

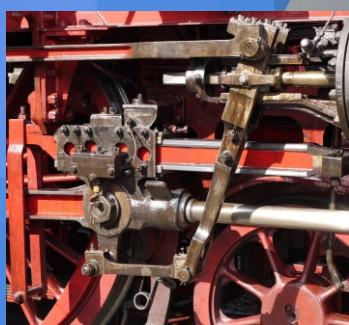
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INDUSTRY 4.0

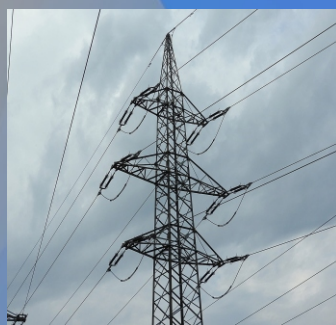
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tel. (+359 2) 987 72 90,
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Trends and applications of artificial intelligence methods in industry

Ivan Kuric*, Martin Bohušík, Vladimír Stenclák, Michal Bartoš, Daria Fedorová, Milan Sága Jr.
University of Žilina, Faculty of Mechanical Engineering,
Department of Automation and Production Systems, Slovakia
ivan.kuric@fstroj.uniza.sk

Abstract: This article describes the actual trends and applications in industry where artificial intelligence models are deployed. This paper provides a more detailed description of the principles and methods of deploying models in the field of quality evaluation in industry and also in the areas of predictive maintenance and data analytics in the manufacturing process. Computer vision is increasingly coming to the fore due to its wide range of applications - object detection, categorisation of objects, reading QR codes and others. The area of predictive maintenance is important in terms of reducing downtime and saving costs for machine components. Models designed for data analytics, in turn, help to optimize the parameters of the production process so that the desired parameter is maximized or its optimal value is achieved.

Keywords: ARTIFICIAL INTELLIGENCE, COMPUTER VISION, PREDICTIVE MAINTENANCE

1. Introduction

This article describes the actual trends and applications in industry where artificial intelligence models are deployed. In this paper, we mainly focus on artificial neural network models, namely convolutional artificial neural network models, nonlinear autoregressive artificial neural network models, and feedforward artificial neural network models.

Implementing computer vision models in the areas of product quality evaluation leads to savings in personnel costs, increased productivity and better management of the organisation of the production process. Computer vision is increasingly coming to the fore due to its wide range of applications. Due to the increasing scarcity of skilled workers, adherence to predetermined product quality, speed and repeatability, artificial intelligence (computer vision) is increasingly being used for product quality control in various industries. It is because of these benefits that we have described in this paper the issues associated with deploying these methods and algorithms to solve sub-problems associated with a specific manufacturing process. In this research, we worked with MATLAB and Python programming languages, which offer different libraries focused on Machine Learning and thus have a diverse range of desired AI models. Camera systems process and evaluate the captured image (within computer vision) - this includes reading text, QR/barcodes, recognizing objects (Fig 1a), determining the position of products, checking the filling of bottles with liquid, etc. This paper summarizes some specific applications of computer vision and training a convolutional neural network using a concrete example. To achieve the best possible computer vision results, it is necessary to create suitable conditions for the camera system to capture the object - use appropriate lighting, prevent larger debris from getting caught on the lens, etc. It is also possible to find leading manufacturers of industrial cameras who provide their own software for some of the applications of computer vision, e.g. distance measurement and orientation of the sensed object.



Fig. 1 a) Detection of protective equipment on the worker [1] **b)** Predictive maintenance [2]

This paper provides a more detailed description of the principles and methods of deploying models in the field of quality evaluation in industry and also in the areas of predictive maintenance (Fig 1b) and data analytics in the manufacturing process. The area of predictive maintenance is important in terms of reducing downtime and saving costs for machine components. Models designed for data analytics, in turn, help to optimize the parameters of the production

process so that the desired parameter is maximized or its optimal value is achieved.

2. Computer vision

Almost all industrially produced goods are more or less intensively visually inspected (inspected by sight). This task is carried out by qualified personnel who have been trained in visual inspection. Nowadays there is a great deal of automation in production, and it is camera systems that reliably replace human operators in the inspection of products. [3]

The tasks of visual inspection are: recognizing familiar objects/patterns, distinguishing surface condition/texture, optical properties (e.g. color), material identification, defect detection, etc.

Significant disadvantages of visual inspection include: monotony, tediousness, tiring work, image evaluation is subjective, lack of good reproducibility, visual inspection is often very slow compared to machine vision, and it is also expensive.

Table 1: Comparison of human visual system and technical visual inspection system [3]

	Human visual system (eyes and brain)	Technical visual inspection system (camera + computer)
Sensors	- low optical resolution - intensity values and dimensions cannot be captured - limited to visible light - spectral perception with three channels	- high optical resolution - ability to capture intensity and dimension values - possibility to use illumination outside the visible part of the spectrum - possibility to use multichannel spectral resolution
Image processing and analysis	- huge number of parallel, highly interconnected and slow neurons - programmed by learning from examples	- one or more powerful processors - algorithm must usually be explicitly designed
Special abilities:	- experience and basic knowledge - adaptability and ability to learn - tremendous cognitive abilities - intuition	- precise calculations - high processing speed - lossless storage of large amounts of data

Computer vision applications

Computer vision as the automatic analysis of images and video by computers, has a wide range of applications - use in the engineering industry, food industry, medical industry, etc. Specific applications of machine vision are e.g. checking the position of parts in automotive production, checking the use of correct parts or fasteners, categorizing objects, checking printed circuit boards, checking defects on products, finding fingerprints on apples, detecting chocolates on a conveyor and placing them in a box via a delta robot, automatically reading license plates on vehicles, the

ability to record multiple players on the ice (during hockey) and then give a penalty to that team, airport security checks, inserting virtual objects into movies, helping drivers by warning them (vibrating the steering wheel) when they are swerving out of their lane, creating 3D models from old photographs, classifying species of plants, etc.

Popular computer vision applications:

- a) Object classification
- b) Object identification
- c) Object verification
- d) Object detection
- e) Object landmark detection
- f) Object segmentation
- g) Object recognition

Checking the date of manufacture and reading barcodes

When bottles/jars are filled with food, the date of manufacture/consumption (Fig. 2a) and the barcode (Fig. 2b), as shown in Fig. 32b, shall be indicated on the packaging of the bottles/jars. These labels and codes are printed by automated production, which can cause the data on the product packaging to be misprinted or not printed at all. In order for the consumer to have all the necessary information on the product as a result, some kind of control must already be included in automated production. The inspection can be either visual (a human operator would inspect individual product packages), which would greatly reduce the number of packages produced, or camera inspection, which in this case is the most appropriate in terms of efficiency and reliability.



Fig. 2 a) Checking the date of manufacture [4] b) Reading the barcode [5]

Gravure cylinder inspection

Gravure printing consists of the continuous movement of the printed material, which presses the pressure roller against the gravure roller (Fig. 3) on which the gravure ink is applied. This type of printing, which makes it possible to achieve high quality printing of full-colour illustrations, is the reason why it is mainly used for printing full-colour high-cost products, e.g. magazines and catalogues.

Computer vision was used for detecting the defects on the printing cylinder, where the accuracy of the automated classification is 98.4%.



Fig. 3 Gravure roller [6]

Searching for animals with thermal cameras

Thermal imaging is the most effective method for finding problems or potential problems in a variety of applications in many fields. For this purpose, thermal imaging cameras are used, which are currently of great use in - search for wanted persons (police helicopters are often equipped with thermal imaging cameras), firefighting (thermal imaging cameras allow you to quickly find out where the fire is located), maritime navigation, road safety, military and defense applications, etc. Fig. 4 shows an image produced by a thermal imaging camera, from which the presence of animals at the

imaged site can be easily detected (by the different colour of the individual objects - yellow/red).

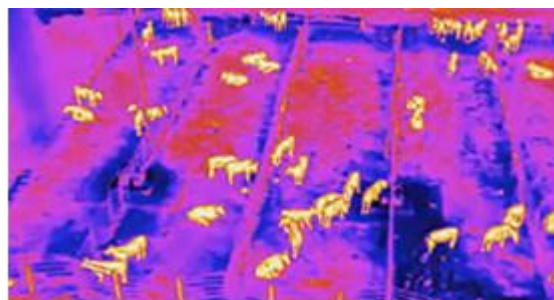


Fig. 4 Drones could apply thermal imaging to identify sick livestock in feedlots [7]

Mobile robots

Humanoid robots, in their design and functions, are similar in appearance to ordinary humans. They should also behave like humans and have similar means of communication to humans. The pace of robotics development is rapid, and individual countries often encourage this development because of its potential to bring economic benefits to the country. For example, the workforce in Japan is declining significantly, seriously threatening Japan's economy, and it is robots that are seen as the current solution. In addition to using robots to produce goods, the aim is to use robots as cleaners, sales assistants, museum guides, carers for the young and old, presenters of TV programmes, and they could also work as teachers. (Newton a Newton, 2019). Hanson Robotics has created one of the most human-like humanoid robots in existence today. This humanoid robot is named "Sofia" (shown in Fig. 5a).



Fig. 5 a) Sofia - humanoid robot [8] b) Spot - the agile mobile robot [9]

Sofia is the world's first robot citizen, and the first Robot Innovation Ambassador for the United Nations Development Programme. Sofia currently speaks at hundreds of conferences (as well as on various TV shows). Its artificial intelligence combines work from the fields of neural networks, expert systems, machine perception, natural language processing, motor control, and cognitive architecture. Sofia is able to recognise human faces, see emotional expressions and also recognise different hand gestures. It can also estimate the feelings of the people with whom it communicates (directly during the conversation) and tries to find a way to achieve certain goals of communication with the communicating people. It has its own emotions that roughly simulate human evolutionary psychology. [8]

Spot is a mobile robot that can handle terrain with great agility, allowing to automate regular inspection chores and data collection in a safe, accurate, and timely manner. The spot has an implemented thermal camera, through which it senses the image in its surroundings. The sensed image is processed by computer vision models. [9]

Object detection on the shoes

Object detection has received a lot of research attention in recent years because of its tight association with video analysis and picture interpretation. Handcrafted features and shallow trainable structures are the foundations of traditional object identification systems. By generating sophisticated ensembles that incorporate various low-level picture features with high-level information from object detectors and scene classifiers, their performance can quickly plateau. With the rapid advancement of deep learning, more powerful tools that can learn semantic, high-level, deeper features are being offered to address the issues that older systems have. [10]

Fig. 6 shows the training of the convolutional neural network where we wanted to detect different parts of the shoe - shoe uppers ("Zvrsok"), quilting shoes ("Presivanie") and the sole of the shoe ("Podrazka").

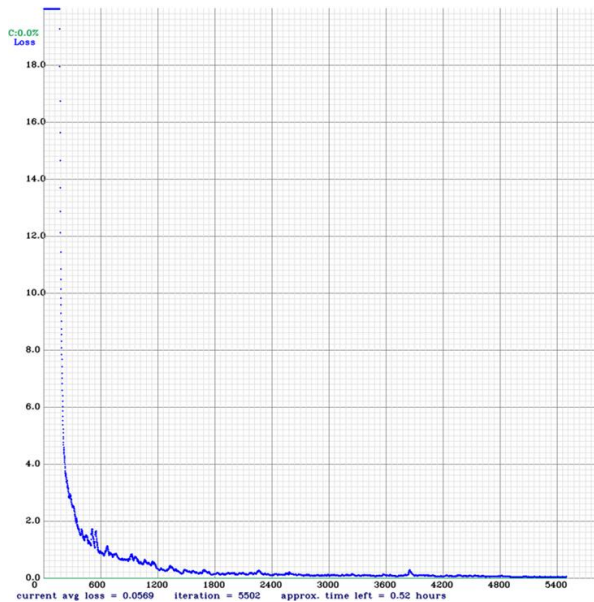


Fig. 6 Training of the convolutional neural network

Training was terminated at 5502 iterations, where the current avg loss reached 0.0569. The trained model was applied to a particular photo where we obtained good results - the neural network model detected all three objects on the shoe (Fig. 7).

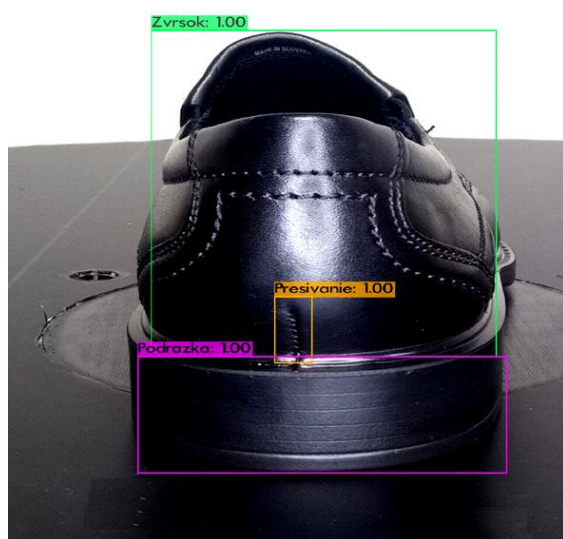


Fig. 7 Object detection on the shoe

3. Descriptive, predictive, and prescriptive analytics

Data analysis is a very important process in the terms of Industry 4.0. Availability of collected data allows the experts to have a better understanding and deeper look at the technological processes and the inner dependencies of multiple parameters.

Descriptive analytics is a preliminary stage of signal processing. This kind of analytics gives a better understanding of what has happened in the past. Descriptive analytics is using data aggregation and data mining [11]. This can be very helpful in the areas of signal detection [12] and cluster analysis [13].

Predictive analytics is an area of forecasting the trends of certain parameters. The main goal of this sphere is to get a better knowledge of what will happen in the future. This knowledge can be very helpful in the area of predictive maintenance and cost-saving in shortening the downtimes of industrial machines. Predictive analytics has an invaluable role in informing the decisions of the maintenance department of the company [14].

Prescriptive analytics is mainly dedicated to finding the best course of action for a given situation and it should be able to suggest decision options for how to take advantage of a future opportunity. This kind of analytics improves the accuracy of all predictions and provides better decision options [14].

4. Evaluation of quality based on the technological processes parameters

If we assume that the error or fault can occur during the production processes of the individual parts of the shoes (for example the shoe sole), it is possible to create a model in which the quantities that may have the greatest impact on the defect could enter the input of the model and thus the model can learn the individual dependencies of the technological processes. Such a model can work alone or together with a model that evaluates the resulting quality of the shoes based on the images. To increase the accuracy of the model it is possible to include in the model input not only the data captured by the camera but also the aggregated technological quantities from specific operations.

As shown in the fig. below, these can be variables such as speed, viscosity, temperature, pressure, or other variables. Each of these mentioned parameters should have some influence on the final quality of the product, so the AI model will be able to abstract the hidden dependencies during the process of training.

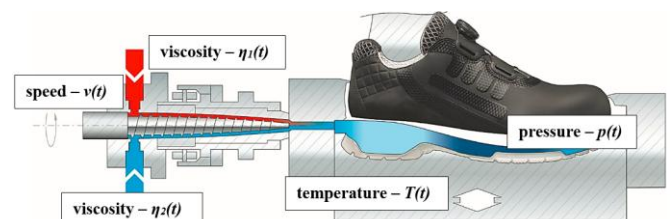


Fig. 8 Technological parameters which may affect the quality of the shoes. [source: findsourcing.com, edited]

5. Aggregation of the incoming data from the technological processes

The goal of the aggregation is to reduce time-series data and prepare the historical data for working with the models of artificial neural networks. Data can be aggregated in several ways. From the time series data of a given quantity (for example the speed), it is possible to calculate the standard deviation, minimum, maximum, or other statistical metrics [15]. The principle of aggregation is given and explained in the figure below.

The resampling periods in this case are belonging to the times when the individual shoes were produced. There needs to be an ID

parameter for each individual shoe that will be used as a parameter on which the aggregation will be done.

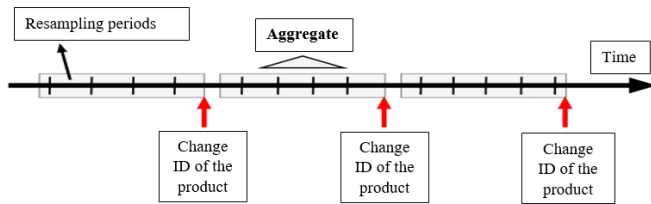


Fig. 9 Aggregation principle of time series data.

The proposed models of artificial neural networks will work with the aggregated data at the input and at the output of the model will be calculated or predicted whether the given input data belong to erroneous or defect-less shoes. If the error probability will be labeled as *qualityError*, we can say that the proposed model would estimate the defects that occurred based on the aggregated technological variables. The mathematical formulation of such a problem would look like in the equation given below:

$$\text{qualityError} = f(\text{std}(\text{speed}), \min(\text{speed}), \max(\text{speed}), \text{avg}(\text{speed}), \text{std}(\text{viscosity}), \dots, \text{avg}(\text{pressure}))$$

This disadvantage is that a numeric identifier is required, on the basis of which the data are aggregated - shoe ID. It is also necessary to have access to the database, in which all necessary time-series data are stored. In order to be able to create a training data set, it is necessary that information is stored during data collection as to whether a given shoe with a specific ID was faulty or error-free.

6. Used mathematical models of simple feed-forward and recurrent neural networks

When working with aggregated data, it is possible to use deep forward neural networks [16] of different sizes. Models may be over-trained on the current data due to insufficient accuracy, or their structure and size may change arbitrarily. In addition to feed-forward neural networks, we can also work with recurrent models. The difference between them is shown in the figure below.

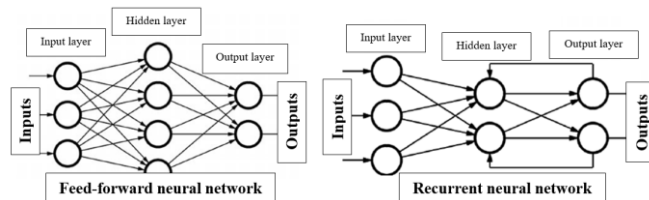


Fig. 10 Simple feed-forward neural networks and simple recurrent neural network. [source: deepai.org, edited]

In addition to predicting whether the shoe will be in the wrong or flawless group, we can also predict the development of individual quantities. We use recurrent Nonlinear Autoregressive Neural networks (NAR) or Nonlinear Autoregressive Neural Networks with Exogenous Input (NARX) [16] for such prediction. Results of such time-series prediction by using a MATLAB model is given in the figure below.

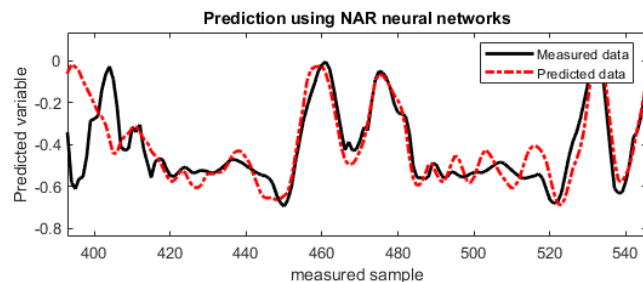


Fig. 11 Time-series prediction by using the NAR neural networks.

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A system for classification of human facial and body emotions based on deep learning neural networks

Atanas Atanasov, Fani Tomova, Dimitar Pilev

Department of Informatics, University of Chemical Technology and Metallurgy, Sofia,
naso@uctm.edu; tomova@uctm.edu; ; pillev@uctm.edu

Abstract: Current paper presents development of system intended to classify human facial and body emotions. It is based on two deep learning neural networks (DNN): - first one used for facial emotion recognition (FER) and second one for body gesture emotion recognition (BER). Combination of the results obtained by the two modalities (facial expression data and body gestures language data) provides more accurate results instead of these obtained using only one modality. After brief analysis of the available pre-trained DNN and datasets for facial and body emotions recognition, based on previous authors' developments, the selection of two DNN models has been done. They are used in the development and verification of present system.

Keywords: FACIAL EMOTIONS RECOGNITION, BODY GESTURES RECOGNITION, DEEP LEARNING, CNN, PRE-TRAINED MODELS

1. Introduction

The emotions are one of the main non-verbal ways used by people to present their attitude to other people, subjects, products, services, computers, robots virtual reality, etc. Main modalities of emotions are human voice, facial expressions, body gestures and postures. Other physical sources (modalities) of emotions are body temperature, blood pressure and heart rate, brain activities, etc. For facial and body gestures emotion recognition, systems based on deep learning convolutional neural networks (DNN) are used. It is proved [1] that unimodal systems have less accuracy of recognized emotions than bimodal or multimodal systems. In this study, we present a bimodal system based on facial emotion recognition and body gestures recognition, based on our papers [2,3]

1.1 Facial Emotions

People show specific emotions and their nuances using various facial expressions involving the eyes, eyelids, eyebrows, lips, nose, chin, etc. The basic emotions are happy, surprise, sadness, anger and fear, disgust, as well as neutral. Ekman and Friesen [4, 5] proposed in 1978 and 2002 a system for coding facial emotions. They named it Facial Action Coding System (FACS). The system classifies the facial expressions on the base of elementary components called Action Units (AUs). Each AU has a number (from AU1 to AU35) related to one or group of the facial muscles. For instance, the emotion Anger given on Fig. 1 is presented with (AU4) brow lowerer, (AU5) Upper lid raiser, (AU7) lid tightener and (AU23) lip tightener.



Fig. 1 Emotion Anger combines AU4, 5, 7 and AU23

1.2 Body Emotions

After the facial emotions, the body gestures, also known as body language, are one of the strongest non-verbal sources of emotions. The body language is related to the position of the head, positions of the arms, hands and fingers, and positions of the legs, as well as the position of the torso. For example, the body gestures corresponding to the emotion surprise [6] given on Fig. 2. are related to one of following combinations: right/left or both hands moving toward the head; moving the right/left hand up; two hands touching the head, face or mouth; both hands over the head; right/left hand touching the face/mouth; self-touch/two hands

covering the cheeks; self-touch/two hands covering the mouth; head shake; body shift/backing.



Fig. 2 Body emotion Surprise

1.3. Analysis of emotions

Through the analysis of facial and body emotions, the behavior of people can be predicted and recommendations or suggestions for the use of services and products can be generated. The analysis of the emotions can be used in human-machine and machine-human interfaces, as well in medicine, police, market of different products or services, etc. For example, in medicine to detect depressive states which increased during the Covid pandemic or to detect different illnesses; In police practice whether a suspect is lying or not; In autonomous cars to propose appropriate routes, avoiding heavy traffic in case the driver is nervous; In market products - what is the consumer's attitude to a product; In computer game industry - to adapt the level of music in some scenes in order to create more adequate virtual reality; In universities to personalize the lecture material on the base of students' emotion during their online training.

2. Recognition of facial and body emotions

2.1. Facial emotions recognition

Facial emotions recognition (FER) is a part of the process of facial image recognition. Convolutional neural networks known as Deep neural networks (DNN) are applied for FER. Initially, these networks trained with large number of photos of human faces (datasets) in order to recognize (classify) faces. For example some datasets include several thousand pictures of the faces of different persons, other datasets include several millions pictures. Pictures in the datasets are labeled with information about the presented face/person. Usually, one dataset contains training, testing and validation subsets of pictures. After training phase, the DNN are checked with testing subset of images in order to estimate their accuracy to recognize cer. Next, the trained DNN can be applied for verification/prediction of emotions of not labeled pictures. In order to recognize facial emotions DNN additionally are trained with specific FER datasets as FER-2013, CK+ RaFD, KAD, MUG, etc., commented in [2]. The whole FER process or pipeline includes

following steps: face detection and cropping, preprocessing of cropped image, deep feature learning and deep classification [7-10], explained in details in [2].



Fig. 3 Typical architecture of CNN for FER

Usually, every DNN for FER “Fig. 3.” contains groups of convolution, activation and pooling layers (CONV, RELU and POOL) used for feature learning and at the end of network there is one or more fully connected layers (FC) intended to seven basic emotions classification.

2.2. Body gestures emotion recognition

The process of body gestures emotion recognition (BER) is similar to facial emotion recognition and uses similar DNNs. First step of the process is person or human detection in the picture and extraction of potential region of interest (ROI). Second step is body pose detection. There are two main types' models of pose detection: - parts based models and kinematic models. In parts based models the body presents itself as flexible configuration of different parts (Fig. 4 left) part. In this case, each part of the body can be detected and examined independently of the others [11]. In kinematic models, the human body is represented by defining a collection of interconnected joints that it simulates a simplified human skeleton. Next step is body features extraction. For this purpose, the DNN trained with EMOTIC, FADO, ImageNet or other datasets and after that used for classifications. The body gestures emotion recognition DNNs contain similar convolutional groups as DNN for FER. At the end of BER DNN the fully connected layer is responsible for the body emotion classification. Some of the body gestures emotion recognition systems are using two DNN models: - one for body emotion classification and second for image scene or image background classification. The output of first DNN provides 26 discrete emotions and the output the second DNN is related to 3 continuous emotion dimensions VAD model (Valence, Arousal and Dominance) [15] proposed by Russel in 2003. The valence categorizes emotions as positive or negative. The arousal categorizes them as neutral, passive and active and the dominance as neutral, low dominance, and high dominance. On "Fig. 4 – right part" the known emotions are presented in 3D VAD model.

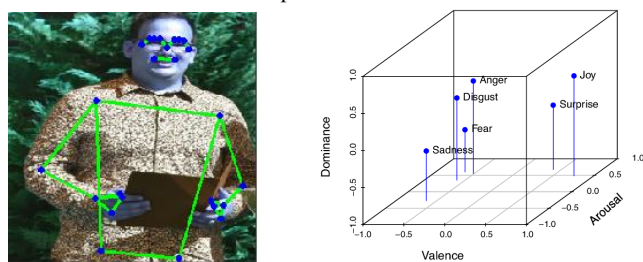


Fig. 4. Part based model

The usage of second model improves the accuracy of emotions prediction because many authors and scientists state that there is strong correlation between facial and body emotions and surrounding scene. Body emotions recognized by the BER DNN vary from well-known basic 6 and 7 (with neutral) emotions to up to 26 (affection, anger, annoyance, anticipation, aversion, confidence, disapproval, disconnection, disquietment, doubt/confusion, embarrassment, engagement, esteem, excitement, fatigue, fear, happiness, pain, peace, pleasure, sadness, sensitivity, suffering, surprise, sympathy, yearning).

2.3. FER and BER Datasets

There are many FER and BER datasets with various number of facial emotion and body gestures images or sequences of images taken in different positions, with different size and scene

background. Only few of them used to train the DNNs in our system are presented below.

Dataset FER-2013 contains 35887 BW images with 7 labeled emotions. Images with size 48x48 are split in 3 subsets for training, testing and validation.

Extended Cohn-Kanade dataset (CK+) includes 327 video sequences with BW 640x490 pixels images of 118 people with 7 labeled emotions based of FACS.

The EMOTIC dataset [16] contains 23571 labeled images of people with different emotions in diverse environments in various places. Emotions classified in 26 categories according to the 3D VAD model.

The Bimodal Face and Body Gesture Database (FABO) database [16] contains around 1900 gesture video sequences split in 10 emotion categories. All emotions are labeled according FACS and VAD.

3. Selection of DNN for FER and BER

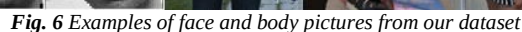
The selection of DNN models for facial emotion recognition has been done in paper [2] presented on ICAI 2020 conference. In this paper after the detailed analysis of pre-trained deep learning networks for FER two models described below are selected. Analyzed DNNs included models as VGG16, VGG19, VGG-Face, Google FaceNet, OpenFace, Facebook DeepFace DeepID and some authors' developments. The selection of second DNN model for body gestures recognition was discussed in the paper [3] and is presented on ICAI 2021 conference. It is described below, as well. The analyzed in second paper models [15-17] were based on ResNet18, ResNet50 and similar to them DNN architectures which differ from each other by different numbers of the convolutional groups, different type of POOL layers based on max or average pooling.

First pre-trained DNN model for FER that we selected is architecturally based on VGG. It has 5 groups of convolutional layers with batch normalization layers between internal convolutional layers. Each group ends with max-pooling and dropout layer. The number of convolutional layers in first group is 2, in second group is 3 and in the last three groups is 4. Input layer provides BW images with size 48x48 pixels and last two layers are fully connected and their output is 7 basic emotions. The number of weights of this model is more than 13 million. Second model was DeepFace framework [7] based on ensemble of 5 pre-trained models (VGG-Face, Facenet, OpenFace, DeepFace, DeepIdI). From the source code of this model we succeed to extract the pre-trained CNN model and features intended only for FER. The architecture of this model has 3 convolutional groups with 5 convolutional layers. First group is simple only one convolutional layer followed by max-pooling layer. Next two groups have 2 convolutional layers followed by one average-pooling layers. Input layer provides BW images with size 48x48 pixels. Output layers are 4 fully connected layers with 2 dropout layers in between. Last output layer returns as result 7 emotions. This model is simpler than first one and the number of its weight parameters is 1.485000. Both models are trained and verified using the FER-2013 dataset. The accuracy of first model is almost 70% and for the second model is 57%. An additional verification of the considered models was made with CK+ dataset. The accuracy of both models is 56%. We selected first model to be used in our bimodal system because it has great accuracy then the second.

Selected pre-trained DNN model for body gesture emotion recognition is based on adapted version of ResNet18 [17], predecessor of ResNet 50. It contains one input layer providing 112x112 pixel RGB images, 21 convolutional groups composed of 2D CONV layer with Batch normalization and ReLU layers. Last layer is Adaptive Average Pooling. Only the first convolutional group includes at the end additional Max pooling layer. The output of the FC layer are 26 emotions and 3 continuous VAD dimensions. The model weight parameters are 11363757. It trained with EMOTIC dataset and produces similar accuracy results as the other model discussed above (trained with the same EMOTIC dataset).



The verification of models is done with our dataset with more than 1000 photos (Fig. 5.), during scientific forums at the university (UCTM) in the last two years with the participation of students and PhD students. Initially, the dataset included collection of 500 photos only of their faces. Now we extended it with 500 photos of the entire body.



Next figures (Fig. 7. to 14.) show the results in recognizing different emotions provided by the system during of the tests. The figures are grouped in two for each of the emotions. The left part of the first figure is the full-length photo of the particular person. On the right are the recognized parts of his body, and below the figure are the recognized emotions (different number for each person), as well as the VAD values. The second figure shows the results of the recognition of facial emotions, with the face given on the right and the recognized emotions in percentages on the left.

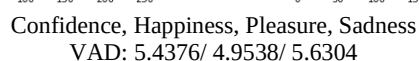
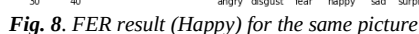


Fig. 7. BER results (4 emotions and VAD values)



Ager, Annoyance, Disquietment, Doubt/Confusion, Fatigue, Fear,
Pain, Sadness, Suffering, Surprise
VAD: 4.4233/ 4.6540/ 5.4249

Fig.10. FER results (5 emotions) for the same picture

Anger, Annoyance, Aversion, Disapproval, Disconnection, Fatigue,
Fear, Pain, Sadness, Suffering S
VAD: 3.7680/ 4.7523/ 4.3812

Fig. 12. FER results (1 emotion) for the same picture

Anger, Annoyance, Aversion, Disapproval, Disconnection, Pain
Sadness, Suffering, Surprise
VAD: 5.6271/ 4.549/ 6.3979

Fig. 12. BER results (9 emotions and VAD values)

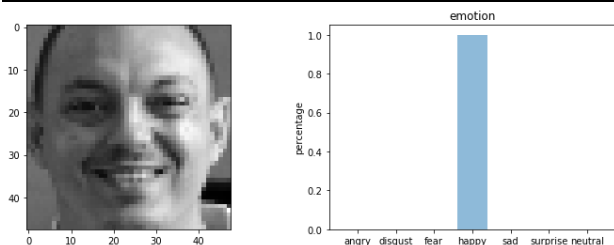


Fig. 13. FER results (Happy) for the same picture

In this case there is no correspondence between the result produced of both models. This can be seen from the position of arms in the other figures (Fig. 7 and Fig. 9). In this case we accept the result of FER classificationj (Happy) as a final.

5. Conclusions

In this study, a brief introduction of human emotions has been done, and especially how the recognized facial and body emotions can be used in different areas. The processes of automated facial and body emotion recognition based on deep learning DNN models for FER and BER are presented. The study is oriented towards the selection of suitable pre-trained DNN models, which can be used to build current bimodal system. Combining the FER and BER DNN models, we have created a hybrid bimodal system that can be used for a variety of purposes, one of which is to improve students' personalized learning based on recognizing their positive, neutral, or negative facial and body emotions. Therefore, our future work will be focused on revealing neutral and negative emotions in order to adapt the teaching material and increase the performance of students, as well to assist teachers in the presentation of teaching material by changing the pace of teaching.

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An Approach of Development Digital Twin Based on CMM as Support Industry 4.0

Slavenko Stojadinovic^{1,*}, Vidosav Majstorovic¹, Srdjan Zivkovic², Vidoje Kasalica¹, Dusan Stanic¹

University of Belgrade, Faculty of Mechanical Engineering, Production Engineering Department, Kraljice Marije 16, 11120 Belgrade, Serbia¹

Military Technical Institute, Coordinate Metrology Lab, Belgrade, Serbia²

sstojadinovic@mas.bg.ac.rs

Abstract: The digital twin (DT) based on CMM as support Industry 4.0, are based on integration of digital product metrology information through metrological identification, application artificial intelligence techniques and generation of global/local inspection plan for coordinate measuring machine (CMM). DT based on CMM has an extremely expressed requirement for digitalization, control, and monitoring of the measurement processes inside Industry 4.0 concept. This paper presents an approach of development DT as one direction information flow based on four levels: (i) mathematical model of the measuring sensor path; (ii) tolerances and geometry of the parts by applying an ontological knowledge base; (iii) the application of AI techniques such as Ants Colony Optimization (ACO) and Genetic Algorithm (GA) to optimize the measurement path, part number of part setup and configuration of the measuring probes; (iv) simulation of measurement path. After simulation of the measurement path and visual checks of collisions, the path sequences are generated in the control data list for appropriate CMM. The experiment was successfully carried out on the example of prismatic part.

Keywords: DIGITAL TWIN, CMM, INDUSTRY 4.0, INSPECTION PLANNING

1. Introduction

Author [1] is one of the first introduced Digital Twin (DT) in 2003, in a course presentation for product lifecycle management (PLM). Also, author [1] incorporated three elements into the model: (i) the physical products of the real world, (ii) their virtual twin and (iii) interfaces that connect the data and information flows from both worlds. The paper [1] define DT as “a set of virtual information constructs that fully describes a potential or actual physical manufactured product from the micro level to the macro geometrical level”. At its optimum, any information that could be obtained from inspecting a physical manufactured product can be obtained from its DT. DT are of two types: Digital Twin Prototype (DTP) and Digital Twin Instance (DTI)” [2]. As a result, physical prototypes can be avoided, and functionality and behavior can be simulated using a model before proceeding into real manufacturing.

The first usage of DT was a year later, by NASA, in Technology Roadmaps [3]. They used it to mirror conditions in space and perform test for flight preparation of their rockets. Since then DT has advanced technologically and expanded its scope of utilization. There is an exponential increase in DT utilization over the last 10 years. Also, increase in potential of DT is expected.

Digital Twins are getting attention because they integrate artificial intelligence (AI), Internet of things (IoT), and machine learning (ML) to bring data, algorithms, and context together, which makes DT a key part of the Industry 4.0 agenda.

Having various definitions has postponed reaching an agreement on a single representative definition of DT. For some members of the community (Schroeder et al. [4], Abramovici et al. [5]) DT is considered as the final product, whereas for others (Rosen et al. [6], Gabor et al. [7]) it is the whole product lifecycle.

Storage of all data in digital format made the implementation of DT conceivable. With arising simulation capabilities, it became possible to perform practical tests in virtual climate. An idea of carrying out a functional DT was embraced by companies like IBM and Siemens.

One of the essential reasons advanced DT technology is quickly being embraced is there are numerous utilization cases across the industrial enterprise: engineering, manufacturing and operations, maintenance and service [8].

Some industries where DT can be highly useful are:

- Industries where developing physical prototypes is costly, time-consuming and resource-intensive (for example manufacturing)- instead of spending time and money building multiple prototypes to test a product, a digital twin is a much more efficient and convenient solution.

- Industries in which exceptional testing is required and such testing is difficult or impossible to perform in laboratories (such as aerospace): The DT can simulate tests that cannot be performed in the lab.
- Industries that require real-time monitoring and prevention plans for dealing with 'emergent behavior' (e.g., health care, supply chain): Keeping an eye on the physical asset's real-time status and being alerted via predictions for an impending problem can be both efficient and effective. This is especially useful for organizations that need to make quick decisions to avoid large losses.
- Industries with multiple parameters that can be optimized cooperatively (such as manufacturing and supply chain): Maintaining and monitoring all sub-components can be a challenging task for very large organizations. Real-time monitoring of all sub-components and collaborative holistic analytics on such large models can be advantageous.

Despite the fact that it is dependent on multiple technologies, which necessitate the use of experts and resources, DT can result in significant cost savings for a one-time investment. DT can shorten design cycles, save money, resources, and time on prototyping, and predict potential hazards in time to mitigate them. This cost reduction could be used as a metric of DT performance for profit-oriented businesses [9].

There are some major areas in which DT has room for improvement:

1. Aspects of Technology: Modular-based DT, Modeling Consistency and Accuracy Enhance DT simulation which allows better monitoring and transparency during processes, VR integration into DT Integration of Cloud/Edge computing and an efficient mapping system between physical and virtual data which reduces uncertainties
2. Aspect of PLM: DT expands into other domains, in other words PLM allows a broader application of DT:
 - Emerging markets (e.g. Construction)
 - Incorporation of smart connected devices into DT
 - Product dependability, security, and privacy throughout the product's lifecycle.
3. Business Aspect: Incorporation of Big Data analytics into DT will provide more insights, resulting in better decision-making support

A modular approach enables the creation of flexible DT, resulting in new application modes while shortening development time [10].

Because of its enormous capacities to realize Industry 4.0, Digital Twin (DT) is attracting ever-increasing attention with the rapid evolution of cyber-physical systems. Businesses in a variety of industries are taking advantage of its capacity to simulate real-time working conditions, forecast and make intelligent decisions, allowing for a quick delivery of a solution to fulfill unique stakeholder demands.

To optimize production performance and maximize profit, digital cooperation is now emphasized with decision-aiding support. The maturity of DT technology reveals its ability to hold a strong position in Industrial 4.0 and manufacturing facility automation, and DT security and privacy concerns are expected to be a key discussion point for future DT [10].

Presented approach for development of DT in this paper refers to already machined PW (Part Work-piece), that is the chain of measurement data retrieved ends with data on measured value generated by software CMM DEA-IOTA-2203 after statistical data processing. The chain of retrieved machine data, the primary goal of this paper, ends by generating DMIS (Dimensional Measurement Interface Standard) code for DEA-IOTA-2203.

The novelty of the research is application into today's trend of industry 4.0 of its production and production metrology. Also, the novelty of the work is that in an efficient and dynamic way it integrates the entire production into one compact whole and thus solves the problem of production costs.

The main contribution of this paper is off-line DT based on DMIS file. The measurement system based on CMM DEA-IOTA-2203 was used as a physical twin, and a virtual machine, generated after modeling and configuring in *PTC Creo* software of both the machine itself and the prismatic parts and fixture clamps, was employed as a digital twin.

Presented approach leaves the possibility of using Web interface and server, because it affords DT simulation and is accessible to participating clients on a cloud platform. On this way, DT allows the activities to be implemented wherever there is an end-client.

2. Metrological Modeling

Metrological modeling generally includes modeling based on metrological features. Metrological features are in fact standard types of tolerances or tolerances defined by the ISO 1101 standard. Depending on the type of tolerance, metrological features may consist of one or more geometric features. In order to metrologically modeling geometric features, they are generally described by a set of parameters [11] whose numerical values uniquely determine each geometric feature.

Metrological modeling can also be based on CAD software. For example, *PTC Creo* software offers a CMM module that can recognize geometric features as metrological and thus perform the distribution of measuring points and form a point-to-point measuring path. This requires prior CAD modeling of the PW and import into the mentioned software module (Figure 1). This method of modeling does not offer the user the ability to enter the new different method of distribution of measuring points.

The application of EO as an object-oriented programming paradigm gives good results. One example of EO implementation in Protégé software is presented in [12]. The main advantage of this AI technique is the classification of knowledge according to the rules of decomposition. The starting point is the standard ISO 1101 and the standard forms of tolerance defined by it, and the end is individual, i.e. special forms of tolerance (for example, parallelism between two defined planes, cylinder etc.).

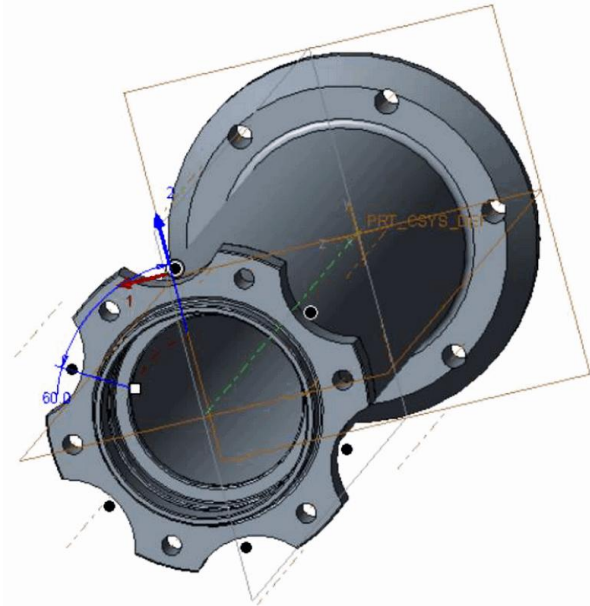


Fig. 1 Modeling in *PTC Creo* software - display of the "Pattern" command in the "Model Taboo" palette

In order to automate the retrieval of feature parameters from e.g. IGES or STL files, this method use the algorithms presented in [11]. By combining CAD software (their output files) and metrological modeling based on geometric features, a hybrid model is obtained that offers the possibility of arbitrary input of measuring point locations. This fact primarily affects to the measurement uncertainty.

3. Optimization and Simulation

3.1 Measuring path optimization

After the distribution of measuring points by geometric features and the generation of the initial measuring path, its optimization follows. It is based on the Ants Colony (AC) technique presented in [13] and methodology presented in [11].

It consists of defining the starting point from which the colony starts and the potential points that the colony visits. In doing so, the weighting factors determine which point has priority in the next iteration of the visit. When touring the points, the colony generates pheromones along the path.

The optimal trajectory is defined by the maximum number of laid pheromones. Compared to the manually programmed path on the CMM and the path generated in the *PTC Creo* software, this optimized path offers savings from 12% to 23%.

In order to complete the DT, it is necessary to conduct an analysis of the setup of PWs and the configuration of measuring probes for each setup. The analysis and then the optimization was carried out in [14]. After the analysis, the optimization of PW setup and configuration of measuring sensors was performed. As a result, it has the optimal number of PW setups and the optimal configuration of the measuring sensors for each setup.

3.2 Measuring path simulation

After optimizing the measurement path from the point of view of visually check the collision and generating an execution file for further post-processing, it is necessary to simulate the measurement path. Depending on the way the path is generated, the simulation is performed in MatLab or *PTC Creo* and PC-DMIS software. The reason for this division lies in the fact that CAD software that integrates CMM inspection does not allow arbitrary input (distribution model) of measuring points.

Simulation in the MatLab environment involves preparation in the form of algorithms or procedures as well as writing code that defines the point-to-point measurement path (Figure 2). The output is three matrices X_{mo} , Y_{mo} and Z_{mo} , which represent the coordinates of the measuring path points along the X, Y and Z axes, respectively. As can be seen, the path is defined for the three axis of CMM. The model can easily include a simulation of more than three axes.

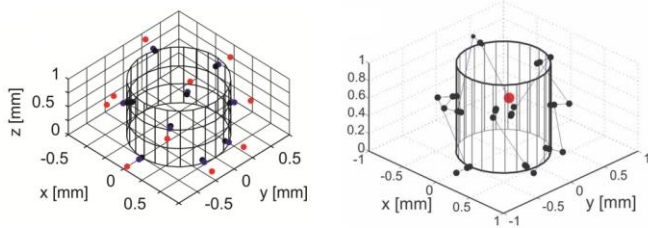


Fig. 2 The distributed measuring points and simulation frames in MatLab software for cylinder inspection

The simulation in PTC Creo environment is based on the already created CAD model measuring system consisting of PW, fixture clamps and CMM. The software offers the option of using its CMM so that the CAD model CMM does not have to be created except in cases of visualization of the existing one. The modeling and simulation procedure is as follows:

- Modeling of the 3D PW;
- Import of the modeled 3D PW into the CMM module (Manufacturing module);
- Setting up the CMM process, includes three processes:
 - Defining CMM workcell;
 - Defining probes or measuring heads;
 - Defining fixtures.
- Setting operations: defined the initial coordinate system of CMM;
- Defining steps of the operations or more specific operations;
- Creating DMIS (.ncl) code and post processing.

In addition to the distributed measuring points by features, in order to create a collision-free path, it is necessary to define node points. In the PTC Creo software as node points use so-called APN points. These points represent collision free points when moving from one feature to another.

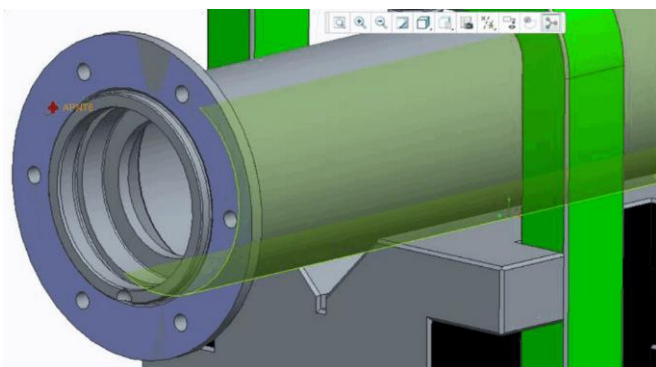


Fig. 3 The selection of "APN" points as the start and end points of the measuring probe

As can be seen from the described simulation procedure, the creation of DMIS (Figure 4) code is the last operation aimed at preparing data for input into the CMM control unit. Probe Path is a command used to display the path of the measuring sensor and generate DMIS code. This code contains information on the movement along the CMM axes, the coordinates of the measuring path points and other necessary information. Specifically, this code was generated for CMM DEA-IOTA 2203. For real measurement on this machine, it was necessary to correct the code and adjust it to the conditions of PW alignment on the CMM table, i.e. determining

the position and orientation of the PW coordinate system in relation to the CMM coordinate system.

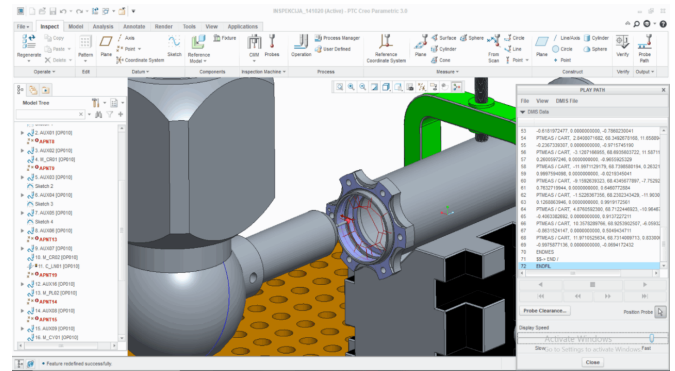


Fig. 4 The defining the measuring path of the cylinder with the written DMIS code

PC-DMIS software enables simulation and real time measurement, i.e. communication with CMM. Also, the software performs statistical data processing based on the acquisition of measuring points and thus generates measurement results. Part of the DMIS code, as well as a graphical representation of the measurement results is given in Figure 5.

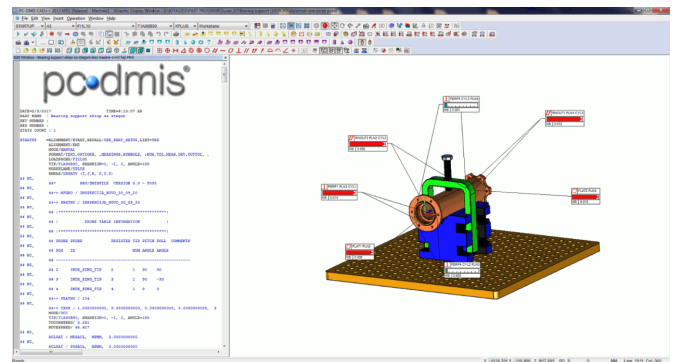
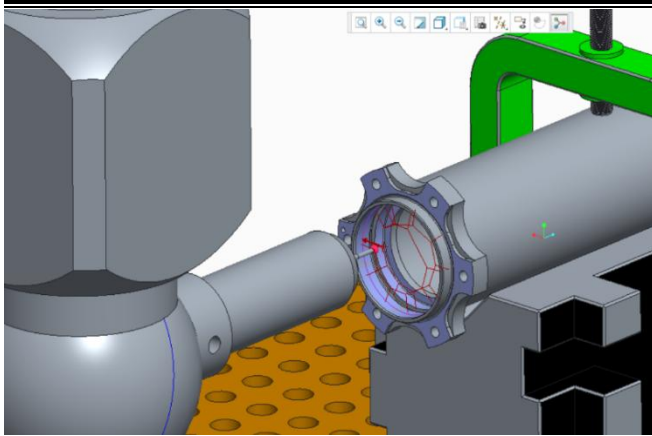


Fig.5 Measurement protocol: a – original code of the program PC-DMIS; b – generated *.ncl code Creo Parametric.

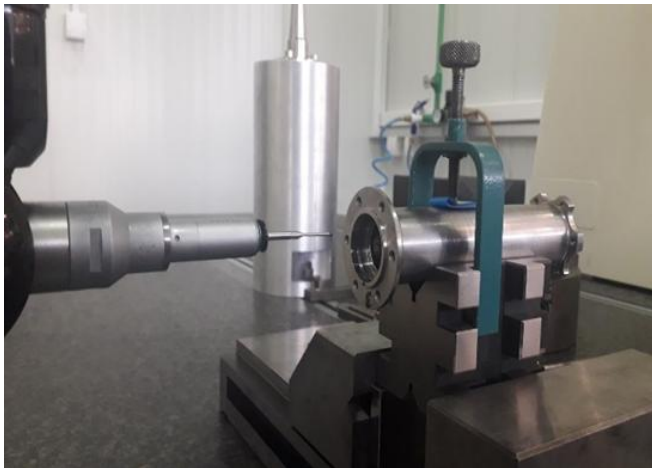
4. Digital Inspection Twin Based on CMM

As it is known DT consists of physical twin and its digital replica virtual twin. In this paper, the DEA-IOTA 2203 machine was used as a physical twin, while the machine model created in PTC Creo and PC-DMIS software was used as a virtual twin. The created DT is shown in Figure 6. Figure 6a) shows the virtual twin in PTC Creo software, while the real process is shown in Figure 6b). It is noted that the developed DT has a one-way flow of information from the virtual to the physical CMM model. As a result, it is impossible to update the data in the opposite direction, i.e. from physical to virtual twin. Given that inspection planning is a one-way process (unrepeatable once completed) this is considered acceptable, and therefore a two-way flow of information within the two basic components of DT is not necessary.

In order to realize DT, it is necessary to harmonize the output-input. The PC-DMIS software allows the import of a .ncl (DMIS) file, previously generated and tested in the PTC Creo software using the standard import → DMIS command block. Previously, a .ncl (DMIS) file was generated in PTC Creo to verify the inspection plan procedure on the virtual CMM. The machine in the functional sense completely coincides with the real measuring machine DEA-IOTA 2203, and on which the plan of inspection of the PW was performed.



a)



b)

Fig. 6 DIT based on CMM: a) PTC Creo measuring path simulation view; b) Display of the assembly of models and clamping accessories on the real CMM DEA-IOTA 2203 [15].

5. Conclusion

The paper presents an approach to the development of DT, whose role is increasingly important today within digital measuring systems. From the aspect of production metrology, the role of the DT is to monitor the measurement process, to improve the quality of processing, accuracy of dimensions and roughness of processed surfaces, and thus to reduce production costs in an efficient and dynamic way.

Research in this paper generates knowledge for the functioning of the process of inspection of measuring parts in modern flexible technological systems and environments, where the need for quality control is extremely important for the production and production metrology as a special scientific discipline.

The result of this paper is a new approach of the conceptual development of the digital inspection twin, based on CMMs - towards off-line DT based on CMM by virtue of the .ncl (DMIS) file. The measurement system based on CMM DEA-IOTA-2203 was used as a physical twin, and a virtual machine, generated after modeling and configuring in PTC Creo software of both the machine itself and the prismatic parts and fixture clamps, was employed as a digital twin. The paper also includes the verification of measurements on a virtual measuring machine and a physical measuring machine with a defined information exchange protocol. The novelty of the research is application into today's trend of industry 4.0 of its production and production metrology. Also, the novelty of the work is that in an efficient, dynamic and automatic way it integrates the entire production into one compact whole and

thus solves the problem of production costs with maximum efficiency.

Besides the to-date developed off-line DT, future research will also include DT development with bi-directional data flow between physical and virtual CMMs. One of the future development directions will be extension of this concept to CMMs of various manufacturers (software). Also, on the basis of proposed methodology, the directions of future research would embrace extension to non-prismatic machine parts and development of digital thread for measurements on a CMM.

6. References

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Low power photovoltaic system implemented by means of flexible module

Svilen Rachev¹, Milena Racheva¹, Lyubomir Dimitrov¹,
Technical University – Gabrovo¹, Republic of Bulgaria
sratchev@mail.com

Abstract: Paper deals with low power photovoltaic system implemented by means of flexible module. Flexible modules powered by sunlight are really a very interesting and promising novelty, being one of the newer alternative energy sources. A selected technical solution with specific characteristics of the individual components is presented. Measurements with digital measuring equipment were performed and experimental results were presented. In conclusion, it is summarized that the tested flexible module gives good results.

Keywords: RENEWABLE ENERGY SOURCES, PHOTOVOLTAIC SYSTEM, ENERGY EFFICIENCY

1. Introduction

Improving energy efficiency in public space was first discussed in the 1970s with the onset of the global oil crisis. In recent years, deepening price problems, fuel shortages and environmental pollution have become an increasingly frequent issue. In addition, public attention is focused on the no less important issue in terms of energy security - high growth rates of the world's population. In May 2021, it numbered nearly 7.8 billion people, and continues to grow rapidly. A number of governmental and non-governmental organizations are taking serious measures to increase the efficiency of energy use and are actively involved in financing projects in this direction. Bulgaria's position as an equal member of the European Union is clearly oriented towards active participation in international efforts to prevent climate change and increase energy efficiency. Bulgarian governments are increasingly accumulating measures and programs related to improving energy efficiency. For this purpose, the Energy Efficiency Act, the Renewable Energy Act, the National Long-Term and Periodic Short-Term Programs on this issue and a number of normative acts were adopted. A good idea in this direction is the Energy Efficiency Program (REECL) established in 2006, which is implemented with the assistance of the European Union and the Energy Efficiency Agency. It provides an opportunity for Bulgaria to reap the benefits of energy efficiency and receive targeted consumer credit and grants through the network of several commercial banks as individuals or legal entities.

The most recently developed direction in the work of research teams is the use of solar energy. Much of the effort is focused on the development and improvement of converters of solar radiation into electricity or heat. Converters of solar energy into electricity are called photovoltaics, and those that convert solar energy into heat are the widespread water and air solar collectors.

Recently, there has been a development in photovoltaic systems for own consumption. In this type of system, solar energy directly supplies the consumers of a household or enterprise, and when it is insufficient, it is added automatically from the electricity grid. This type of system is a great way to optimize costs and reduce electricity bills many times over. It is also possible to use completely autonomous systems not connected to the grid.

Based on the above, the paper focuses on the use of renewable energy sources (RES) and in particular the use of solar energy as the preferred technology for decentralized electricity generation. The aim of the authors is to study a photovoltaic system, which is undoubtedly estimated as a share of RES.

The research thesis defended in the present paper is formulated as follows: the use of RES and in particular solar energy as the preferred technology for decentralized electricity generation, directly correlates with issues of energy efficiency and environmental protection.

2. Some considerations

In November 2009, the Bulgarian government adopted a strategy aimed at turning Bulgaria into a "green paradise". Ecology, alternative energy, organic food, energy-saving technologies that

lead to a significant reduction in energy costs, increase comfort and quality of life are the main highlights of the strategy.

With regard to alternative energy, it is assumed that in 1÷2 decades it will be cheap enough to compete with conventional energy. Then it is logical to wait 1 ÷ 2 decades and then invest in "green" energy. Why should we do it now and increase the price of electricity significantly? Proponents of green energy claim a fixed high electricity purchase price for the next 25 years. That is, all the RES power capacities that will be installed today, to redeem all the energy at a non-market price for the next 25 years. For such investors, this is promising - a guaranteed profit without any risk. But for taxpayers and electricity consumers, this is a guaranteed additional cost for the next 25 years. The cost of electricity from wind, solar and small hydropower plants is higher than from traditional power plants. This cost is calculated in the subscribers' accounts. Thus, in the areas where there are the most renewable power plants, people pay the most for electricity. This, of course, contradicts the Energy Act, which requires all citizens to bear the same weight from alternative energy sources.

In this context, the way in which the final price of electricity for consumers is formed is of interest. In general, the electricity market is divided into a regulated market and a free market. On a regulated market are household and business consumers of medium and low voltage. The final prices of electricity for the regulated market are formed along the production-transmission-distribution-supply chain. The formation of the price of electricity for end users is carried out as follows. Based on the prices of individual producers – thermal power plants, hydro power plants, nuclear power plants, alternative sources, which are paid by the National Electricity Company¹ and which are regulated by the Energy and Water Regulatory Commission², National Electricity Company prepares a single (united) price, also regulated by the Energy and Water Regulatory Commission. A transfer fee and an access fee are added to this price. For its part, the access fee is paid to the Electricity System Operator for maintaining a cold reserve of 1170 kW and for all other services it provides. The transmission fee is also paid to National Electricity Company for the 110 kV high voltage (HV) network, and for the 230 V low voltage (LV) network is paid by the electricity distribution companies. These fees are also regulated by the Energy and Water Regulatory Commission. 20% VAT is charged on the price thus obtained. In this way the accounts of the protected consumers are formed - household customers and small companies with employees up to 50 people and annual turnover up to BGN 20.5 million. Large consumers negotiate electricity at prices and volumes directly from producers and traders. These prices are free.

A novelty in Bulgaria is the opportunity for homeowners in neighboring facilities to be able to cooperate and apply for

¹ The main activity of National Electricity Company is the production and trade of electricity. The company occupies a central place in the Bulgarian electricity system, with an installed capacity of 2737 MW. The company is the largest producer of green electricity in Bulgaria, with production of 31 hydro power plants.

² The Energy and Water Regulatory Commission is an independent specialized state body of the Republic of Bulgaria, a regulator of two sectors: energy and water supply.

European funding for the installation of photovoltaic modules on the roofs. In this way, they will be able to produce electricity to use for their own consumption and reduce their bills. In addition, they will be able to sell electricity. By creating your own photovoltaic power plant, you can significantly reduce your dependence on corporations, as well as achieve protection against rising prices [1]. The idea is enshrined in the National Energy Strategy until 2030 with a horizon of 2050 and in the Green Pact. There are still no such energy cooperatives in Bulgaria for consumers who produce and sell electricity. An online training on 'The potential of Bulgarian municipalities and independent energy communities' is currently underway.

The idea of introducing preferential electricity prices from small photovoltaic plants is to encourage people to invest in those to cover their own consumption, with only the surplus to be sold to energy companies. On the other hand, energy companies warn that photovoltaics installed on abandoned buildings are pumping up the price of electricity that all consumers pay. These are photovoltaic modules, supposedly mounted on roofs for their own needs, but in reality they are placed on toilets, barracks and dilapidated buildings in depopulated settlements. In reality, the energy produced by them is not used for own needs, but is sold directly to the company that connected the installation. And the energy company is obliged to buy electricity at preferential prices from small power plants up to 30 kW. Currently, the purchase price for such power plants is BGN 160.11 per 1 MWh, and for power plants up to 5 kW - BGN 193.33. This is more than the base price set by the Energy and Water Regulatory Commission, which for the period from July 1, 2020 to June 30 2021 was BGN 90 / MWh, and for the period July 1, 2021 to June 30, 2022 was BGN 119 / MWh, which is an increase of 32% [2]. Consumers are loaded after the energy company enters as an expense the funds for the purchase of green energy from these photovoltaics in the price "Debt to society", which in turn affects that of electricity for households.

With the preservation of preferential prices and the mandatory purchase of electricity from power plants up to 30 kW in the last 2 years there is a mass construction of such. 1,300 'roof power plants' under 30 kW have been installed in the country and hundreds of other projects are waiting to be connected, commented the energy companies. Thus, in 2020, 226 photovoltaic power plants up to 30 kW are connected to the network of the electricity distribution company (EDC) in Northeastern Bulgaria 'EDC North', and their total number is currently 339. In Western Bulgaria on the territory of "CEZ Distribution Bulgaria" there are 550 units photovoltaic power plants up to 30 kW with a total installed capacity of 13439 kW. By the beginning of 2021, 405 such power plants have been put into operation in Southeastern Bulgaria on the territory of EVN operator. The total annual amount of electricity produced by these 405 plants is 15015000 kWh, while only 1.26% of this energy is consumed by the sites on whose territory the plants are located. An additional 293 are active (unfinished) procedures for joining EVN operator.

3. Technology and materials

Research and development in the field of photovoltaic conversion of solar energy is aimed mainly at reducing the cost of electricity generated by them. This can be achieved in three ways: by increasing the efficiency of photovoltaic cells; by lowering their price; or by seeking a compromise between these two approaches. In all cases, it is assumed that photovoltaic modules must operate reliably for 20-30 years.

Currently, monocrystalline Si is the most common semiconductor material not only for the production of photovoltaic cells, but also in the entire electronics industry. Its technology continues to develop rapidly, mainly in the direction of obtaining high-quality pure material and lowering its price.

Higher efficiency is obtained from multi-transition photovoltaic cells made of amorphous Si alloys. In this type of photocells,

materials reacting to waves in different regions of the solar spectrum are deposited one on top of the other, ie. of different lengths.

Polycrystalline photovoltaic cells based on CuInGaSe₂ (CIGS) and CdTe have all the advantages of amorphous Si. They have a high absorption coefficient, use very little material and their production can be easily automated. In addition, they have some additional advantages - these materials do not degrade under lighting and are obtained through cheap and affordable technologies.

Flexible photovoltaic modules are also based on CIGS, which allow extremely high light absorption. The CIGS layer is only one micron, absorbing sunlight almost completely (99%). The total thickness of a solar cell is about 30 microns. This makes it thinner than human hair. Thanks to the flexibility factor, CIGS solar modules can be applied to various surfaces, such as curved structures. Flexible modules are unbreakable, much thinner and much lighter than conventional solar panels. An additional advantage of flexible panels over others is their ability to be less affected by high ambient temperatures [3].

The trend towards sustainable energy is observing a significant development in the different types of photovoltaic modules. The effective capture of each ray is on the agenda. The main disadvantages of conventional cells placed on flat roofs or occupying tens of acres of land are their staticity and the resulting low productivity.

Innovative flexible modules are lighter and take far less time to install than common technologies. The advantage is that they do not need to mount frames. With the photosensitive foil can be laminated not only the roofs, but also the dense parts of the facades of buildings. In this way, a lot of unused space can be used.

The products are already available on the market, and the range of applications is constantly being enriched. The characteristics of flexible photovoltaic modules allow them to be used in the automotive industry and in the development of solar-powered land, air and water vehicles. The current goal is to reduce the cost of flexible modules, although their price is competitive with existing standard installations [3].

The standard photovoltaic modules are heavy and hard, the front protective layer over the solar cells is 3-4 mm thick and is made of hardened ultra-light. This standard combination has been tested for more than 70 years and is undoubtedly the best option for the protection of cells from atmospheric influences and protection. The main disadvantage of the classic photovoltaic modules is their solid weight and massive body. They usually require constant constructive fixation and are best suited for domestic and commercial/industrial applications [4].

Flexible modules obviously cannot use glass for protection, and polymers are used instead. The most popular films have always been considered as substitutes for glass, they are lighter and more fragile, but even if it is a chemical choice, polymers cannot compare with glass in one longer period of time. It should be noted that flexible photovoltaic modules, as a whole, have a shorter operating life than traditional modules and many of the low-quality modules have a lifespan of up to 1-2 years [4].

One of the decisive factors in determining the lifespan of flexible photovoltaic modules is the coating material. The two more popular types are PET and ETFE. PET is a polyester plastic, and ETFE is based on fluorescent polymers. ETFE as a material has a very high ratio of sunlight absorption and reflection, thanks to which the module is highly efficient [5]. While PET-laminated flexible photovoltaic modules usually have a lifespan of up to 5 years, ETFE-laminated flexible photovoltaic modules have a lifespan of up to 10 years.

The main feature of flexible photovoltaic modules, in addition to significantly reduced weight (up to 80% lighter than conventional

modules, ease allows installation in places where heavier modules are impossible to install), is the elasticity of the structure [3, 6]. They can usually be mounted without the use of heavy or constructive fixing elements - fastening with glue, bushings or zippers. They are easily transferable and can be transferred to other areas, which makes them great for home or a range of applications such as camping, trucks, buses, caravans, campers, boats and for charging different types, for example canopies of solar garages and vehicles [6]. The thin flexible structure allows their use in non-standard types of surfaces. One of the things that should be noted about flexible photovoltaic modules is that they cannot be torn or blown, but are very vulnerable to sharp objects and breakage [4].

4. Components of low power photovoltaic system with flexible module

Taking into account the market availability, as well as the economic dimensions, warranty conditions and available service network, an autonomous system was assembled. The implemented photovoltaic system, in addition to the flexible photovoltaic module, as a main component, includes several other basic components.

Photovoltaic flexible module ECOFLEX 100 Wp [7]

Specifications:

- Rated power: 100 Wp
- Cells: 36 pcs.
- Efficiency: 17.7 %
- Application: for solar systems with a voltage of 12 V
- Maximum current (I_{mp}): 5.99 A
- Maximum voltage (V_{mp}): 16.7 V
- Open circuit voltage (V_{oc}): 19.7 V
- Short circuit current (I_{sc}): 6.51 A
- Dimensions: 515 x 1225 x 3 mm
- Weight: 3.5 kg



Fig. 1 General view of a photovoltaic flexible module 100 Wp

Controller SOLSUM 6.6X [8]

High-performance charge controller with built-in protection against deep discharge and overvoltage, LED charge status display, temperature-compensated recharge protection via built-in sensor and battery charging according to the linear volt-ampere characteristic.

Specifications:

- modul current: 6 A
- consumption current: 6A
- voltage: 12/24 V



Fig. 2 General view of the controller SOLSUM 6.6X

Sinusoidal inverter MSP 352 [9]

Used if AC consumers are to be powered. The device generates from 12 V DC voltage of the battery 230 V AC voltage with a real sine wave as a local output, turning off at overvoltage or undervoltage. There are overload and short circuit protections. The voltage is precisely controlled by a microprocessor so that there are no sudden fluctuations in voltage and the shape of the curve is as close as possible to the ideal sine wave.

Specifications:

- Input voltage: 11-15 V DC
- Low voltage cut-off: 11 V
- Output voltage: 230 V AC pure sine wave
- Idle current consumption 1.2 A
- Constant output power: 350 W
- Peak output power: 700 W

Rechargeable batteries Panasonic LC-RA1215P [10] – 2 pcs.

Specifications:

- Valve Regulated Lead-Acid (VRLA) Battery
- 12 V, 15 Ah
- Voltage regulation
- Cycle use: 14.5 V~14.9 V (25°C)
- Initial current: less than 6.0 A
- Standby use: 13.6 V~13.8 V (25°C)

5. Experimental results

The experimental setup thus created allows the measurement of technical characteristics, as well as the possibility of processing this data. The measurements have been done in front of Building 2A of the Technical University of Gabrovo, Bulgaria.

Measuring equipment used on June 10, 2021:

- UT-81B – digital multimeter with graphic display - for voltage measurements;
- PeakTech 3440 – graphical multimeter - for current consumed measurements;
- Voltcraft PL-110SM – for solar radiation measurements.

Below are the results of measuring DC consumers with a rated voltage of 12 V DC. The main goal is to obtain information about the current consumed in different cases, which is crucial for the normal operation of the low-power photovoltaic system. The slope of the PV module has been changed and the intensity of the solar radiation on its plane has been measured.

Table 1: Measurement of DC consumer - submersible heater CARE 12 V DC/200 W [11]

φ_{ac}	Global intensity of solar radiation, W/m^2	Intensity of solar radiation on the plane of the PV module, W/m^2	Incline of the PV module	Current through the load I, A
08:52	817	829	80°	4.663
08:58	820	934	60°	4.681
09:04	822	840	40°	4.681
09:10	824	835	20°	4.681
09:16	825	827	10°	4.681

Table 2: Measurement of oscillating (rotating) fan SAYOTA 12 V DC [12]

φ_{ac}	Global intensity of solar radiation, W/m^2	Intensity of solar radiation on the plane of the PV module, W/m^2	Incline of the PV module	Current through the load I, A
09:22	826	840	80°	0.225
09:28	828	845	60°	0.223
09:34	832	851	40°	0.222
09:40	836	847	20°	0.221
09:46	839	842	10°	0.225

Table 3: Measurement of fan with heater UNITEC 12 V DC / 150 W [12]

φ_{ac}	Global intensity of solar radiation, W/m^2	Intensity of solar radiation on the plane of the PV module, W/m^2	Incline of the PV module	Current through the load I, A	
				Without heater	With heater
10:02	840	852	80°	0.120	4.682
10:08	842	857	60°	0.119	4.683
10:14	845	861	40°	0.119	4.683
10:20	847	858	20°	0.118	4.682
10:26	850	853	10°	0.117	4.681

Table 4: Measurement of compressor RAIDER RD-AC08 12 V DC [13]

φ_{ac}	Global intensity of solar radiation, W/m^2	Intensity of solar radiation on the plane of the PV module, W/m^2	Incline of the PV module	Current through the load I, A
10:46	851	865	80°	3.922
10:52	853	869	60°	3.906
10:58	857	873	40°	3.913
11:04	859	870	20°	3.926
11:10	862	865	10°	3.937

Table 5: Measurement of saving lamp SOLSUM ESL 12 V DC/7 W [8]

φ_{ac}	Global intensity of solar radiation, W/m^2	Intensity of solar radiation on the plane of the PV module, W/m^2	Incline of the PV module	Current through the load I, A
11:20	863	887	80°	0.502
11:26	865	891	60°	0.504
11:34	868	894	40°	0.505
11:40	872	883	20°	0.507
11:46	873	878	10°	0.508

Table 6: Measurement of saving lamp SOLSUM ESL 12 V DC/11 W [8]

φ_{ac}	Global intensity of solar radiation, W/m^2	Intensity of solar radiation on the plane of the PV module, W/m^2	Incline of the PV module	Current through the load I, A
11:52	875	889	80°	0.753
11:58	883	891	60°	0.755
12:04	887	898	40°	0.757
12:10	891	897	20°	0.760
12:16	895	896	10°	0.763

The intensity of solar radiation is a major factor in the production of electricity from photovoltaic modules. Different types of electrical consumers were tested - purely active, active-inductive and non-linear loads. It has been found that even at the highest current consumption of 4.682 A (in the case of a UNITEC fan with heater switched-on), the tested flexible photovoltaic module

ECOFLEX 100 Wp (with a maximum current of 5.99 A) can ensure normal operation.

4. Conclusions

In recent years, the idea of using renewable energy sources is gaining popularity and for good reason! Undoubtedly, the energy development of our planet is associated with major challenges arising from population growth, improving living standards, requirements for reducing environmental pollution and reducing resources of organic fuels. To address these challenges in the global energy market, RES are gaining ground as the preferred technology for decentralized electricity generation.

In addition, the absorption of energy resources provided by renewable energy sources is a means to achieve sustainable energy development in a country. The economic pressure from rising liquid fuel prices requires the implementation of measures to develop local energy sources and especially those with negligible environmental impact. Encouraging energy production from renewable energy leads to a reduction in the energy dependence of the national economy. Their use and their integration into the energy system provide a key perspective for the development of the innovative economy of the future.

Taking into account the economic and financial conditions, as well as the opportunities for the absorption of the energy potential of RES, it is absolutely necessary to direct the efforts towards saving electricity produced from conventional energy resources and imported liquid fuels.

In this context, one of the most promising and controversial energy applications of solar resources, as a major representative of RES, in recent years are photovoltaic systems. It is a fact that the dynamic development and growth of the photovoltaic sector in Europe over the last decade has been largely supported by favorable regulations and incentives for RES. As a full member of the European Union, Bulgaria also prioritizes the need for environmentally friendly development and more mass introduction of renewable energy sources. Geographical location and solar radiation are suitable for the implementation of the photovoltaic system and this type of project attracts investor interest in view of the opportunities for free use of energy resources, modular implementation and a wide range of applications.

Currently, solar energy is in a phase of rapid development. New types of modules are being developed, their efficiency factor is being increased, production costs are being reduced. Even today, each of us can become a full participant in the energy market by buying and selling electricity. By creating your own photovoltaic power plant, you can significantly reduce your dependence on corporations, as well as protect yourself from rising prices.

The presented experimental setup in the development proves that photovoltaic systems are an important resource, the rational use of which can become the basis for increasing energy security and independence and energy efficiency. Cloudiness and shading have been shown to be important factors. Clear time is needed to accurately measure solar radiation. Only then is there a maximum approximation of the curve to the theoretical one. But for practical purposes it is necessary to measure in different atmospheric conditions. This gives a real idea of the possibility of using solar energy in a particular place - in this case Gabrovo, Bulgaria. The area has a value of solar radiation of 1291 kWh/m² on a horizontal surface or 1482 kWh/m² on an optimal incline.

The flexible photovoltaic modules, powered by sunlight, are really a very interesting and promising novelty. Big and small, wide and narrow, for more or less power - they all require money to buy. Most likely, such items will fill the market very soon, as there is a general decline in the prices of this product.

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New concepts of severe plastic deformation combined processes

Panin E.A.¹, Naizabekov A.B.², Volokitin A.V.¹, Akhmetova G.E.¹, Volokitina I.E.², Tolkushkin A.O.³

¹Karaganda Industrial University, Temirtau, Kazakhstan;

²Rudny industrial Institute, Rudny, Kazakhstan;

³Ural Federal University named after the First President of Russia B.N. Yeltsin, Ekaterinburg, Russia
e-mail: cooper802@mail.ru

Abstract: On the basis of review of last developed combined metal forming processes the new concepts of severe plastic deformation combined processes aimed at further improving the deformation performance are proposed. The presence in all three proposed variants of the ECAP scheme will allow deforming without significantly changing the initial dimensions of the workpiece.

Keywords: METAL FORMING, SEVERE PLASTIC DEFORMATION, COMBINED PROCESSES, ECAP.

In recent years, the principle of implementing severe plastic deformation (SPD) in metal forming is one of the main ways to improve the properties of processed materials by grinding the structure to an ultrafine-grained state. The most well-known classical SPD method is equal-channel angular pressing [1-3] is discrete by its nature and does not allow the deformation process to be carried out continuously, as well as to process large-length workpieces. Because of these two disadvantages, this method still remains investigated only at the laboratory level.

In order to increase the productivity of the ECAP process, it is necessary to get rid of these technological shortcomings. This is possible if the ECAP is combined with other metal forming processes that allow deforming long blanks and having the possibility of continuous deformation, i.e. with the rolling or drawing process. For this purpose, a number of combined deformation processes have been developed in recent years. These include the following processes: "rolling – ECAP" [4] (Fig. 1, a), "screw rolling – ECAP" [5] (Fig. 1, b), "ECAP – drawing" [6] (Fig. 1, c).

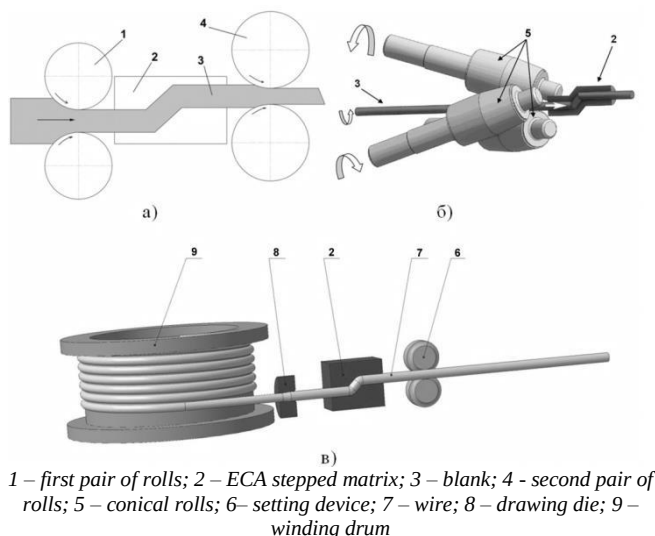


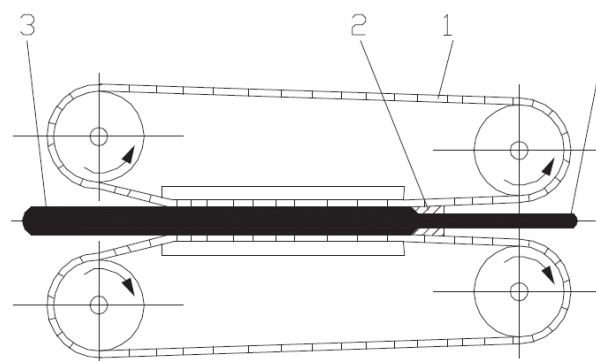
Fig. 1. Schemes of combined processes

When implementing these combined processes, conditions for continuous deformation of unlimited length workpieces are created. Moreover, in the first case, this becomes possible thanks to the rolling rolls installed on both sides of the matrix. The first pair of rolls, due to the contact friction forces, capture the workpiece and push it through the channels of an equal-channel stepped matrix. After the workpiece completely exits the channels of the matrix, it is captured by a second pair of rolls, which also, due to contact friction forces, capture the workpiece and completely pull it out of the matrix. When implementing the combined "screw rolling – ECAP" process, after the workpiece completely leaves the gap of rolls, the next workpiece is fed to them, which, after passing through the rolls and entering the matrix, pushes the previously deformed workpiece out of the matrix.

When implementing the combined process "ECAP – drawing", the pointed end of the wire is set into an equal-channel step matrix,

and then into a calibration fiber, i.e., in essence, the process of metal movement does not differ from the movement of wire in the fiber during the standard drawing process. After the end of the workpiece comes out of the drawing, it is secured with gripping tongs and wound onto the drum of the drawing mill. In this case, the process of stretching the workpiece through an equal-channel step matrix and a calibration fiber is realized by applying a pulling force to the end of the workpiece.

A feature of the Linex method (Figure 2), proposed by specialists of Western Elektrik Co (USA), is that the pressure required for the implementation of the process is created through the use of active friction forces that arise between the flat surfaces of the links of infinite chains and the upper and lower planes of the workpiece having a rectangular cross section [7].



1- drive chains, 2- matrix, 3- workpiece, 4- product
Fig. 2. Scheme of the continuous pressing process by Linex method

At the same time, the value of the pressing pressure turns out to depend on the ratio (difference) of the friction forces on the non-lubricated and lubricated planes of the workpiece. This method is used for the production of aluminum tires and wire at the factories of the company Vencuck (USA).

It is also possible to combine material processing processes in different aggregate states. In this case, the most well-known method is the combined process of casting, rolling and pressing (Fig. 3) [8]. In this process, the metal in the liquid state is fed to the cooled rolling rolls, which act as a crystallizer. Upon contact with the rolls, the metal hardens, is rolled and pressed through the matrix.

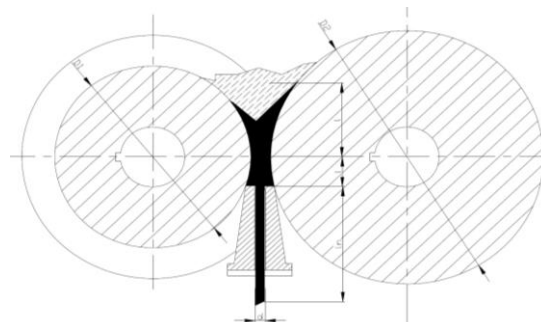
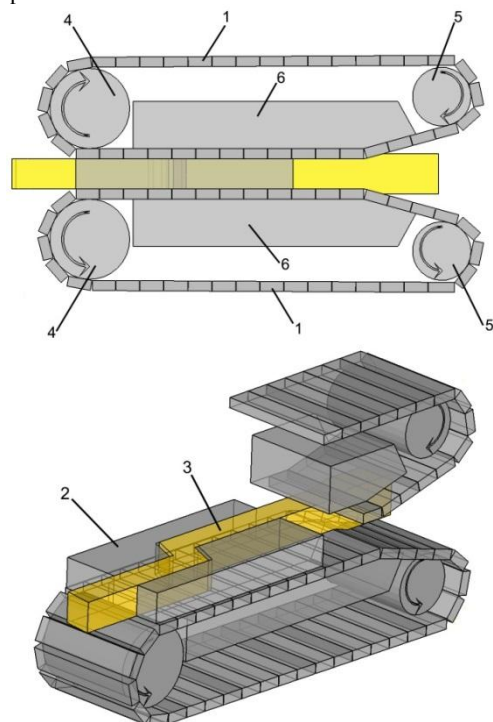


Fig. 3. Combined casting, rolling and pressing process

Based on the analysis of these processes, the following new concepts of combined processes were proposed:

1) combined process "ECAP – Linex" (Fig. 4) for continuous pressing of non-ferrous metals and alloys, the key difference of which from the classical Linex process will be the possibility of deformation without significant change in the initial dimensions of the workpiece.



1 - movable belt blocks, 2 – ECAP matrix, 3 – blank, 4 – idle pulleys, 5 - drive pulleys, 6 - fixed locking blocks
Fig. 4. Combined process "ECAP – Linex"

Deformation in this device is carried out as follows. The heated workpiece is fed to the device, where movable tape blocks grab the workpiece and push it through the channels of the fixed matrix. Each belt gripping block is clad on two pulleys, one of which is idle, and the other is driven by an electric motor. It is due to this that the tape gripping blocks are set in motion. The horizontal forming of the tape gripping blocks is created due to their

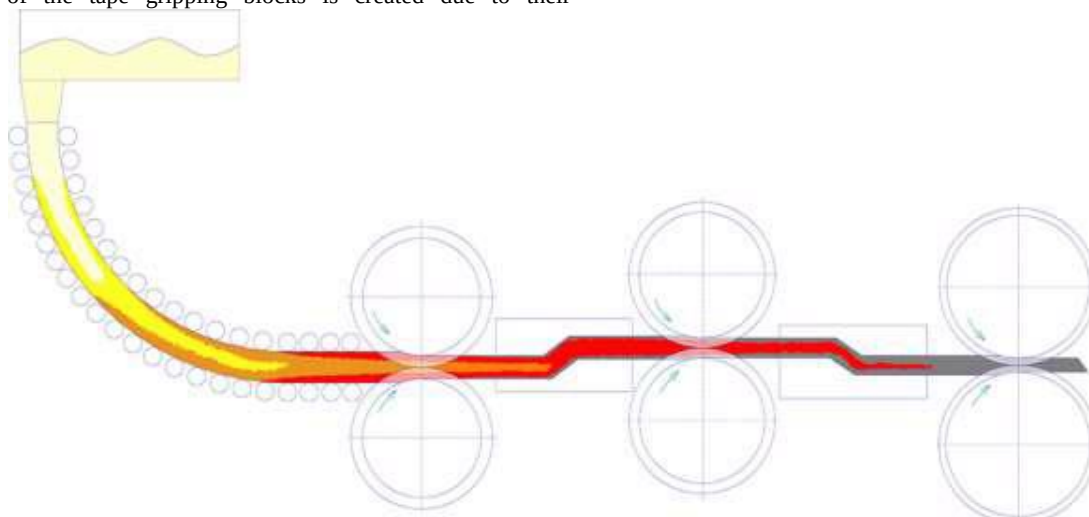


Fig. 6. Scheme of the combined process "casting-rolling-ECAP"

Conclusion

The considered combined deformation processes have significant technological advantages over classical discrete SPD processes. At the same time, they also have certain disadvantages. The proposed new concepts of combined processes of severe plastic deformation are aimed at further improving the deformation performance. And the presence in all three proposed variants of the

movement along the workpiece and fixed locking blocks that perform a clamping role. To reduce the deformation force, grease is applied to the walls of the fixed matrix, while there is no lubricant supply to the moving parts in order to increase the gripping ability.

2) combined process "rolling-ECAP" with combined rolls (Fig. 5). The previously considered rolling- ECAP deformation scheme, despite all its advantages, still has one drawback. With multi-cycle deformation according to this scheme, the workpiece will be compressed several times in height, which as a result will lead to a significant change in the size and shape of the original cross-section, which is often undesirable, and sometimes a negative factor. Therefore, this scheme has been improved by replacing the second pair of horizontal rolls with vertical rolls. Thus, after leaving the matrix, the workpiece will receive compression not in height, as before, but in width. As a result, the change in the shape and size of the cross-section will not be so intense.

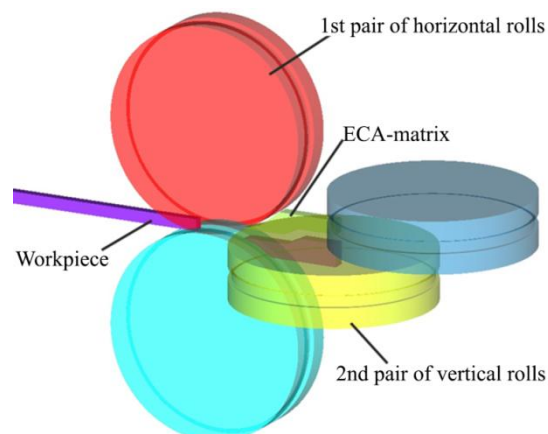


Fig. 5. New scheme of the combined process "rolling-ECAP"

3) combined process "casting-rolling-ECAP". Since the "rolling- ECAP" process itself is quite innovative, it was decided to carry out its further improvement. The proposed process option will include a casting and rolling unit combined with the well-known design of the "rolling- ECAP" process. At the same time, a scheme with two pairs of rolls is possible, as well as with three or more (Fig. 6).

ECAP scheme will allow deforming without significantly changing the initial dimensions of the workpiece.

Acknowledgments

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Reverse engineering in automotive design component

Kender Štefan¹, Brezinová Janette¹
 Technical University of Kosice, Slovakia¹
 stefan.kender@tuke.sk
 janette.brezinova@tuke.sk

Abstract: The paper presents the possibilities of using reverse engineering in the digitization of automotive components and their modification. A CAD model of the part was created based on the scanned point clouds. Subsequently, this model was compared with the original cloud points. The point clouds were scanned by a laser 3D scanner in PolyWorks software. The reference 3D model was created from a point cloud in the CATIA program. The comparison of the scanned point cloud and the reference model is performed in PolyWorks. The Check IMAlign project module is used for this. This module allows you to compare the scanned point cloud, it is merged from several scanned lines into one whole point cloud, which are created by a CAD model. The preparation of the 3D scanning arm FARO PLATINUM ARM and the process of scanning the prototype of the front fender of the car are described.

Keywords: REVERSE ENGINEERING, DIGITIZATION, POINT CLOUD, CAD MODEL, DESIGN COMPONENT

1. Introduction

At present, the process of Reverse Engineering is a very often used term, which refers to the engineering activity of creating objects equivalent to their model, on the basis of which they were created. The basic precondition for the implementation of Reverse Engineering is therefore the existence of an object that needs to be converted into a 3D form. Another important part of this process is the tool for implementing the transfer of a real object into a virtual form. This tool is digitization. With the help of 3D scanners or in other words digitizers, it enables this engineering activity to be carried out. This technology has found its application in many areas, such as industry, healthcare, culture, film and many others.

The paper points out the possibility of using digitization as a support for reverse engineering in modeling a real car component. It offers a description of the procedures for the implementation of digitization and creation of 3D models from the acquired point cloud. The aim is to create a model of the fender of the vehicle identical to the model. The reconstruction of the point cloud into the resulting 3D surface was processed in the Catia V5 software using the surface creation method with the support of a polygonal network. This made it possible to create a continuous enclosed area from which the resulting area model of the car's front fender could be generated.

2. Possibilities of using reverse engineering

The primary goal of the reverse engineering process was to implement the transfer of the real model into digital form. Over time, new applications of reverse engineering have emerged in many other industries, not just the engineering industry. Examples of such applications are research of historical objects, development of computer games and applications or even in the process of quality control in production and the like. The problem with reverse engineering is that, in theory, this technology is widely applicable and there are many possibilities for its application, but in practice it is a little different. The main brake on the use of the reverse engineering process is the price of 3D scanners and specialized software. In both cases, it is in the order of thousands to tens of thousands of euros. [1]

Possibilities of using reverse engineering:

Packaging design - allows you to use the exact areas and textures that were obtained by scanning the necessary samples when solving the packaging design.

Product ergonomics - allows you to use the data obtained by digitizing hand-made models and mock-ups when completing the final product design.

Digital archiving - thanks to the ability to archive tools, samples and prototypes in digital form, it is possible to save

significant financial resources that would otherwise be needed to store these items.

Additional production - enables the production of products that their original manufacturer no longer produces, by obtaining a digital product model.

Spare parts - in the case of a product that is no longer manufactured, no spare parts are produced for it or it is unique, it enables the production of a replacement part by scanning the damaged part.

Digital media, games and animations - reverse engineering can also be used as a means of creating digital characters and scenery for computer games, movies and animations from the concept of an artist / designer model.

Cultural and artistic heritage - allows you to scan a variety of works of art with high resolution and care for the scanned product for the needs of their restaurant or reconstruction.

Healthcare - Reverse engineering helps to create accurate reproductions of organs or bone structures.

Orthopedic engineering - in the process of creating orthopedic aids, the scanned data provide extremely important data, without which the designers would not be able to design the final product exactly tailored to the customer.

Many other uses - significant assistance in product design, CAD model updates, software analysis of real components using various FEM systems, rapid production of models by Rapidprototyping, creation of parts for vehicle tuning and much more. [2, 3]

3. Digitization of an automotive component

The whole process of digitization is always carried out in several consecutive steps:

- In the first step, it is necessary to perform an analysis of the shape of the component that will be scanned. If the part is too complicated, it is good to divide it into several smaller parts and scan them independently.
- Based on the analysis carried out in the first step, the type of 3D scanner is selected, followed by the specific model with which the scanning process itself will be implemented.
- After selecting a suitable 3D scanner, it is necessary to prepare it for calibration (if necessary) and it is also necessary to prepare the scanned part for scanning.
- In the fourth step, the process of scanning or digitizing the component itself follows. This step is quite difficult and any error in this step means that the scan will have to be repeated.

- After a component is scanned, clouds of scanned points, which appear to form areas, are stored in the software that communicates with the scanner. These clouds need to be modified before they can be exported to CAD software. In this step, the so-called scan cleaning and alignment is performed.

- In the next step, the modified point cloud is exported to CAD software, in which its reconstruction will take place. Before the reconstruction itself, it is necessary to adjust the point cloud in CAD software, either by trimming or filtering the number of points. There are several ways to reconstruct scan areas, depending on the complexity of the component.

- After the creation of surfaces and their connection, a comprehensive model is created, with which it is possible to work in various ways [4 - 6].

Scanned component

A component that is the body part of the vehicle was designated for scanning. This is the left front fender of the VW Polo. Specifically, it is a part originating from a model under the group designation 6N2 manufactured from October 1999 to October 2001.

The component that was to be digitized was a bare molding. It was not treated in any way against corrosion, it was not sprayed with paint or any varnish.



Fig. 1 Front fender of the car and FARO Platinum Arm Laser Scan V3 connected to PC

The FARO Platinum Arm Laser Scan V3 scanner was chosen for scanning. This device combines CMM touch scanner technology with a non-contact laser scanning method. The device can operate in seven axes. In terms of dimensions, the device is 1.8 meters high and is therefore the smallest of the offered scanners of this type of the mentioned manufacturer. The laser scanning method was chosen for the needs of digitization of the given component. This is mainly due to the scanning speed, as the laser scanner allows you to obtain up to 19,200 points per second, which would not be possible with a touch screen. Overall, the tactile method is laborious and suitable for measuring rather than scanning objects. The system is connected to a PC via a USB port, where it works with Polyworks software, but it is also compatible with Geomagic or Rapidform software. The manufacturer states the accuracy of laser scanning $\pm 35\mu\text{m}$. At the ideal distance of the scanning head from the body, the system can scan 640 points in one line, which in practice corresponds to approximately eight centimeters wide of the incident beam. The scanner can scan up to 30 images per second. The scanning head weighs a total of 370 grams, which is not a lot of weight, but when shooting larger objects, it still causes considerable physical fatigue.

Scanning process

The scanned object had to be properly prepared and secured against any movement. The entire scanning process took place in collaboration with software designed to support the 3D digitizer. In this case, Polyworks software was used. All points that the system subsequently scanned were simultaneously displayed on the software desktop on the PC screen. On the computer monitor, the scanned points appeared as a uniform surface, but only ostensibly due to their tight arrangement. If the laser head was at a greater

distance than specified, the system could not correctly record the surface points of the object. The digitizer does not always ideally capture images in one line. These disturbances were caused by poor reflection of the laser beam from the surface of the scanned object, or in the case of digitization of complex shapes, where erroneous reflections of the rays also occurred.

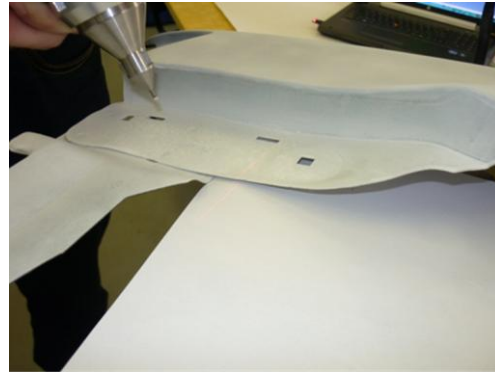


Fig. 2 Scanning component.

The biggest problems were caused by the corners and edges of the fender in question. All these problem areas therefore had to be scanned several times in succession until a sufficient number of points were obtained lying on these surfaces for future reconstruction of the object in CAD software. This fact significantly prolonged the whole process of digitization. After all the necessary points have been scanned, they have been corrected and modified so that they can be exported to an IGS file. Overall, the process from the beginning of the digitization to its completion and the storage of the point cloud took about an hour.

Point cloud adjustment

The point cloud had to be modified in Polyworks software before its export in IGS form. The so-called scan overlap reduction is required. When scanning a component, it was not possible to avoid partial overlapping of individual scans of the object surface. However, these overlapping points were completely unnecessary and rather made it more difficult to work with the overall set. They unnecessarily increased the amount of data that needed to be modified and would make the whole reconstruction difficult. Therefore, it was necessary to eliminate these overlaps using the automatic function. The course of this step can be seen in Figure.3,

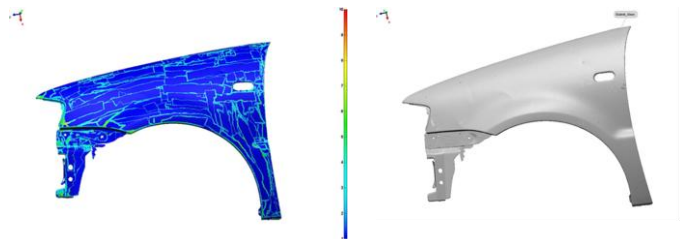


Fig. 3 Scan during overlap reduction and the resulting point cloud.

CAD model creation

Working in Catia V5 software was the last and most time-consuming operation in the process of renovating fender surfaces. At the beginning of the whole operation, it was necessary to open a new product in the Shape module and specifically in the DigitalizedShape Editor.

The entire digitized cloud contained more than two million points. Such a volume and thus also a point density is unnecessary for construction. Therefore, the DigitalizedShape Editor contains a Filter command that reduces the number of scanned points. However, this is not a random filter. The system required determining the size of the radius around each point where no other point should be located. In this way, he was able to reduce

unnecessary information from the scan. P used a dog olomer two millimeters. In practice, this means that the points were at least two millimeters apart. This step reduced the entire scan to 78,398 points. The filtration resulted in 3.33% of the scanned points as a percentage. This may seem like a significant minimization of the scan, but in practice this reduced number of points was enough to reconstruct the surface of the scanned fender.

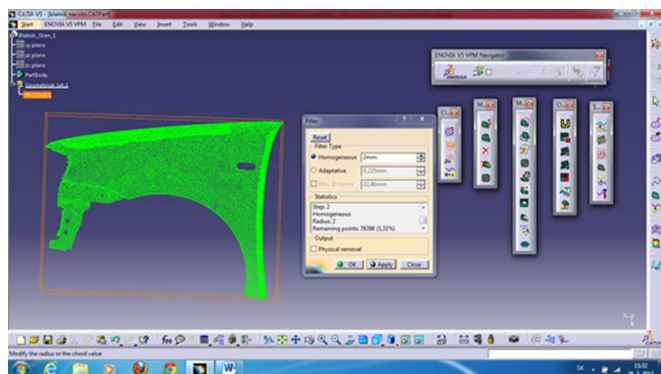


Fig. 4 Point cloud filtering.

The last step before the actual reconstruction of the VW Polo fender was the creation of the so-called polygonal network. This step was performed using the MeshCreation function. When creating the network, the software had to define whether it would be 2D or 3D mesh. It was also necessary to indicate whether the network should be shaded, smoothed, in the form of triangles, and it was very important to define the maximum distance of neighboring points that make up the individual sections of the network. As can be seen in Figure 7, the resulting polygon mesh was in 3D, shaded, smooth, and the maximum distance of adjacent points was 6 millimeters.

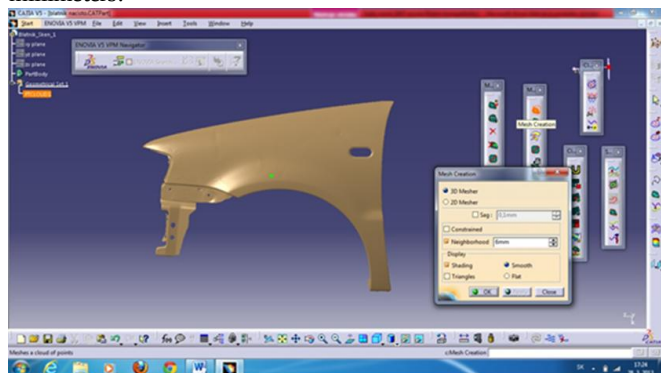


Fig. 5 Polygonal network creation.

After the network was created, several smaller holes were created on the surface of the object. If a larger point distance dimension were used, these holes would not have to be created at all, but the accuracy of the network would be reduced. The software developers also anticipated such a possibility, so it was possible to easily heal these holes using the FillHoles feature. The program required the maximum diameter of the holes to be sealed and subsequently marked them on the software desktop.

4. Reconstruction of surfaces using 3D curves

Reconstruction of surfaces using 3D curves was performed in the Quick Surface Reconstruction module, which is located in the shape directory. After switching to the mentioned module, the first steps of creating the geometry of the object could be performed. On the right side of the desktop, there was a 3D Curve icon between the commands.

Gradually, curves were created between which a reconstructed fender area was to be created. The goal was to create several surfaces on different parts of the object and gradually connect them. It was impossible to create the required surface reconstruction using

only the curves describing the edges of the fender, because such an area would be inaccurate and there would be too much deviation of the modeled surface with respect to the actual surface of the body. Due to the greatest possible accuracy, the gradual creation of partial areas of the scanned fender was started. In the case of the formation of these sub-areas, it was necessary for the individual curves that were to create these areas to form closed geometric shapes. If a situation occurred in which the created geometric shape did not occur, the software was not able to create the described surface. The creation of shapes with four vertices was ideal. In such cases, the software usually created the required areas without any problems. In the case where a break or edge appeared on the polygon network, in most cases there was an attempt to place a curve on it. This is due to the easier connection of individual surfaces using other functions of the Catia V5 software as well as to minimize uneven transitions between individual parts of the fender Fig. 6.

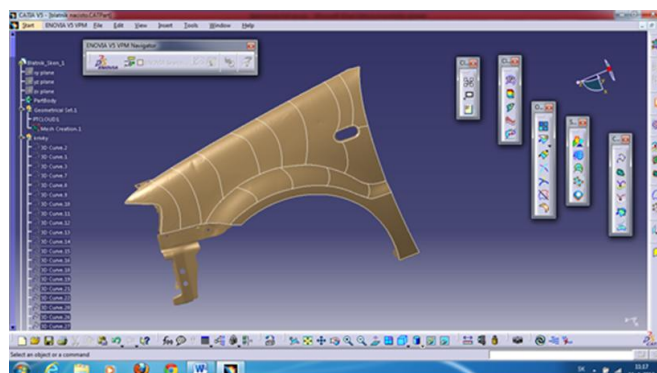


Fig. 6 Polygonal network creation.

After the creation of individual closed geometric figures, the reconstruction of partial areas followed. First of all, a network of 3D curves was created on the front of the fender, ie on the part that is part of the vehicle's exterior design and is visible when looking at the vehicle. Subsequently, the areas from this network were reconstructed. This was followed by the lower part with the handle, the rear part, oriented to the cab with the driver, and finally the upper part, which is clamped to the beam of the vehicle structure. The area between the curves itself is created using the Power Fit function, which is found in the QuickSurfaceReconstruction module of the Catia V5 software. In this function, the surface to be created is defined not only by the boundary curves, but also by the so-called pulling of the surface to the triangulation network. This minimizes the total deviation of the created area from the triangulation network.

After entering all the necessary data and pressing the Apply icon, the created area between the boundary curves was displayed on the software desktop. If a surface was created within the tolerance specified in the Power Fit work window, no warning is displayed in the bottom window. Likewise, the software did not point out any major deviations, and therefore their value. In figure number 40 it is then possible to see this mentioned area, which was created at the beginning of the whole process of reconstruction of the geometry of the object by translating 3D curves.

As soon as all partial areas of the fender were created, the activity of connecting these sections of the scanned object was started. To implement this step, it was necessary to switch to the Generative Shape Design module. After expanding the options located below the Join icon, there was a Healing option that allowed these partially created areas to join. The Healing function also made it possible to join surfaces that had certain gaps between them, which was different from the Join function. After selecting this option, it was first necessary to define the areas that needed to be joined. The program required the marking of at least two areas. However, their maximum number was not limited in any way. After defining the connected sections, it was necessary to determine the connection parameters. These were the continuity of the connection, the distance of the merging and the distance of the objects. In the

case of determining tangential continuity, it was then possible to define the angle of the tangent and the angle of the objects. In the case of this work, continuity through individual points was usually chosen, in other words Point continuity. To ensure the connection, the merging distance was then chosen to be 1 mm, which was the maximum possible value. In the case of object distances, the maximum possible value, ie 0.1 mm, was similarly determined.

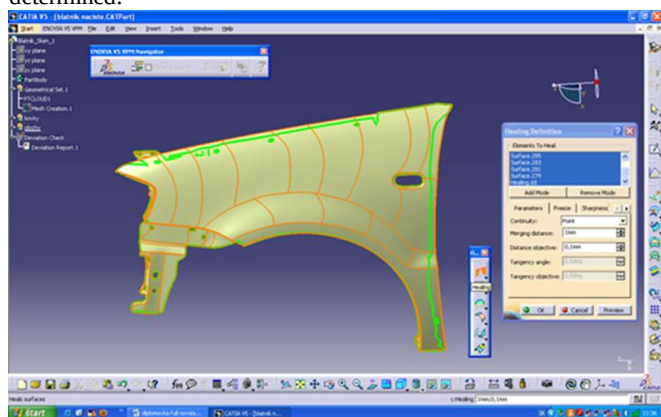


Fig. 7 Joining surfaces using the Healing function.

After creating all the holes and defining the necessary roundings, a finished 3D model of the fender of the VW Polo 6N2 is created. This model was created using the method of translating 3D curves. This model was relatively high, which is represented by Fig. 7. In this figure, it is possible to see the overlap of the polygonal fender network and the 3D model. The more intense the overlap of these elements, the more accurate the model with respect to the polygon network, and thus to the point cloud itself and the real scanning object.

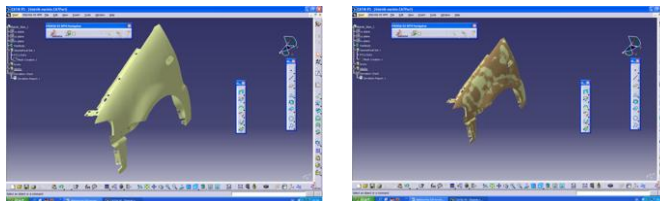


Fig. 8 3D model of the fender and overlapping 3D model and polygonal network.

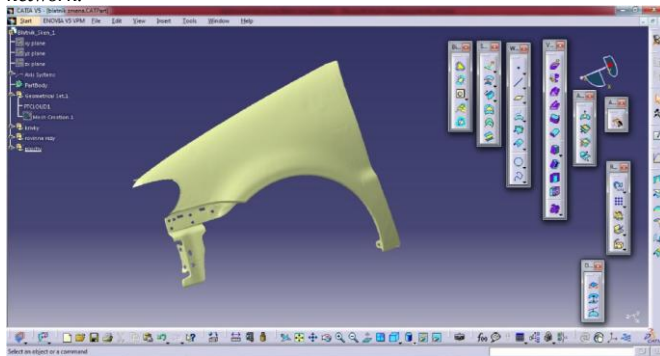


Fig. 9 Final modified 3D model of the fender.

5. Conclusion

Digitization can be used in many ways. This includes, for example, the measurement of deviations, deformations or anomalies, the preservation of historical artifacts and the like. One option may be to use digitization in reverse engineering processes. It can be the creation of a product design or the creation of product innovations. The subject of scanning and reconstruction of the geometry of the shape was the fender of the VW Polo car. Its modification was based on the fact that when creating a facelift of vehicles, the original handles and basic dimensions of the

component are usually retained, only the shape design changes. The change was made in the area of the headlight compartment. A change in the contour copying the shape of the headlight was made, which was replaced by a new type of headlight. Another innovative change that was made was the relocation of the turn signal to the rear-view mirrors. In this case, this turn signal light is no longer in the area of the front fender. This was the subject of a second major change, when the opening for the original turn signal light was removed and the area was filled with the Multy-sections Surface function. Both of these adjustments were made by creating 3D curves, the Extrude function in Generative Schape Design, and then trimming the required areas with the Trim function.

By creating such a modified model, only one of the many applications of digitization in practice was presented. In this particular case, it turned out that with the help of a 3D scanner and suitable software, the designer is able to promptly realize his design visions. That's why 3D scenarios and digitization are an integral part of the vehicle design process today.

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Fintech in the financial services market – opportunities and threats. Case study of Poland

Marek Szczepański
Poznan University of Technology, Poland
marek.szczepanski@put.poznan.pl

Abstract: *Fintech is increasingly important and potentially the most rapid change in financial services sector, changing the way financial services firms operate and transforming debt and equity markets, payments, credit assessment, regulatory compliance, personal finance and many other facets of financial services. The aim of the article is to analyze the impact of Fintech on the financial services market in Poland in the 21st century, with particular emphasis on the banking and insurance sector. The author intends to answer the question whether modern solutions proposed by IT companies in the field of payment processing, data collection and processing in Big Data technology and financial consulting constitute competition, or are complementary to financial services offered by banks and insurance companies, and to identify opportunities and threats for the further development of Fintech in Poland.*

Keywords: FINTECH, FIANCIAL MARKET IN POLAND, DETERMINANTS, OPPORTUNITIES, THREATS.

1. Introduction

Financial Technology (abbreviation: Fintech or FinTech) refers to use of software and digital platforms to deliver automated and improved financial services to consumers (individuals, companies and institutions). Fintech denotes companies or representatives of companies that combine financial services with modern, innovative technologies. As a rule, new participants in the market offer Internet-based and application-oriented products. This new, digital tools are sources of product and process innovations in financial sector, and often challenge and disrupt established business models (for example in banking industry, insurance, mutual investment funds and asset management companies) by creating new and more efficient means of service delivery (multi-channel, digital and mobile access), as well as new, more tailored products.

While innovation in finance is not a new concept, the focus on technological innovations has increased significantly. Fintech solutions that make use of Big Data analytics, artificial intelligence and blockchain technologies are currently introduced at an unprecedented rate. Fintech is increasingly important and potentially the most rapid change in financial services sector, revolutionising the way financial services firms operate and transforming debt and equity markets, payments, credit assessment, regulatory compliance, personal finance and many other facets of financial services.

Fintech is transforming and impacting the financial services industry in many ways – in terms of operations, customer experience, regulations [1]. New ways of communication of the customer with their bank, insurer or other financial institution, additional functions in mobile banking and surprisingly simple payment methods (eg. payments by phone or watch) - these are just some chosen areas of everyday contact between technology customers and products from the Fintech sector [2]. Fintechs have entered a new stage of their evolution: from competitor to trusted partner of traditional financial institutions. Through partnerships with traditional financial institutions, Fintechs can scale their technology and access growth capital, and financial institutions can improve product offerings, increase efficiency, and lower costs. These are all goals with special relevance to low-income customers, who look for products that are more convenient, less expensive, and higher quality.

Fintech companies can be categorized into the following 12 types, based on the services offered:

1. Debt financing: Lending services without the need for collateral and borrower evaluation
2. Transactional services/currency trading: Similar to that of banks but at a lower cost
3. Payment methods: Electronic means of payment
4. Crowdfunding /crowd lending: Raising funds for the purpose of investment
5. Cryptocurrencies and blockchain: Cryptocurrencies as a digital means of exchange as well as the technology they are based on (blockchain)
6. Insurtech: Companies that apply technology to the insurance sector

7. Online customer identification: To identify people remotely through electronic means

8. Big data: Entities that generate added value with the collection and management of data, and intelligent analysis of data (including Artificial Intelligence) and generation of services using this data

9. Financial infrastructure: Improving existing technology for financial service provision

10. Advice and financial management: Investment advisory services, management services or trading platforms

11. Personal financial management: Comparison websites for financial products, and personal finance optimization services

12. Neobanks and challenger banks: Online, fully-digital (branchless) banks using alternate traditional models, e.g. using smartphone apps for account management, or using social networks to establish relationships with clients.

The Fintech sector develops worldwide, but the pace and the direction of this development are different in each country. According to the “Global FinTech Report” of PWC (2019), almost half of all firms in both financial services and technology, media and communications (TMT) have fully incorporated FinTech-based products and services into their strategic operating models [3].

According to the “Pulse of Fintech H2’21 report [4], global fintech investments in 2021 recorded US \$ 210 bn (with 5,684 deals).

It should be noted that in addition to the opportunities related to the development of the Fintech market, there are also new threats, especially related to operational risk (cybercrime, IT system failures, imperfections related to the increasing use of Artificial intelligence (AI) in the area of financial services). A separate, new type of risk are hacker attacks used in military technology (eg Russia's war in Ukraine), but also a serious threat to civil infrastructure, and for the financial services sector and its customers.

In the first part of the article, a review of the literature on development of Fintechs will be presented, as well as the classification of the main segments of the Fintech market in Poland and the main types of operational risk relevant to this market. The second part will present the overview of the Polish Fintech market. In the third part results of research on the opportunities and threats of this market in Poland will be presented and discussed. In final part conclusions will be formulated.

In the research, which results are presented in this paper, the methods of analysis and synthesis, description and explanation as well as the method of critical analysis of the literature were used.

2. Literature review

Fintech issues are of increasing interest to researchers not only in technical sciences, but also in management sciences, economics and even the humanities. There is nothing surprising in this, as the next civilization breakthrough related to the introduction of Industry 4.0 also covers the financial services sector, which has a huge impact on the socio-economic development, as well as on the lifestyle of consumers around the world. The investigation of drivers and barriers of Fintech development requires an interdisciplinary approach. In this short literature review, only selected publications

in the field of management sciences and economics will be considered.

The researchers representing management sciences are interested in the Fintech business models [5-7]. The analysis of the 629 FinTech business model papers in the Web of Science database indicates that currently the most hot-topic in FinTech research are mobile payment, microfinance, peer-to-peer lending platform, and crowdfunding. The research shows that the traditional and new-finance co-exist and cooperate one with another, instead of competing [8-9].

The greatest advantages of the products offered by Fintech sector indicated in the literature [8-9] are:

- reduction of transaction costs (in comparison with traditional banking, insurance or asset management operations),
- enabling real-time settlements (eg. on-line money transfers or payments);
- the possibility of investing in different categories of financial and real assets (commodities, Real Estate, raw materials etc.) via special on-line trading platforms and instruments, available also for individual customers, not only for corporate clients.

Another subject of research is risk management framework for Fintechs. It is important for financial market supervisors (state institutions) to use such a framework to monitor innovative products proposed by Fintechs, and to use advanced supervisory technology (SupTech). Also Fintechs need clear regulations and support to improve their competitiveness. Many authors analyzing Fintech market came to conclusion that there is a need to transform compliance and supervision to develop uniform, market-driven risk management tools, which could help to mitigate the barriers between Fintechs and supervisors. Especially operational risk management is important for the current and future development of Fintech sector. Risk management models and tools are needed, which are relevant for the main three technologies used by Fintechs [10]:

- 1) **Big data analytics**, with its application to peer-to-peer lending, with main risks arising from credit risk, and systemic risk;
- 2) **Artificial intelligence (AI)**, with its application to financial robo-advice, with main risks arising from market risk and compliance risk;
- 3) **Blockchain**, with main application to crypto-assets, with main risks arising from fraud detection, money laundering risk, IT operational risk and cyber risks.

Fintechs which use Artificial Intelligence I are exposed to new types of AI (see table 1).

Table 1. New operational risks triggered by AI

People Risk	Process Risk	IT System Risk
- Risk of loss authority - Risk of loss control - Risk of losing job (substitutes by AI) - Risk of losing skills	- Risk of algorithms (bias) - Risk of algorithms: feedback - Risk of algorithms: abuse	- Erroneous conclusions and/or false positives (IT system) - Risk of cyberattack

Source: [11]

Electronic, automated payments can be used for different purposes - also for money laundering or even terrorist financing. Anti-money laundering (AML) and terrorist financing (TF) in financial institutions are regulated by the Fourth Anti-Money Laundering Directive of European Union (AMLD4). This directive has been implemented in Poland also for Fintech sector. It integrates the AML/CTF (counter terrorist financing) system with the international money laundering (ML) and terrorist financing standards adopted by the Financial Action Task Force (FATF). Poland is a member of the FATF.

Nevertheless, many issues related to dynamic development of Fintech sector in Poland have not been regulated, and Polish

Supervision Financial Authority (Komisja Nadzoru Finansowego, abbreviation: KNF) has not enough legal and IT tools to effectively control this market [15]. The working group of KNF has identified changes in legal environment of Polish Fintech sector (see table 2).

Table 2. Examples of required changes in legal environment of FinTech identified by the KNF working group

Required action	Expected outcome
Require regulation	new instruments for start-up funding
	compulsory publication of rules interpretations for the KNF
	creating a mechanism to review the KNF interpretation
	legal and business advice for new transborder payment services providers
	national framework for crypto assets including taxation;
Regulation change	possibility to dematerialize shares in companies
	clarification of rules for financial instruments digitalization
	possibility to tokenize documents such as cheques,
	bills of exchange, waybills or bills of lading
	allowing for digital document form to substitute written form
	decreasing length of getting a license for payment services process;
	excluding small payment institutions from obligation
Interpretation/practice change	of data processing in computing cloud
	precise interpretation of the term "innovativeness" by the KNF
	provide possibility for new securities creation
	robo-advice – clarification whether there is a need for regulated
	outsourcing requirements for the algorithm provider

Source: [12]

Overview of the Fintech sector in Poland

Poland is the biggest Fintech market in Central and Eastern Europe, with an estimated value of €856 million (the whole estimated value of innovative financial solution in East and Central Europe respectively: €2.2 billion [15]. The number of Fintech companies has been increasing systematically, also during COVID 19 pandemic (see Fig. 1).

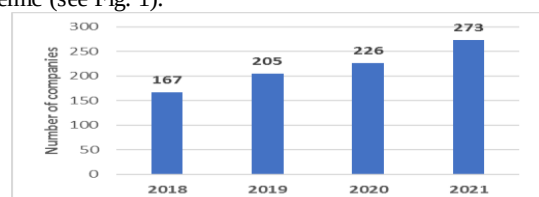


Fig 1. Number of Polish Fintech companies operating in Poland from 2018 to 2021

Source: [13]

The Map of Polish Fintech sector included 273 Fintechs and fintech projects on 2021. Additionally, 39 companies were included in the foreign section, which covers foreign entities providing their modern financial services to Polish clients. In total the Map of Polish Fintech 2021 includes 312 companies [14-15]. The most represented sector on the Map of Polish Fintech 2021 are Digital Payments. 66 Fintechs provide various payment services, with expected total value of US \$ 50.40 bn in 2022. In Digital Payment segment, the number of users is expected to amount to 21.35 mln. users by 2026 [16].

The second on the list is the „software providers” sector. Twenty Fintechs provide corporate financial management services and 17 - personal finance services. The same number of Fintechs, other than lending companies, provide various services in the area of loans and credits. Insurtech deserves special attention. In 2020 the Map included eight entities classified as Insurtechs. In 2021 there are twice as many, i.e. 16. It is a significant growths.

Most of services provided by Fintech companies are offered to other companies (B2B) or to banks. Only half of Fintech ventures dedicate their services/products to individual customers.

The main fields of activity of Polish Fintechs can be also classified in different way (see table 3)

Table 3. Polish Fintechs: fields of activity

Payment	Mobile payments Online payments Mobile transfers Other form of payments
Analytics	Big data Data (business) analytics Big data analysis Machine learning Artificial intelligence used for automated advice Chatbots
Banking infrastructure	User interface Processing enhancement Infrastructure technology Software companies in the financial sector
Distributed ledger technology	Cryptocurrency Crowdlending Invoice trading
Deposit and lending	Crowd investing Crowd lending Invoice trading
Investment management	Roboadvisor Social trading Hybrid models Advice supported Digital investing
InsureTech	Software technology in insurance
Accounttech	Software companies in the financial sector

Source: [16]

The biggest center of Fintechs is Warsaw, home to nearly 45% of startups in the country, and also a hub of financial technology in the region. Other important Fintech centers are Poznań, Wrocław, so called Tri-city (Gdańsk-Gdynie-Sopot, on Baltic Sea), and other, smaller destinations (see fig. 2).

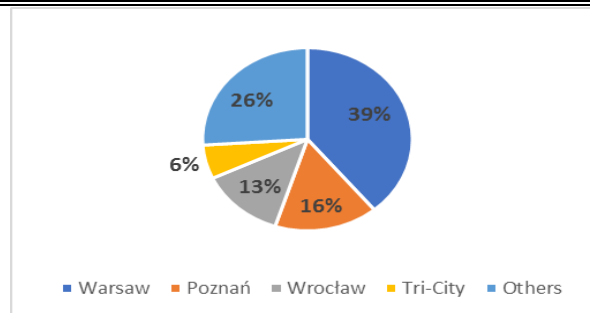


Fig. 2. Participation on the map of Polish Fintech market
Source: Cashless.pl

The Global Financial Centres Index (GFCI) ranks capital of Poland as the 12th most competitive major Financial Centre in CEE, and 45th in the world. Just 9 years ago (2013) the term “Fintech” was not widely known in Poland. But local financial institutions (such as MBank or Multibank) were one of the most innovative in Europe. It hasn’t changed since then.

The development of Fintech sector in Poland takes place in conditions specific to local market. It should be noted that there are some differences between needs and capabilities of Polish consumers of financial services in relation to residents of other economically developed countries. Compared to high-income countries, Polish adults less often save money and less often keep their savings at a financial institution, although a positive saving trend can be observed over time. Similarly, borrowing money is less popular in Poland than in other high-income countries, for example Euro Area countries (see table 4).

Table 3. Chosen financial inclusion indicators in Poland

Indicator	Poland	Euro Area
Personal Savings (as % of GDP)*	1.23	13.34
Households Debt to income**	55.9	96.79

*Data from December 2021 ** Data from December 2020

Source: [17]

Fintechs are developing and expanding in co-operation with traditional financial institutions. The banks are good examples of ventures that are driving innovation. They constantly invest in improvements and novelties in various areas, such as modern sales channels (including online channels), remote client service technologies, digitalization of traditional branches or new payment methods.

One of the sources of dynamic development of Fintech sector in Poland is strict co-operation with traditional banking sector. For example, in 2017 five Polish banks took part in fintech Alior Bank projects (see table 5).

Table 5. Six Polish banks conducted an assessment of Fintech projects

Bank	Fintech project	Scope of activity
Alior Bank	HugeThing.vc	investors and finally commercialization of projects with the greatest potential. Alior Bank is the partner of the current fourth edition of the accelerator, which is looking for solutions related to blockchains, biometrics, and artificial intelligence.
ING Bank Śląski	Akcelerator ING	ING accelerator was created to develop innovative ideas and transform them into products and services attractive to customers. This is a place where teams work

		like startups, with the support of ING Group experts and external experts (eg service designer, growth hacker). Employees who work in the accelerator are posted there for 100% of the time.
mBank	mAkcelerator	The mAccelerator is a venture capital fund that manages assets worth over EUR 50 million. It specializes in investments in the rapidly growing business in the early stages of development operating in different sectors of the economy. It focuses on unique technological solutions that have the potential to revolutionize entire areas of the economy
PKO BP	Let's Fintech	Technology Enterprise Forum with the support of PKO Bank Polski serves to select and support the most interesting technological start-ups.
Pekao SA	Social StartUp	Social StartUp is a program in which the most promising and innovative social enterprises selected in the competition receive advice and development grants. It is implemented by the Ashoka Foundation and UniCredit Foundation, in cooperation with Bank Pekao SA
Millenium	317 G Coworking	Launched in cooperation with the Warsaw School of Economics, the Coworking Center is a space for students who have their own start-ups or plan to open them. This is the first center of this type at the Warsaw School of Economics and the only place adapted for this at the university.

Source: own elaboration

One of the greatest assets of the Polish Fintech sector is a human capital and highly skilled IT professionals. The great potential has been already identified by leading technology providers. In 2015 Google opened its Campus Warsaw which was the 5th in the world and 1st in the CEE region. Another incubator was opened by Microsoft in 2017.

Examples of Fintech solutions are secure mobile applications²⁹ for banks and online services (loans) or online factoring, in which the entire procedure and assessment of the customer's credit (payment) ability is carried out electronically and remotely, and entities offering these services use, among other things, databases of economic information offices, social networking sites such as Facebook, LinkedIn or Instagram.

What is interesting, mobile device users run banking operations even more frequently used than average in Europe (see fig. 3).

Source: Report on the work of the Financial Innovation Working Group (FinTech), KNF (The Polish Financial Supervision Authority) 2017.



Fig.3. The use of mobile devices for financial operations (survey)
Appendix: the question has been asked to mobile device users
Source: [18] Finance Barometer ING, 2017

In recent years Fintech development mainly centered on co-operation with the banking industry. But other financial institutions, especially insurance companies, also introduced many new products in IT systems, to improve customer service and internal operations. One of such examples are special apps (prepared in co-operation with Insurtechs) which facilitate the entire insurance process. Mobile functionalities are also used in private health insurance, to facilitate making doctors' appointments. This kind of service is shared through the mobile app of PZU (the state-owned leading insurer in Poland).

The most important fintech entities that have their headquarters in Poland are: PayU, Blue Media), Currency One, Finanteq, VoicePIN, ZenCard. Examples of foreign fintech entities are Revolut30 and N26. But the most popular became Blik mobile payment system offered by about a dozen banks in Poland. Online payments are its most popular functionality (75% of all Blik operations). In 2018 users made 100 million online transactions with Blik, with total value of 12 billion zloty (2.8 billion euro). already in 2019 Polish payment system Blik surpassed cards (MasterCard, VISA) online payment [16]. While transactions carried out via BLIK, DotPay, Przelewy 24, PayPal and other leading payment systems are relatively safe, well documented, and there have been no high-profile cybercrimes related to them in Poland, There are much more frequent and serious attempts to phishing and cybercrimes related to unauthorized access via internet to bank accounts and bank cards.

Results and Discussion

Analysis of statistical data, reports of commercial companies analyzing Fintech market in Poland and literature review allow to identify the most important opportunities and threats to the development of Fintech sector in Poland (see table 6).

Table 5. Opportunities and threats to the development of Fintech Sector in Poland

Opportunities	Threats and risk factors
Mutual co-operation with banks	Legislation favors banks
Available technology: increasing number of mobile phone users and secure Internet services	smartphone below EU average
Trust in banking system above the average in EU	The overconfidence exposes users of Fintech services provides for banks to cybercrimes
Big home demand. Openness of Polish citizens to financial innovations.	Problems with finding new customers.
Positive trends in education	Weak co-operation between science and industry

Innovation Hubs in Polish cities	Regulations not sufficient for Fintechs, still high level of bureaucracy, especially relevant for start-ups
Increasing number of IT, finance and economic students	Poland has not effective strategy of keeping and attracting talents
Increased demand on Fintech services	Problems with start-up financing, especially with venture capital

Source: [9] [15-16], own elaboration

The outbreak of the COVID-19 pandemic in March 2020 undoubtedly provided many opportunities for the development of the Fintech sector. For example, it took only two weeks to increase the amount of contact-less payments without a PIN from 50 to 100 PLN - after the two-years discussion. The results of the last surveys show that Fintechs in Poland, especially start-ups, face many challenges, such as:

- the lack of clear regulations;
- the availability to find skilled staff/experienced managers;
- finding customers,
- data cost,
- brain drain of most talented IT experts to other countries (mostly West Europe, USA).

But Fintechs have also many advantages in relation to traditional financial institutions, which became even more transparent in times of COVID pandemic, such as:

- increased demand on cashless payment,
- increased demand on on-line financial services,
- more flexibility of Fintechs,
- innovative potential and human capital of IT workers.

When it comes future prospects for development of Fintech sector in Poland, many issues remain open. For example, in which direction further regulation of this market should go in order to avoid overregulation and bureaucratization. Another important subject for discussion (in science and public policy) is creation and development of economical and institutional conditions for acceleration of knowledge transfer from scientific institutions (universities, research institutes) to Fintech sector and better commercialization of new, innovative research projects and achievements.

Conclusions

The Polish Fintech market develops systematically and dynamically, in spite of risk identified in this articles (including lack of regulations and crisis conditions connected with COVID 19 pandemic and new, not fully estimated threats caused by Russian war in Ukraine, the neighbor country of Poland). Most of the companies operating in Fintech sector are start-ups, for which access to capital and favorable tax conditions are important, not only at the stage of their creation, but also for their further development. So far, the activity in the field of digital payments shows greatest dynamics. But also other areas of Fintech activity (specified in table 3) have great development potential. This applies especially to Fintechs co-operating strictly with banks and insurance companies (Insurtechs).

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Managerial decision-making in the era of industry 4.0

Nadezda Jankelova¹, Diana Puhovichova^{2,*}

University of Economics in Bratislava, Bratislava, Slovak Republic¹

University of Economics in Bratislava, Bratislava, Slovak Republic²

nadezda.jankelova@euba.sk, diana.puhovichova@euba.sk

Abstract: Fourth industrial revolution also known as Industry 4.0, is a concept that significantly influences the entire operation of businesses and management. It necessitates changes in individual managerial functions, not excluding decision-making. In management theory, managerial decision making is defined in terms of content through descriptive and normative theories. The aim of the presented article is to examine the normative and descriptive understanding of decision - making in the context of adaptation of individual approaches to changes in the business environment - especially adaptation to technological progress related to the fourth industrial revolution. An overrated aspect of decision-making in this era is its rational side due to the rapid development of computer technology and the availability of rich software support. On the other hand, there is a tendency to bring to the decision-making process the involvement of all involved, collective judgment, the ability to learn from the development of the situation or openness to feedback. The understanding of the decision-making process thus moves from its traditional concept to a new understanding, which includes the above-mentioned factors. Development leads to their integration in the form of a direction that does not yet have a name but means a synergy of rational decision-making and critical thinking and reasoning in the context of descriptive theories. The overall optimal result of the decision-making process is influenced by objective criteria through a rational-normative model, environmental characteristics and subjective influences, personality, and cognitive complexity of the manager.

Keywords: FOURTH INDUSTRIAL REVOLUTION, INNOVATION, MANAGEMET, DECISION-MAKING

1. Introduction

The dynamic development of the 21st century has brought another revolution in the form of digital transformation of the business world. We are talking about the fourth industrial revolution, commonly referred to as Industry 4.0 [1 - 3]. The term can be understood as a completely new revolutionary stage, which aims at the full integration of operational systems and information and communication technologies (ICT) - especially as the Internet of Things (IoT), creating so-called cyber-physical systems (CPS) [4, 5]. Thus, according to previous claims, Industry 4.0 is a unified system of information technology, people, machines, and tools that ensures the smooth flow of goods, services, and data in a controlled manner through the value chain, activities with a high level of autonomy and a high level of ability to transfer relevant information for decision-making [6,7]. Other studies add that the concept of Industry 4.0 describes the increasing digitization of the entire value chain and the resulting interconnection of people, objects, and systems through the exchange of data in real time [8,9].

For this reason, implementing Industry 4.0 is an important strategic decision, and before making such an important decision, executives must assess the readiness of the companies to implement Industry 4.0 [10,11]. It is considered a high-tech strategy [12], where continued dynamic developments in various areas are raising expectations for the performance of those systems in terms of reliability and responsiveness to support decision-making [13,14].

It is the management decisions made by executives in an Industry 4.0 environment that have an important impact in the areas of implementation of modern technologies, control and analysis of necessary data, data security, risk management, compliance with established regulations, etc. [15].

The aim of this presented article is to identify, at a theoretical level, changes in managerial decision-making in the context of the impact of the fourth industrial revolution, through the available scientific literature. Given the need for constant additions and changes resulting from the development of society and the necessary changes in the environment, but also in the thinking and behavior of business management, such as the current crisis, but in its background emphasizing the impact of computerization, knowledge, mutual trust between partners, development and involvement of people and with regard to the emphasis on the need for qualitative methods due to the uniqueness of the tasks and variability of the environment, it is our intention and main goal to examine, critically evaluate and provide our own views on rational-logical (normative) and descriptive decision-making in the current understanding of managerial decision in the conditions of the Industry 4.0.

2. The Fourth Industrial Revolution

The modern phenomenon was originally introduced in Germany, then adopted by other countries [16,17]. Countries have set up programmes to support the development and deployment of Industry 4.0 elements. In Germany, where the whole revolution started, "High-Tech Strategy 2020" has been introduced, in the United States we are talking about the "Advanced Manufacturing Partnership", in China "Made in China 2025", and in France the program "La Nouvelle France Industrielle" [18 - 22].

Industry 4.0 is oriented towards new technological trends in the manufacturing industry. Technological phenomena such as automation, robotics, nano- and biotechnology, advanced materials, the Internet of Things, artificial intelligence, 3D printing, big data, etc. are creating strong impulses for structural change in many industries and sectors and are driving significant changes in society. The fourth industrial revolution marks the transition from a phase of simple digitization to innovation based on combinations of material, digital and biological technologies [23].

According to World Economic Forum founder Klaus Schwab, Industry 4.0 is creating a world in which virtual and physical systems of production interact flexibly on a global scale [24]. Based on the above, we can say, that the main aim of Industry 4.0 is the production of cyber-physical systems (CPS), which is based on the integration of heterogeneous data and knowledge [16,17].

The opportunities and benefits expected can be far-reaching in the form of highly flexible mass production, real-time coordination, optimization of value chains, reduction of complexity costs or the emergence of entirely new services and business models, or acceleration of decision-making [23].

On the basis of mentioned facts, we can conclude that technological progress and the related innovations play a challenging role in companies. The impact of Industry 4.0 transform into an increase of competitiveness of companies. It is the fourth industrial revolution that is transforming into significant changes in many areas that go beyond the industrial sector. Industry 4.0 is blurring the boundaries among human capital and technologies.

3. Managerial decision-making

Decision-making is one of the so-called ongoing managerial functions and we meet with this function in the implementation of each sequential managerial function (planning, organizing, leading people, control, etc.). It is one of the most important activities performed by business managers and is therefore often considered as core of the management. Due to its position in management, decision-making is focused on a very wide range of issues. We

emphasize that the issue of decision-making is in the center of attention of various scientific disciplines (economics, psychology, exactly oriented disciplines such as operations research, game theory, decision analysis and others), each of which seeks to provide a contribution to improving the quality and efficiency of decision-making. In the available domestic and foreign literature, we meet with a wide range of opinions, concepts, focused on individual areas of decision-making. The basis for defining the main groups are the constantly emerging and differing views on the issue, using of the degree of rationality and intuition in decision-making. This creates the rational and psychological (descriptive) framework of managerial decision-making.

From a historical point of view, rationality in decision-making, its basics and beginnings are generally known. Mainly, it was Von Neumann-Morgenstern's model of the theory of expected usefulness and its axioms (complexity, transitivity, continuity, monotonicity, substitution), which provided a very elegant and convincing framework for explaining economic choices. The American mathematician and statistician Leonard Savage identified normative theory with the problem is clear and unambiguous. The goal is clearly defined and achievable. All variants and consequences are known. The preferences are clear. Preferences do not change. There are no restrictions. The final selection maximizes the profit. Rational decision leads to 10 acceptances of the principle of rationality and thus held a strict view of the essence of normativity in decision-making. Other famous persons of scientific life, such as Friedman and Markowitz, monitored and tried to clarify some ambiguities in the function of usefulness, which reigned in decision-making for a very long time. The aim of the monograph is to look at rationality in the current period of Industry 4.0 and to examine the views of theorists on its place in the decision-making process.

In addition to normative principles, decision theory is also based on a description of decision-making. In fact, the decision-making process is seldom unambiguous and straightforward, most managers face many limitations, loops are formed in the decision-making process, and access to information is also problematic [25]. Descriptive theories seek to clarify how decisions in real life are actually made. It is a description, analysis and evaluation of decisions that have already been made, a description of their course, people's behavior in decision-making and the likewise. Decisions are not only governed by the rules of mathematical logic, but various abbreviations and heuristic solutions are applied, which then manifest themselves in deviations from rational thinking. The representative of this group of theories is the so-called prospect theory. We agree that psychological aspects play an important role in the decision-making process. Although the first theories and models of decision-making were provided by mathematics, statistics, and economics, they gradually „psychologized“ and a behavioral economy emerged. In the decisions-making process, decision-makers are very often influenced by various prejudices, states, or tricks of the mind, and even if they try to be rational in any way, they fall into their trap. They also think that they have so much experience and accumulated judgment that they can make intuitive decisions without any problems. Surveys also show that almost a third of managers rely more on „feel good“ than on rational problem-solving. Neuroscience has also become a new element and area of interest, penetrating decision-making, and posing a challenge for researchers. Its influence is considerable, and it introduces the depiction of brain processes in decision-making into the study of decision-making. Thus, a new scientific discipline - neuroeconomics - is developing. All these aspects create the psychological framework of decision-making. Opinions of the authors on their application, resp. the degree of application or involvement in solving decision-making problems varies. It is therefore not at all strange that modern management has to deal with this issue.

4. Results

The area of decision-making, given the wide-ranging software support already in use, will be one of the areas most affected by the fourth industrial revolution. Various simulations can be used, virtual presentations, which, according to [26] to facilitate the decision on which processes would make the most of the investment in Industry 4.0 technologies. On the one hand, such virtual analyzes can represent significant cost savings without disrupting ongoing production processes. On the other hand, it represents a huge investment and consideration of costs and benefits. A thorough assessment of the overall effect of investments in industry 4.0 is one of the main obstacles to implementation in management practice [27,28]. It is important for the company to be able to define the requirements for a software solution. The second step should be the ability to modify the software according to the needs of the company. Last but not least, to find out whether the program is able to plan effectively also with regard to the product life cycle and possible changes by suppliers. It is questionable whether and to what extent companies in Slovakia are ready for this change. Business areas are also an area of interest not only within the decision-making function, but also in management. Industry 4.0 research has already highlighted the need to rethink existing business models due to the ubiquity of digital and new information technologies, increasing virtual communication and open communities [29]. The core of the business innovation model is the innovation process and the ability to identify a good idea, including the ability to transform such an idea into a business model that brings added value and generates revenue [30]. Competition for new business models should be designed to allow the use of data to improve industrial applications that benefit end-users. Companies have a high degree of responsibility, including the protection of confidential data. Breakdowns of data protection data and the use of private information for inappropriate and harmful purposes can be destructive to business rumors. Industry 4.0 tools will be able to produce huge amounts of data that will improve decision-making, lead to early detection and prediction of problems. However, the whole process will be difficult to analyze the data. It is questionable how companies in Slovakia will be able and willing to invest in equipment that will be able to both integrate data and interpret it, of course. Currently, observations from the practice of companies applying Industry 4.0 indicate that the biggest obstacles are ignorance, when top management expects the implementation of advanced methods of management, diagnostics, prediction, but middle management, which should implement these changes, cannot realize visions with their knowledge, respectively to correct them and ultimately to correct their superiors in what the company really needs. Much of the attention in the scientific literature on decision-making in the context of Industry 4.0 is devoted to the manufacturing process, where the use of Industry 4.0 technologies such as the Internet of Things, augmented reality, extensive data analysis, machine learning and artificial intelligence can actually increase the autonomy of manufacturing systems, including operators and production facilities by supporting problem solving and other decision-making processes. The number of decision models that are used to find optimal solutions is increasing. Marr [31] states that decision-making processes will be able to be decentralized, which is related to the ability of cyber systems to make simple decisions and be autonomous. However, the literature lacks the described models that would analyze or evaluate the impact of Industry 4.0 technologies on decision-making processes. Rosin et al. [32] recognize the potential benefits of Industry 4.0 technologies for operational decision-making and propose a general model covering several types of autonomy that can be accepted by management, depending on the decision-making steps they want to strengthen in the use of technology. Based on the Mintzberg model, they proposed an ideal decision-making

process (Figure 1). It is adapted to the decision-making process, which requires the identification of a problem in a broader sense (problem or opportunity) in production.

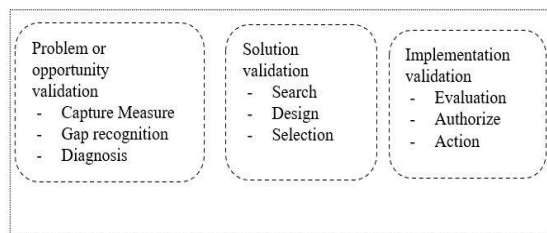


Fig.1 Decision-making process in an operational context.
Source: Rosin et al. 2016

This process involves three phases similar to Mintzberg: validating a problem or opportunity, validating a solution, and validating an implementation with the individual steps shown in the figure. This model of the decision-making process can then be used to define different types of autonomy and the use of Industry 4.0 technologies. Such technologies can help a workplace that include operators and / or machines to improve one or more steps in the decision-making process. Lin et al. [33] is based on Simon's four-phase decision-making model, including phases, in the conception of the decision-making model in the Industry 4.0 era intelligence, design, selection and implementation. The first phase is used to simplify and create knowledgeable assumptions about the real-world problem so that decision-makers can understand situations and correctly define potential problems or opportunities. The design phase includes selecting the appropriate model for decision analysis to find potential decision alternatives for the most likely scenario. The selection phase focuses on the application of algorithms to model-to-model solutions and finding solutions from decision-making alternatives. The implementation phase verifies the performance of the obtained solutions. The model is shown in Figure 2.

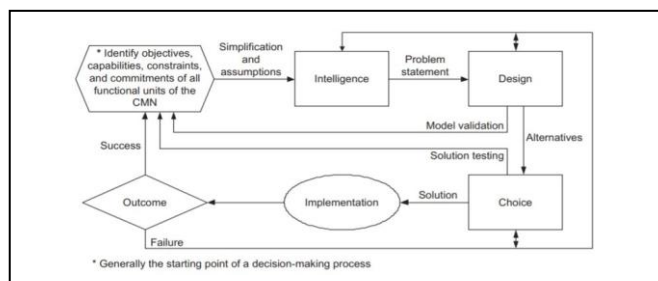


Fig.2 Decision-making model for Collaborative Manufacturing (adapted from Lin et al. 2012)

The fourth industrial revolution also brings a revolution to decision-making processes. The context of this revolution speaks of improving the rational side of decision-making through EBDM as a concept of normative theories. Of course, evidence-based decision-making as part of a rational approach to decision-making seems desirable. New analytical tools that Industry 4.0 offers for investigating „big data“ promise to provide additional unbiased records. On the other hand, technological progress in improving the decision-making process is reopening issues related to facts, prejudices, and beliefs. For many years, decision support systems and technologies have aimed to improve the efficiency of human decision-making processes, strengthen rational thinking, and prevent prejudice, error, and bias. However, Industry 4.0 also makes significant progress in neuroscience, where cognitive research has highlighted issues of implicit cognition, psychological and naturalistic processes, and the impact of social cues as elements of human thought [34]. Decision support is therefore not just in rational models, but in complex cognitive and analytical decision support systems. Analysts or scientists who support research in

decision support must consider descriptive aspects in the form of characteristics, behaviors, and attitudes of those who will use the analysis, systems, outputs and results. Industry 4.0 means emerging computational techniques appropriate for ‚big data‘, but also brings the need to discuss big data at the academic, legal, business or political level, focused not only on analytics and types of technologies in decision support, but also on prejudices, preferences and the ability of managers to think and judge [35, 36]. Some critics even predict that analytical and decision support tools will lead to the destruction of clear thinking, rational discourse, and moral behavior [35, 37, 38]. Ekbja et al. [35] draws attention not only to analytics as an accompanying phenomenon of the current industrial revolution, but also to how we understand the numbers and how we subsequently interpret the results. More possible discussion and thinking is a possible solution to over-reliance on data. Discussion is recommended as a step or phase of a dialogue, multiperspective and discursive decision-making process. The decision-making process should not be based solely on personal opinion but should be supported by evidence. Decision-making requires impartial facts, expert analysis, and thoughtful commentary / discussion. Therefore, the challenge of future decision-making processes is to support decision-making through the use of brain function as a predictive organ capable of using mood, context, and social stimuli for active inference [39], rather than trying to deactivate these abilities. Decision-making scientists, management scientists, and information systems developers have not yet completed the task of predictably and effectively building computer support systems for the steps of logical thinking, classical argumentation, or group decision-making. Now, with the advanced analytical tools, virtually endless data repositories, and the fast-distributed computing technology at our disposal, we can consider scientific advances that are likely to demonstrate a wide range of things we still do not understand in the field of human cognition. Cognitive calculations are in their infancy [34]. In the scientific literature, in connection with approaches to people in the context of Industry 4.0 and work in teams or groups, several 68 concepts appear, related to the strategic use of technology and digital assets of the company to achieve the set goals. In recent years, researchers started to talk about concept of knowledge-oriented leadership [40], which is a combination of transformational and transactional leadership style. The essence of this type of leadership is the emphasis on learning and innovation, complemented by innovative role modelling, dissemination of knowledge, support for decision-making, delegation, consultation, and mentoring. Digital leader or Digital leadership helps organizations create workflows and business processes that enable the rapid deployment of new technologies, products, and services. However, being a leader in the digital age means not only technological implementation, but also digital understanding and building a digital culture. However, Oberer-Erkollar [41] states that, despite the clear naming of a leader in the Industry 4.0 era, there is a lack of comprehensive research and naming the competencies of leaders able to meet the challenges of the fourth industrial revolution. The virtual leader and leadership of virtual teams is gaining attention in connection with the change in the work environment and the rapid pace of progress in information and communication technologies. The requirements for this type of leadership move to the level of subsequent decision-making in a virtual environment, as well as the ability to manage a network of interconnected companies, design virtual operations, create and maintain virtual relationships with internal and external members or components, and ability to demonstrate it. Leading virtual teams is one of the main challenges, as it is very difficult for a team leader to directly manage the activities of each member due to their different geographical location. As a result, the leader must use different skills, delegate, and then motivate in another way. There is a high dependence on the skills of team members, on the identification of goals by team members, which is again very difficult to achieve in a virtual environment. A virtual leader cannot physically observe members and should be creative in order to practically follow members' expectations. The virtual leader must

have an intuition and sense of understanding that „electronic silence“ means consent and acceptance rather than inattention [42].

5. Discussion

The Industry 4.0 is revolutionizing managerial decision-making processes through a high degree of automation and digitization of workflows. This will have a significant impact on competition not only for the companies, but for a part of countries' competition, which must make significant changes in preparation for business transformation. These changes also create new challenges for company management and for the adaptation of new tools and techniques applied in the implementation of individual management functions. Research in the field of the fourth industrial revolution neglects the deep managerial challenges that are the basis of its implementation. The most important issues we have defined in the decision-making function for the era of the fourth industrial revolution are: – decentralization of decision-making, related to the ability of cyber systems to make simple decisions and be autonomous, – building on evidence, not information and data, – greater need for critical thinking and reasoning, discussion, ability to interpret, – focusing on decision-making support not only in rational models, but in complex cognitive and analytical decision support systems – progress in neuroscience, decision-making support through the use of the brain as a predictive organ capable of using mood, context and social stimuli for active inference. The fourth industrial revolution supports decision-making with its tools. The creators of this support should try to strengthen the intended rationality of the target user while avoiding the introduction of „irrationality“ in the analysis and decision-making processes. Effective technologies must consider the complex social nature of decision-making as well as the multifaceted nature of evidence. Their knowledge and response create a space for learning about other contexts and impacts, especially in the social field. The authors agree that the fourth industrial revolution will have an impact on all areas of our lives, disrupting existing socio-economic structures. In general, forms of service provision will change, including new forms of education and professions - probably up to half of today's professions will disappear in 15 years and completely new ones will be born that we do not yet know exactly. Lifestyles will change, and so will ways of managing public affairs in general. Technological innovation, which is growing exponentially, will also lead to social innovation. It is therefore a great challenge for managers and scientists to examine what strategy to set when implementing concept 4.0, not only within the boundaries of their own company, but including the entire corporate ecosystem.

6. Conclusion

Decision-making is a key characteristic of a successful organization and one of the most important roles of a manager. The ability to make the right decisions is a complex phenomenon and represents an interplay of both rational and descriptive elements, taking place in social groups, within the framework of social relations in companies. Based on the amount of studied professional literature, we state that there is a predominant interest in the normative understanding of decision-making, and many authors try to examine in detail this area in decision-making processes in context of Industry 4.0. We are inclined to believe that analysis, automation, or adherence to precisely defined steps in decision-making processes are really necessary in today's information age, and we dare say that they are paramount with regard to the Industry 4.0 era. On the other hand, we strongly emphasize that the behavioral economy, its knowledge, and conscious incorporation into decision-making are an integral part of achieving an effective course of a rational process. Awareness of the fact that we can fall into one of the psychological 76 traps, the knowledge that the action of different types of emotions can significantly affect our decision-making, can significantly improve the quality of our decision-making processes. Due to the rapid development of computer technology and the availability of rich software support, rational

approaches to decision-making lead to a re-understanding of their importance and also to a change in their understanding. There is a tendency to bring to the decision-making process the involvement of all involved, collective judgment, the ability to learn from the development of the situation or openness to feedback. The understanding of the decision-making process thus moves from its traditional concept to a new understanding, which includes the above-mentioned factors.

The problem of normative and descriptive theories in decision-making is addressed by many scientists, who highlight the positives of one or the other side of decision-making methods. In any situation, whether it is ordinary decision-making or decision-making in crisis conditions and at the same time in times of technological progress, it is not possible to overestimate only one aspect of decision-making. Development leads to their integration in the form of a direction that does not yet have a name but means a synergy of rational decision-making and critical thinking and reasoning in the context of descriptive theories. The overall optimal result of the decision-making process is influenced by objective criteria through a rational-normative model, environmental characteristics and subjective influences, personality, and cognitive complexity of the manager. In the decision-making process, rationality is mostly limited and is limited by the amount of information obtained. Therefore, this process is characterized not only by analysis, but also by constant evaluation, intuition, and political behavior.

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Integrated CRM system for Bulgarian agricultural sector

Georgi Kolev, Tsvetelina Ivanova, Daniela Tzakova

University of Chemical Technology and Metallurgy, Bulgaria

georgi.i.kolev@abv.bg, t.ivanova@uctm.edu

Abstract: Agriculture is a sector in Bulgaria that contributes significantly the GDP. In the past 20 years steady trends for increasing the arable land, while the number of agricultural holdings decreases. The enlargement of the size of the agricultural holdings is strongly associated with the need for implementation of the advances of information and communication technologies, Industry 4.0 and artificial intelligence. The present paper presents the development of an integrated Customer Relationship Management (CRM) system for agricultural applications. The developed CRM system implements the following functions: customer data management, management of contracts for clients, management of agricultural land, management of processing costs, production revenue management. For the development of the presented integrated CRM system, the needs of the agricultural producers and the work with their clients have been studied in detail.

Keywords: CRM SYSTEM, AGRICULTURAL APPLICATIONS, SYSTEM INTEGRATION, DATA MANAGEMENT.

1. Introduction

The development of a Customer Relationship Management system (CRM system) within each organization aims to manage, automate and integrate sales, marketing and support functions. In this way, long-term and mutually beneficial relationships with customers are created by understanding their individual needs. The CRM system can be a stand-alone system or an integrated module of a larger business information system of the organization. The implementation of an integrated management system is a complex process that can last from several months to years depending on the size of the organization and the complexity of the included business processes [1]. Integrating the information system into an existing organizational structure is a complex task that depends on the flexibility of the system and the ability to easily set up, as well as the ability, desire, setting and training of employees to accept and use modern information technology applications. The effective implementation and use of information systems in management goes through the selection of appropriate technological solutions, good organization of their integration into the existing structure and training of staff (employees and more managers) who will serve and use it in their work.

According to PricewaterhouseCoopers, customer relationship management CRM is a strategy for building long-term and mutually beneficial relationships with customers by understanding their individual needs [2]. The CRM model of interaction assumes that the customer is the center of the business philosophy, and the main directions and goals are the activities to support effective marketing, sales and customer service. Maintaining these business goals includes collecting, storing and analyzing information about consumers, suppliers, partners, competition, as well as internal processes in the company.

CRM systems represent a whole class of software. The CRM system is an information system designed to automate the business processes in the company, ensuring the interaction of all its divisions with customers. This system is on the one hand designed to satisfy and retain customers, and on the other hand provides serves to optimize the company's activities.

The main goal of the implementation of the CRM system is to create a tool for attracting new customers and developing relationships with the existing customers. Customer relationship management, especially in financial enterprises, is of strategic importance for their success. Online banking, Internet insurance, personal care for health and insurance fund clients are difficult, even unthinkable, without an integrated CRM system [2].

- CRM system allows to structure and gather in a single database information about customers, partners and suppliers, even competitors. Archiving the history of relationships allows the

employees to "remember" the entire history of negotiations and agreements with customers and suppliers.

- The organization of electronic exchange of information minimizes the problem of "lack of information" between departments and employees of the company. Electronic business processes have a real contribution to the company's activities, and do not remain only on paper.

- Analysis and forecasting tools allow company management to make decisions quickly and efficiently. Marketing receives tools for solving tasks in the field of planning, budgeting, conducting advertising campaigns and analyzing their effectiveness. The company receives tools for quality management, storage and use of accumulated knowledge.

The CRM system may include an operational part, ensuring the execution of transactions and operational reporting, unified database, analysis subsystem, distributed sales support system.

The development of a CRM system can be the first step in building an integrated management system by integrating it with other functional modules: supply chain management (SCM - Supply Chain Management), finance (Financials) and financial management of supply chains (FSCM - Financials Supply Chain Management).

According to the statistical platform for business analysis Statistica [3], the global customer relationship management software (CRM) market is expected to grow to \$ 43.5 billion in 2024. This is a forecasted increase of almost \$ 1 billion from 2019 at a compound annual growth rate (CAGR) of 0.4%. Salesforce is the world's leading provider of customer relationship management (CRM) applications with a market share of 19.5% in 2020. The company is the market leader with a large margin, followed by SAP and Oracle with about five percent market shares [3].

Manufacturers of CRM systems are beginning to offer integration of their products with external applications, which adds the element of social media in CRM. These innovations help businesses to reach the customers through social media. CRM manufacturers see social media as a cheap way to improve customer support. This allows customers, for example on Facebook or Twitter, to state their problems and to get help. As the amount of data on the Internet grows, so does the need to analyze that data, so CRM vendors are offering better and better tools for analyzing data. The supply of mobile CRM applications is growing, which is gradually making CRM systems look and behave like mobile applications. Wireless technology will increasingly allow real-time decision making. CRM manufacturers are increasingly offering solutions through the SaaS model (Software as a service), based on Cloud technology.

Agriculture is a sector in Bulgaria that contributes significantly the GDP. In the past 20 years steady trends for increasing the arable

land, while the number of agricultural holdings decreases. The enlargement of the size of the agricultural holdings is strongly associated with the need for implementation of the advances of information and communication technologies and artificial intelligence to meet the requirements of the current industrial revolution or German Initiative Industry 4.0.

An in-depth study of the level of digitalization of Bulgarian agriculture and rural areas is presented in [4]. There the great variation in the degree of digitalization in the different sub-sectors of agriculture, holdings/farms of different legal types and sizes, and in different regions of the country is visualized. The majority of farmers are not familiar with the nature of digital agriculture, with only 14% using modern digital technologies. The main obstacles and risks in the introduction of digital technologies are the qualifications of employees, the amount of investment, unclear economic benefits, data security, lack of standardization.

The present paper presents the development of an integrated Customer Relationship Management (CRM) system for agricultural applications. The developed CRM system implements the following functions: customer data management, management of contracts for clients, management of agricultural land, management of processing costs, production revenue management. For the development of the presented integrated CRM system, the needs of the agricultural producers and the work with their clients have been studied in detail. Thus, the requirements for "precision farming" will be fulfilled.[7]

2. CRM development and integration

According the census of agricultural holdings that was conducted in 2020 in Bulgaria by the Ministry of Agriculture, Food and Forestry, its regional and municipal structures [5] and the comparison with data from 2003, there is a steady downward trend of the number of the agricultural holdings in time, while the total area of arable agricultural land increases due the increase of the arable land of the holdings above 10 hectares. This statistical survey

in agriculture is conducted every 10 years on the recommendation of the Food and Agriculture Organization of the United Nations (FAO). The rules for its conduct are established by Regulation (EU) 2018/1091 of the European Parliament and of the Council and the Law on the Census of Agricultural Holdings in the Republic of Bulgaria in 2020. The observed tendencies determine the necessity for implementation of integrated information systems as an essential tool for digitalization in the agricultural sector.

The functional requirements for the CRM system are defined, according to the most essential needs of the agricultural producers (Fig. 1). The aim of the integrated CRM system is connected with management, automation and integration of information about the activities connected with customers, land owners, contracts, lands, production, rents, payments, processing costs, products, sales, marketing and support functions.

The defined functions can make the integration of the CRM system with other systems like Supply Chain Management (SCM) system, Financials, Professional Service Automation (PSA), and in this way developing a larger business information system of the organization.

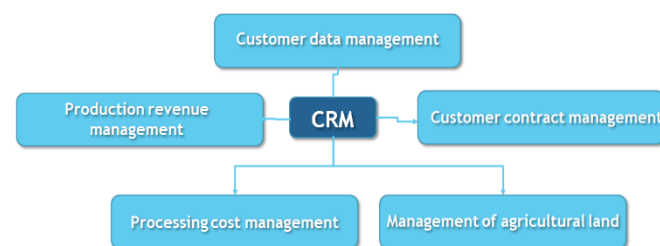


Fig. 1 Functional requirements for the CRM system

3. Database system design

The ER diagram (Entity-relationship diagram) of the developed system is presented in Fig. 2.

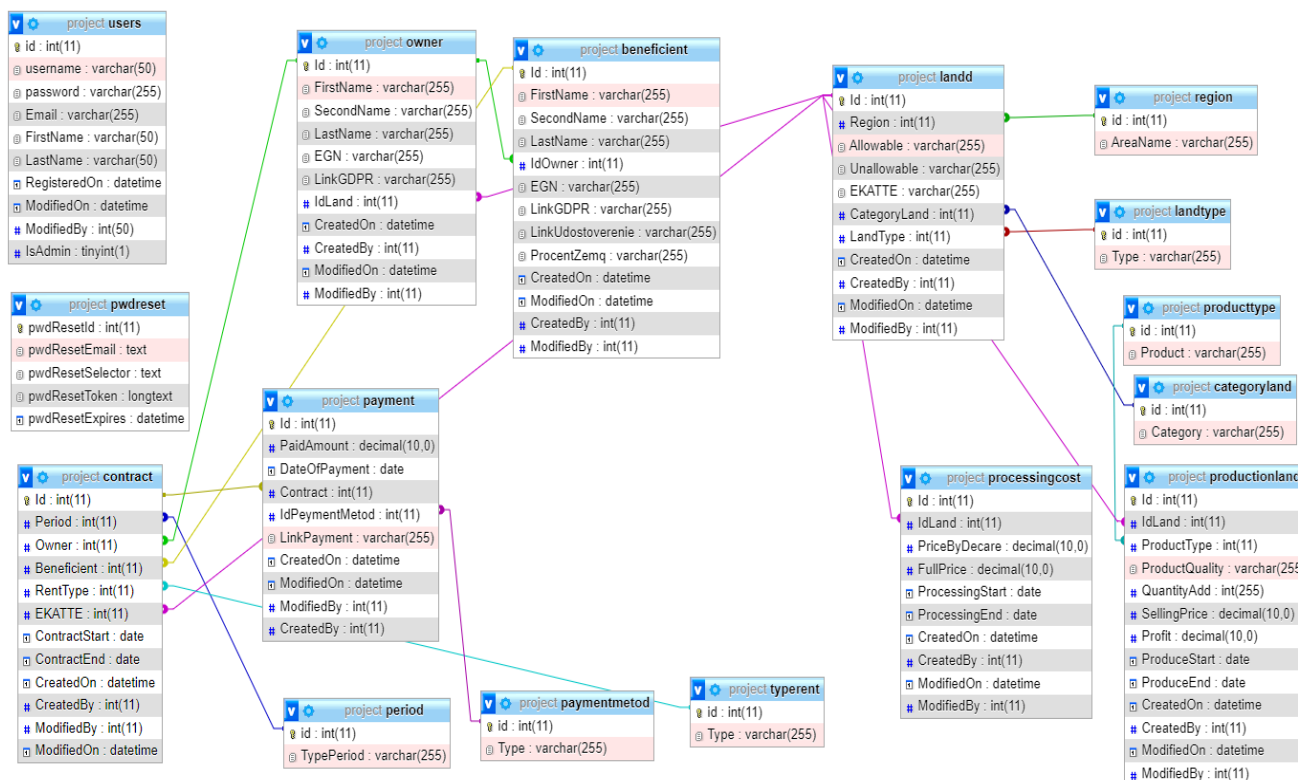


Fig. 2 ER diagram

The relational database consists of 16 tables:

1. "Beneficiary" table – contains information about heirs in case the owner is deceased, keeps a link to a copy of the document verifying the right of ownership and percentage of the land;
1. Table "categoryland" – contains information about different land categories like field, meadow, etc.;
2. Table "contract" – contains information about contracts like type of period, the unique identifier for the land, owners, beneficiaries, start and end date of the contract;
3. Table "land" – contains information about all available lands, their allowable and unallowable area, etc.;
4. Table "landtype" – contains information about land types - the type of soils;
5. Table "owner" – contains information about landowners;
6. Table "payment" – contains information about confirmed payments and a link to a document confirming the payment;
7. Table "payment method" – contains information about payment methods – cash or bank transfer;
8. Table "period" – contains information about different types of contracts' periods;
9. "Processingcost" table – contains information about processing costs for each land;
10. Table "productionland" – contains information about produce, profit, selling price, etc.;
11. Table "producttype" – contains information about different the types of crops;
12. Table "pwdreset" – additional table which eases the process of resetting users' passwords;
13. Table "region" – contains a list with all available regions in Bulgaria;
14. "Typerent" table – contains information about the different types of rent, like money, produce or combined;
15. Table "users" – contains information about system users.

4. Design and development of an online CRM system interface

PHP, HTML, CSS, BOOTSTRAP and AJAX provided by jQuery Foundation are used to implement the CRM management functions during the development of the CRM system's interface. The developed system eases the process of land management. It helps tenants of agricultural lands to manage their contracts with landowners and their heirs, to effortlessly control performed payments, to track the produce, invested funds, actual profit, etc. The developed system contains more than 20 web forms which allow filling importing and editing all required information for management of a specific land.

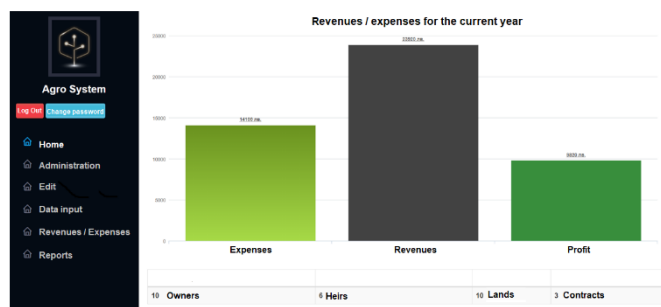


Fig. 3 Home page

The home page of the interface is presented in Fig. 3. There are defined several categories: "Administration" (visible only if the user is an administrator), "Edit", "Data Input", "Revenue / Expenses", "Reports". They give possibility to reach all other pages of the developed interface.

The "Administration" category, which is visible only for administrator users, contains the following pages: "Land category", "Region", "Land type", "Product type", "Payment method", "Rent type", "Period", "User registration". All these web pages allow changes to the main administrative data.

The "Data Input" category contains the pages: "Adding a client", "Adding a contract". These web pages allow the user to add information about new clients and new contracts.

The "Edit" category contains the pages: "Client", "Heirs", "Agricultural land", "Contracts". These web pages allow the user to edit existing information about clients (landowners), heirs and the agricultural land.

The category "Revenues / Expenses" contains the pages: "Expenses / Revenues for land", "Paid Rent". These pages show information about made expenses for corps and produce, including profit and performed payments to the landowners.

The "Reports" category contains the pages: "Processing costs", "Revenues from production", "Paid rent".

The home page also shows the main user reports "Expenses", "Revenue", "Profit" for the current year, number of active "Owners", number of active "Heirs", number of registered entities for "Land", number of active "Contracts".

Below the logo of the home page there is an "Exit" button that deletes the session and logs out the user, and a "Change Password" button that forward the user to the password change form.

5. Conclusions

The present paper presents the development of an integrated Customer Relationship Management (CRM) system for agricultural applications. The developed CRM system implements the following functions: customer data management, management of contracts for clients, management of agricultural land, management of processing costs, production revenue management. For the development of the presented integrated CRM system, the needs of the agricultural producers and the work with their clients have been studied in detail.

Acknowledgements

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Energy audit analysis in private residential apartment in Tirana city

Elena Bebi*, Klodian Dhoska¹, Majlinda Alcani¹, Enxhuina Sakaj¹, Serxhi Qosja²

Faculty of Mechanical Engineering,
Polytechnic University of Tirana, Albania¹
Department of Manufacturing and Civil Engineering,
Norwegian University of Science and Technology, Norway²
ebebi@fim.edu.al

Abstract: Recently, Albania as a developing country is focusing on the energy efficiency in residential and industry sector. Residential sector has very high contribution energy consumption in Albania due to many construction buildings without energy efficiency standards implementation. Most of the contribute city is Tirana where energy consumption in residential sector is very high in comparison to the other cities in Albania. Our research work will be focused on analysis of the energy audit on a private residence apartment which is located in the area of Tirana. The purpose of this paper is based on the relevant standards and norms to give appropriate recommendations for the implementation of energy efficiency which would increase the energy performance of this building.

Keywords: ENERGY AUDIT, EFFICIENCY, CONSUMPTION, ELECTRICITY, RESIDENTIAL.

1. Introduction

Nowadays, Albania as a developing country is focusing on the energy efficiency in residential and industry sector. Energy efficiency is one of the biggest challenges that energy sector is actually facing in Albania [1-6]. Continuous developments and ever-increasing demand for energy on the one hand, both in public and private buildings, in industry and in many other fields, and on the other hand, the constant increase in energy prices is pushing every day the different sectors that to invest in increasing energy efficiency by reducing the cost of energy they pay each month, reducing energy consumption and consequently reducing greenhouse gases. Currently, the residential sector with a share of 30% represents the second largest sector after transport sector which correspond to 43% [1, 7].

Based on it, this paper will briefly analyze a private residence apartment which is located in the area of Tirana. Albanian legislation, normative and European directives have been taken into account for analysis of energy audit in residential buildings [8-11]. iSBEM software has been used for conducting energy audit to provide the energy performance certificate when ranking the building according to the energy performance.

The purpose of this paper is to give appropriate recommendations for the implementation of energy efficiency which would increase the energy performance of this building. The results during the analysing of this paper will be given in accordance to the Albanian legislation as well as with the European Norms for the energy performance of the buildings.

2. Materials and Methods

Residential apartment that is taken in consideration in this research work is located in the area of Tirana city. The apartment is located on the sixth floor of a seven-stores building. The living area of the apartment is 120 m² and consists of two bedrooms, living room, kitchen / dining room, two bathrooms and two loggia balconies. Fig. 1 depict the residential apartment view that we need to make energy audit.

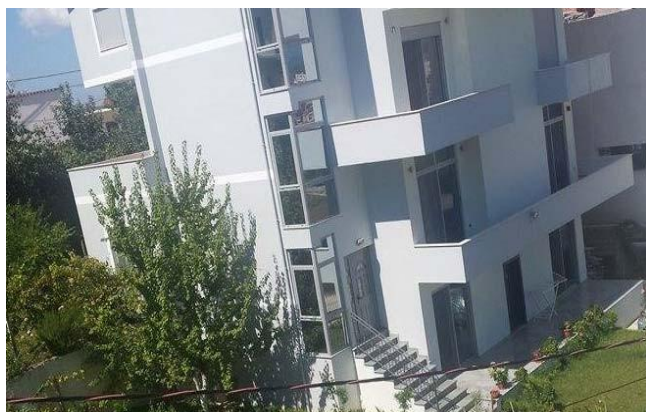


Fig. 1 Residential apartment view, located in Tirana

In the Table 1 and 2 is shown apartment data accompanied with usage profile and the main electrical/electronic usage devices.

Table 1. Apartment data and usage profile

Apartment Data		
Year	2010	
Area	120 m ²	
Usage Profile (DIN 18599)	Used time	From 0.00 Until 24.00
	Ventilation used time	0.00 - 24.00
	Operation time (heat/cool)	6.00 - 23.00
	Ventilation daily time usage	24 h/day
	Usage time of the system (heat/cool)	17 h/day

Table 2. Apartment data and usage profile

Electrical/Electronic Devices	Power	Usage
Oven	4 kW	Everyday, 1 Hour, 1 Year
Fridge	1.1 kW	All the day, 1 Year
LCD TV	0.3 kW	4 hours a day, 1 Year
Air condition	2.8 kW	2 Hours a day, 1 Year
Washing Machine	2 kW	2 hours in 2 days, 1 Year
Ironing	2 kW	30 min a day, 1 Year
Boiler shower 80 litre	2.5 kW	2 hours a day, 1 Year
LED lamps	200 W	5 hours a day, 1 Year

Based on the above data we will analyze an energy audit of the residential apartment during the last three years. Our methodology will be focused on the energy consumption during the last three years by taking into account also the electricity bills and heating of the sanitary water.

3. Energy Audit Analysis

The briefly analysis of the energy audit has been started on electricity consumption for the last three years by referring to the meter reading and electricity invoices, see Fig. 2

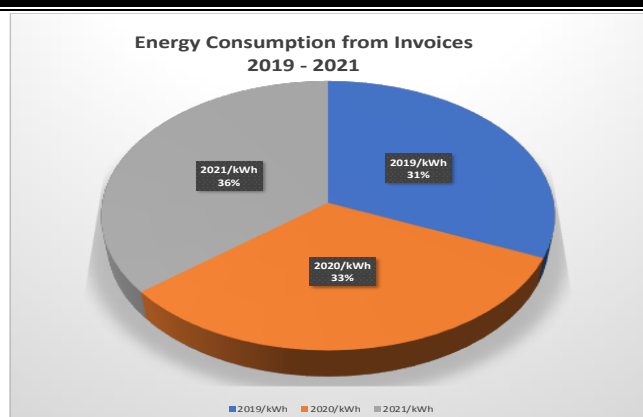


Fig. 2 Energy consumption from electricity invoices, 2019-2021

Energy audit continue by taking into account the electricity consumption in kWh and Albanian “Lek” (ALL) that was used only for heating / cooling of the area of the apartment as can be seen in the Table 3 and Table 4.

Table 3. Electricity consumption in ALL from heating/cooling area

Months	Consump. 2019 (ALL)	Consump. 2020 (ALL)	Consump. 2021 (ALL)	Av. Consump. 2019 – 2021 (ALL)
January	2945	3325	3420	3230
February	2755	2992.5	2745.5	2831
March	1890.5	1805	2033	1909.5
April	1862	1824	1871.5	1852.5
September	1786	1662.5	1586.5	1678.3
October	1843	1748	1634	1741.7
November	1881	2194.5	1881	1985.5
December	2850	2375	2565	2596.7
Total	17812.5	17926.5	17736.5	17825.2

Table 4. Electricity consumption in kWh from heating/cooling area

Months	Consump. 2019 (kWh)	Consump. 2020 (kWh)	Consump. 2021 (kWh)	Av. Consump. 2019 – 2021 (kWh)
January	310	35	360	235
February	290	315	214	273
March	199	190	197	195
April	196	192	192	193
September	188	175	167	177
October	194	184	172	183
November	198	231	198	209
December	300	250	270	273
Total	1800	1572	1700	1690

Another key point will be focused on the analysis of the electricity consumption in kWh and Albanian “Lek” which is used only for sanitary water as can be seen in Table 5 and 6.

Table 5. Electricity consumption in ALL from sanitary water

Months	Consump. 2019 (ALL)	Consump. 2020 (ALL)	Consump. 2021 (ALL)	Av. Consump. 2019 – 2021 (ALL)
January	950	1045	950	982
February	760	807.5	855	808
March	760	855	855	823
April	665	760	760	728
May	665	760	665	697
June	475	570	475	507
July	475	475	475	475
August	475	475	475	475
September	475	570	570	538
October	665	760	665	697
November	855	855	760	823
December	950	855	855	887
Total	8170	8787.5	8360	8439

Table 6. Electricity consumption in kWh from sanitary water

Months	Consump. 2019 (kWh)	Consump. 2020 (kWh)	Consump. 2021 (kWh)	Av. Consump. 2019 – 2021 (kWh)
January	100	110	100	103
February	80	85	90	85
March	80	90	90	87
April	70	80	80	77
May	70	80	70	73
June	50	60	50	53
July	50	50	50	50
August	50	50	50	50
September	50	60	60	57
October	70	80	70	73
November	90	90	80	87
December	100	90	90	93
Total	860	925	880	888

In the Table 7 is shown all the combinations of the electricity consumption in kWh for heating/cooling area, sanitary water and mixing during the years 2019-2021.

Table 7. Electricity consumption in kWh from sanitary water

No.	Energy Cons. Categories	2019 (kWh)	2020 (kWh)	2021 (kWh)
1	Heat/Cool	1800	1572	1700
2	Sanitary Water	860	925	880
3	Mixing (LED, Oven, etc.)	75	50	70

To make the comparison between the energy needed for heating in the current state and after the recommended measures for thermal

insulation of the building, the energy needed by the building to be air conditioned in the current conditions in which it is located, taking into account the energy requirements for heating/cooling.

Calculations for the energy demand for heating take into account:

- Energy losses due to heat transfer of structures (calculation of coefficients for window, wall, doors etc. are given in the standards).
- Degree days of the area where the apartment is located
- Indoor and outdoor design temperatures
- Air infiltrations in the building

Fig. 3 depict energy losses of the residential apartment in current situation. Total energy losses due to heat transfer and air infiltration were 19668 W or 19.7 kW (including air infiltrations 0.35 V/h).

Based on the Albanian law [9] for the approval norms, rules and conditions of design and construction, production and storage of heat in buildings we calculate the Gvt volume loss coefficient.

$$G_{vt} = \frac{Q_0}{V * \Delta t} \quad (1)$$

where Gvt is volume loss coefficient, Q₀ is heat transfer losses, V is apartment volume, t_b is indoor temperature and t_j is outdoor temperature. Volume loss coefficient correspond to 0.7 which is in accordance to the Albanian normative.

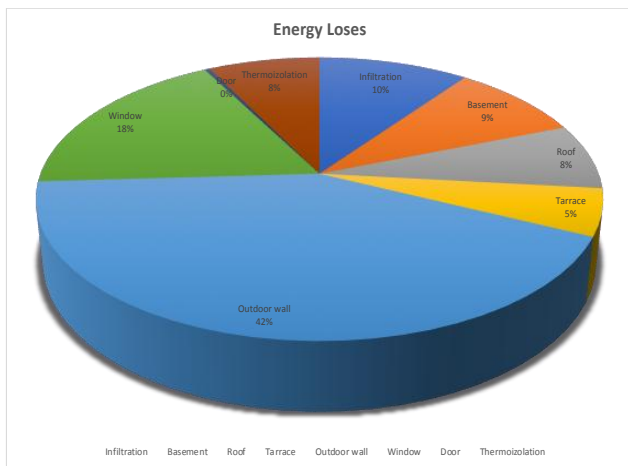


Fig. 3 Energy losses of the residential apartment

Energy requirements are based as if the building is heated in current conditions and it is with this energy performance. Energy required has been calculated as follow:

$$E_{year} = \frac{Q_0 * Grd * h / day}{\Delta t} \quad (2)$$

Where E_{year} is annual energy required for heating/cooling, Q₀ is total heat losses (transmission + infiltration), Grd is grade per day, h/day is number of hours of the building that will be heated and Δt is the temperature differences. Table 8 depict the final energy needs of the building for heating/cooling at the current state.

Table 8. Energy needs for heating/cooling

Comfort in the current state	Heating/Cooling 17 h/day
Annual Energy Needs	24423.7 (kWh/year)
Annual Specific Consumption	85 (kWh/year)

Based on the European norms type 2002/91/EC [12] in relation to the energy performance of the buildings we have defined that energy audit correspond to the D category as can be seen at Fig. 4.

Energy Label: Heat Demand Classification	from	to
A++	0.00	6.50 kWh/msa
A+	6.50	13.00 kWh/msa
A	13.00	26.00 kWh/msa
B	26.00	52.00 kWh/msa
C	52.00	78.00 kWh/msa
D	78.00	104.00 kWh/msa
E	104.00	130.00 kWh/msa
F	130.00	156.00 kWh/msa
G	156.00	kWh/msa

Fig. 4 Heat Demand Classification

4. Conclusion

In this research work we have briefly described an extensive literature regarding the calculation methods for the recommendation and implementation of energy efficiency measures in individual buildings. Based on the Albanian legislation, the following were calculated:

- Heat transfer coefficients of the building structure
- Calculation of the heat loss coefficient with Gvt transmission where the building under study was in accordance with Albanian legislation.
- The energy classification of the building according to European Norms (Class D).

Our results of the heat loss in buildings have shown this building had a higher energy consumption than what was recommended by the European norms. Based on it we will show some recommendations for improving the energy consumption of the apartment which are as follows:

- Thermal insulation of outdoor walls
- Thermal insulation of the terrace
- Thermal insulation of the roof
- Thermal insulation of the floor
- Installation of solar panels

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