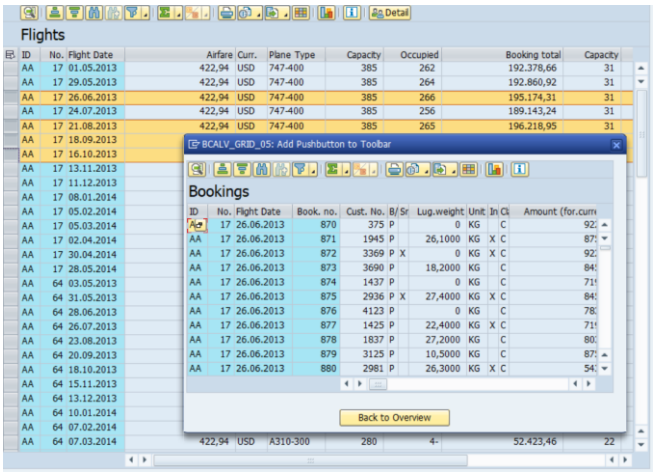


Fig. 7. Additional Pushbutton on the Toolbar, (SAP)

The User can return to the basic list by pressing the 'Back to Overview' button.

Editing a list is a common requirement. Screen characteristics can be easily changed dynamically in SAP GRID List as shown in Figure 8.a. and 8.b., choosing the Change/Display icon.

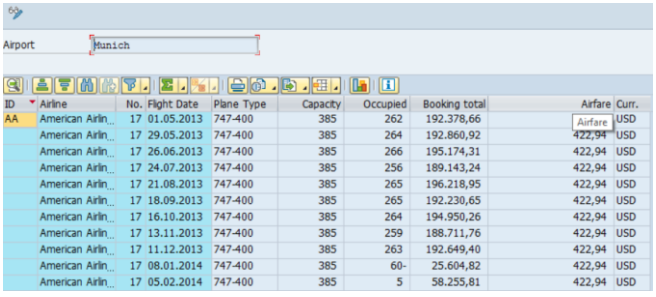


Fig. 8.a. Display cell data in SAP GRID List, © SAP

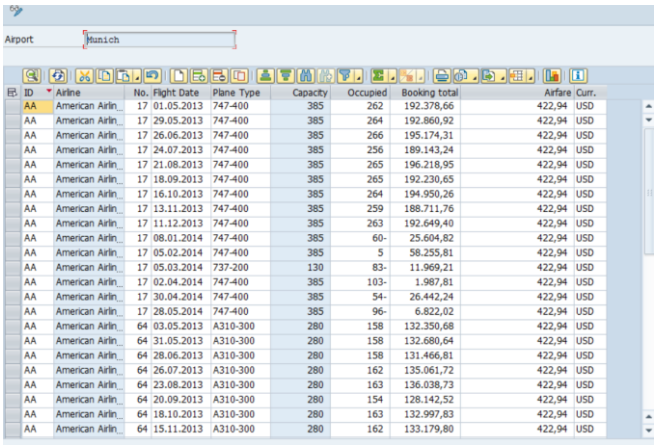


Fig. 8.b. Display&Edit cell data in SAP GRID List, © SAP

The examples shown above, demonstrate various concepts and solutions. They reflect numerous list functions, which can be implemented separately, according to business needs.

New trends of SAP developments follow simplification, shortened expressions instead of applying long, complex statements followed each the other.

An easy deployment of SAP ALV LIST with shortened expression is the application of the cl_salv_table standard class.

A simplified development way of SAP ALV List is shown in Figure 9a and Figure 9b. Program demo_alv_reporting calls the factory and the display methods, and displays the list in a straightforward way.

```
cl_salv_table=>factory(
  IMPORTING r_salv_table = DATA(alv)
  CHANGING  t_table = scarr_tab ).
        alv->display( ).
```

Fig. 9.a. ALV List with SALV_TABLE, ©SAP

Airline	Airline URL
American Airlines	http://www.aa.com
Air Berlin	http://www.airberlin.de
Air Canada	http://www.aircanada.ca
Air France	http://www.airfrance.fr
Indian Airlines	http://www.aa.com
Alitalia	http://www.alitalia.it
British Airways	http://www.british-airways.com
Continental Airlines	http://www.continental.com
Delta Airlines	http://www.delta-air.com
Air Pacific	http://www.airpacific.com
Japan Airlines	http://www.jal.co.jp
Lufthansa	http://www.lufthansa.com
Lauda Air	http://www.laudaair.com
Northwest Airlines	http://www.nwa.com
Qantas Airways	http://www.qantas.com.au
South African Air.	http://www.saa.co.za
Singapore Airlines	http://www.singaporeair.com
Swiss	http://www.swiss.com
United Airlines	http://www.ual.com
Indian Airlines	http://www.aa.com

Fig. 9.b. Reporting with SALV_TABLE ALV List, ©SAP

Shortened expressions effectively improves the readability and the performance of SAP applications. Simplified solutions definitely makes harder debugging and analyzing the development. It might be advantageous to be familiar with

older, but reliable and sustainable solutions on one hand, and novice, innovative approaches on the other hand.

CONCLUSION

Appropriate solutions required for business needs. However, application of right choices usually depends on the actual environment, long-term strategies, organizational knowledge, resources and so on at Company level.

SAP Reporting by means of ALV List exemplifies different approaches that might be adequate for a particular purpose.

The aim of this paper is to demonstrate that knowing different development ways and techniques is advantageous.

Similar comparisons can be made in different topics, like in Informatics, Robotics, Electronics, Higher Education Studies, etc. as follows.

- Robust techniques can be applied in an interdisciplinary, popular research area, like Cybernetics. [4] New trends are popular in robotics. [5]
- Reliable research methods enable resulting in new research results. [6-11]
- Various educational studies and methodologies should be applied at the universities and at workplaces. [12-15]

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