Informatics Control Measurement
in Economy and Environment Protection

3/2018

Informatyka Automatyka Pomiary

w gospodarce i ochronie środowiska

www.e-IAPGOS.pl

ISSN 2083-0157

Kwartalnik Naukowo-Techniczny

fot. archiwum WNTU

**Winnicki Narodowy Uniwersytet Techniczny
(Winnica, Ukraina)**

3/2018

lipiec – wrzesień

Wydanie pod redakcją naukową
prof. dr hab. inż. Waldemara Wójcika

INFORMATYKA AUTOMATYKA POMIARY
W GOSPODARCE i OCHRONIE ŚRODOWISKA
Informatics Control Measurement in Economy and Environment Protection

p-ISSN 2083-0157, e-ISSN 2391-6761, www.e-iapgos.pl

INTERNATIONAL PROGRAMME COMMITTEE – RADA PROGRAMOWO-NAUKOWA

EDITORIAL OFFICE – REDAKCJA

Redakcja czasopisma
Informatyka, Automatyka, Pomiary w Gospodarce i Ochronie Środowiska
Instytut Elektroniki i Technik Informacyjnych
Politechnika Lubelska
ul. Nadbystrzycka 38A
20-618 Lublin
tel. +48 81 53 84 309
fax: +48 81 53 84 312
www.e-iapgos.pl
iapgos@pollub.pl

PUBLISHER – WYDAWCA

Politechnika Lubelska
ul. Nadbystrzycka 38D
20-618 Lublin
tel. +48 81 53 84 100
www.pollub.pl

PRINTING HOUSE – DRUKARNIA

Agencja Reklamowa TOP
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  Kluszczyński K. *Modelowanie – umiejętność czy sztuka?* Informatyka, Automatyka, Pomiary w Gospodarce i Ochronie Środowiska – IAPGOS, 1/2016, 4–15, DOI: 10.5604/20830157.1193833.

CONTENTS – SPIS TREŚCI

DOI: 10.5604/01.3001.0012.5273

FLOW VELOCITY MEASUREMENTS IN THE OPEN CHANNELS

Volodymyr Drevetskiy, Roman Muran
National university of water and environmental engineering, Department of automation, electrotechnical and computer-integrated technologies

Abstract. *This study aimed at determining dependencies between incident wave height and flow velocity in open flow channels by utilizing computer vision algorithms. Authors use computer modeling and experimental studies to check possibilities of flow velocity measurement by measuring incident wave height in front of semi-submerged artificial obstacle placed in the open flow channel.*

Keywords: fluid flow, computer vision, artificial obstacle

POMIAR PRĘDKOŚĆ PRZEPŁYWU W OTWARTYCH KANAŁACH

Streszczenie. *Badanie skierowane na wyznaczenie zależności pomiędzy wysokością nadchodzącej fali a prędkością strumienia w otwartych kanałach z użyciem narzędzi widzenia komputerowego. Autorzy korzystają z modelowania komputerowego oraz badań eksperymentalnych do sprawdzenia możliwości wyznaczenia prędkości strumienia poprzez pomiar wysokość fali padającej na częściowo zanurzoną sztuczną przeszkodę znajdującą się na otwartym kanale.*

Słowa kluczowe: przepływ płynu, widzenie komputerowe, sztuczna przeszkoda

Introduction

Measuring the velocity of fluids in the open channels is an important problem in monitoring the state of natural open streams. The 24-hour monitoring of flow velocity in rivers is a key task for the prevention of emergencies and timely public awareness about floods, preventing the erosion of the river bed and collapse of the bridge supports. Available systems are not autonomous and require human participation to conduct measurements near the hydrometric station. This study is aimed at developing a method for measuring the velocity of water in an open stream based on a combined hydrodynamic-optical method.

There are two common methods of measuring the velocity in open channels – contact and non-contact. Among the contact ways, the most widely used methods utilize buoyes, hydrometric turbines and hydrometric tubes. These methods are easy to use but require frequent maintenance and operator presence during measurements and do not provide high accuracy. Typical non-contact methods include thermal, ultrasonic and acoustic methods. Their advantage is high accuracy, however, they require a significant preparations and have high cost [1].

1. Main ideas and methods

Main idea of the developed method is to measure the height of the water level in front of the obstacle, half-immersed in the flow, with the help of modern microprocessor and computer vision systems. Semi-immersed obstacle, creates turbulence zones in the profile of the flow, that result into difference in pressure, water level, change in the direction of flow. With the help of the cameras installed near the obstacle, authors suggest to perform photo and video shooting of the level difference zone (incident wave) in front of an obstacle, and the resulting images are processed by means of computer vision resulting in measuring the altitude of the incident wave with sufficient accuracy.

Most of the available studies in the area of near-obstacle flow are aimed at reducing turbulence around it, but in this study it is important to increase the incident wave height by choosing shape of an obstacle that will create the most disturbance of the flow. Available studies of similar bodies are carried out for vortex flow meters using the Karman effect for measurements, but the obstacles there are completely immersed in the flow [2].

Initially, authors researched the existence of a dependence between the height of the incident wave in front of an obstacle and the flow velocity in the open channel. To choose the optimal form of an obstacle, authors performed computer modeling in Solidworks environment. Main criterias of optimality were the geometric sizes of turbulence zones and the technological availability of selected shape. Authors selected obstacles of different shapes and forms: cylindrical, rectangular, triangular and created 3D models of each of them by means of the 3D-CAD system. To visualize the size of the turbulence zones for different shapes, the model contained four obstacles placed near each other. The simulation was done by the finite element method, and the polygonal mesh of the model consisted of 17460 elements.

A visualization of the flow parameters was performed with emphasis on the size of turbulence zones around the selected obstacle models at a flow velocity of 0.55 m/s (Figure 1). According to the simulation results, cylindrical and rectangular obstacles are streamlined and as a result create small turbulence zones around them. The V-shaped form leads to the formation of a large turbulence zone behind the obstacle, but the size of the turbulence zone in front of an obstacle may not be sufficient to obtain the measurement signal. The A-shaped obstacle fits set criterias of optimality: it is least streamlined and creates the largest turbulences in the flow, with the formation of significant zones of turbulence not only behind but also ahead of obstacles. This will provide a reliable measurement signal and extend the range of measurements, as the turbulence zones will be observed at a lower flow velocities in the open stream.

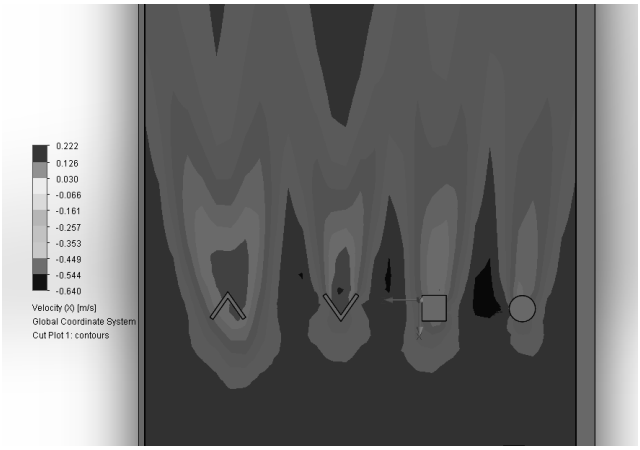

Fig. 1. Modelling of flow around different obstacles in CAD system Solidworks

Based on simulation results, authors performed experimental studies of the flow around obstacles of different shape. Obstacles were placed in the rectangular channel, with a width of 0.965 m (Figure 2), according to the computer model.

During the experiment, authors observed formation of two zones of level difference, in front and behind obstacles, and the formation of zones of turbulence around them (Figure 3).

Measurements were carried out at critical points, in particular at the highest point of the crest of the incident wave and in the zone of the lowest level behind the obstacle. Figure 4 depicts a level difference caused by obstacles of various shapes, where point 1 is the point of reference for water level in an open stream, measured in the zone that was not affected by turbulence; 2 is the

point of the highest level ahead of the obstacle, on the crest of the incident wave; 3 is the lowest point behind the obstacle.

The following results were obtained: the largest size of turbulence zones and incident waves were observed for the A-shaped obstacle, which confirms the results of computer simulation.

Fig. 2. Obstacle prototypes placed in rectangular channel

Fig. 3. Photo of turbulence zones around the obstacle: 1 – obstacle, 2 – free surface, 3 – incident wave, 4 – turbulence zone behind the obstacle

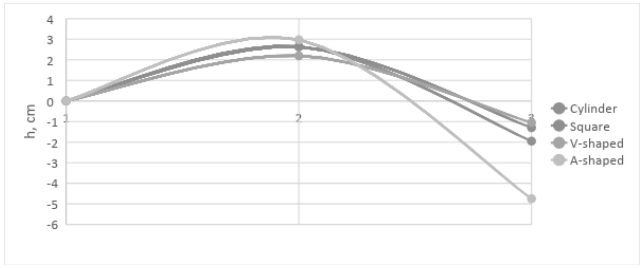

Fig. 4. Experimental results of water level differences for different shapes of obstacles

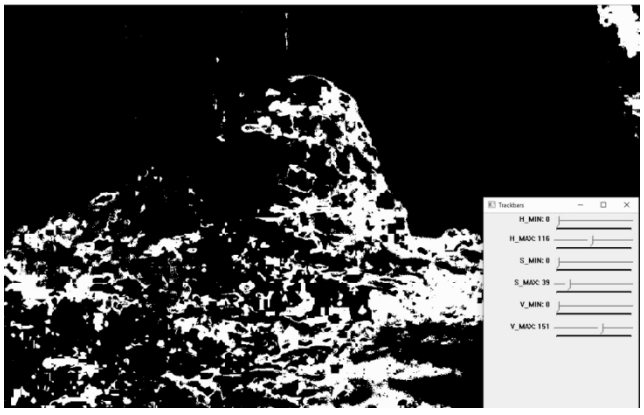

Fig. 5. Processed and filtered image of incident wave

Also, during the experiment, a preliminary test was performed to investigate technical capability of image capturing and processing. To do that, a few photos were taken for further software testing and setup. The resulting image (Figure 5) was processed using a threshold filter to select the contours of the incident wave in relation to the free surface. Based on that, authors confirmed expediency of using the optical method for obtaining the measurement information.

To visualize hydrodynamic processes occurring around the selected obstacle, a re-simulation was conducted in the Solidworks environment. According to the results of modeling, in front of the obstacle there was a separation of the flow into two parts - the ascending, which appears on the surface in the form of an incident wave and descending, resulting in the vortex at the bottom of an obstacle. Investigation of the downstream part of the flow is important for hydraulic engineering and research on bridge support erosion, but since this study is aimed at measuring the flow velocity, the further direction of research is connected with the ascending part of the stream (incident wave). The simulation results are shown in Figure 6.

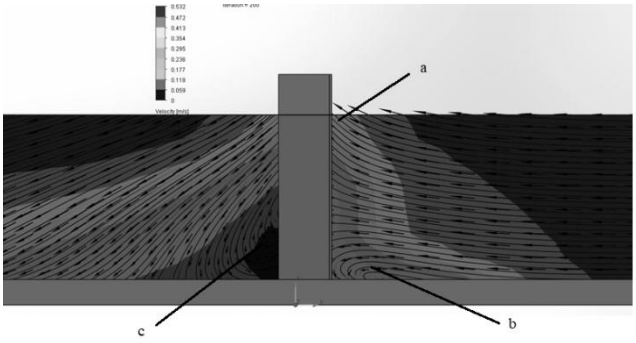

Fig. 6. Modelling of flow around the obstacle SolidWorks: a – incident wave, b – downflow, c – vortex behind the obstacle

To confirm the existence of a dependence between the height of the incident wave in front of the obstacle and flow velocity in the open stream, repeated experimental studies with the selected obstacle were conducted. A pre-selected body of A-shaped form was placed in a channel of rectangular shape with known geometric sizes.

During the research, measurements of the flow velocity and height of the free surface of water were made. The formation of turbulence zones around the obstacle was observed, in particular - two zones of significant difference in water level in front of and behind the obstacle. Measurements were made at the water velocity in the channel from 0.21 m/s to 0.55 m/s, which is a typical value for plain rivers. As the speed increased, an increase in the size of the turbulence zones and the height of the water level changes around the obstacle were observed. Based on the experimental data authors determined dependence of the incident wave height on the speed of water in the open channel for the selected obstacle. The given experimental data are obtained for the selected obstacle, and are approximated by a polynomial: $y = 48.29x^3 - 56.552x^2 + 35.419x - 4.6681$ with determination coefficient $R^2 = 1$ (Figure 7).

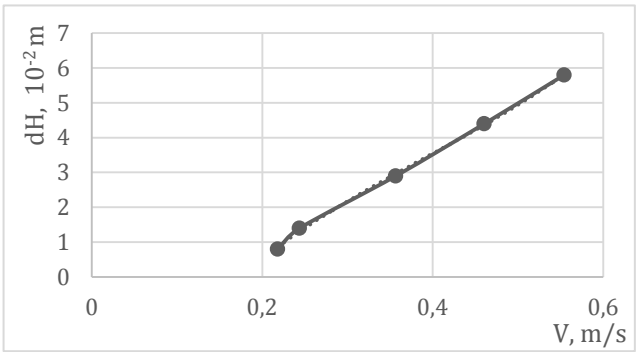

Fig. 7. Experimental dependence between incident wave height and flow velocity

Also, during experimental research, created measurement complex was tested. It consists of the webcam that was installed both in front and next to the obstacle, which allows real-time photo and video shooting of hydrodynamic processes occurring near an artificial obstacle (Figure 8), and the server that processed the received visual information using developed software.

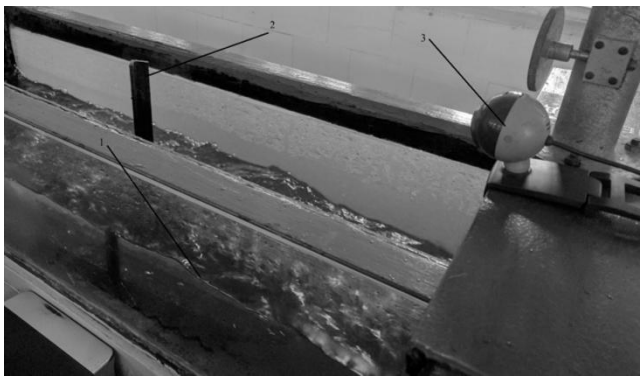

Fig. 8. Image capturing of incident wave: 1 – rectangular channel, 2 – artificial obstacle, 3 – camera

OpenCV library and CodeBlocks environment were used to collect and process image and video data. The developed software uses threshold filters with the ability to manually adjust, which is appropriate for changes in light levels and color of a stream. The image processing was carried out in several steps: first, the necessary part of the image, which contains the incident wave, was cut out. Next, the color model of the image was converted from RGB (red, green, blue) to HSV (hue, saturation, value). The convenience of this method is to simplify getting measurement results, since the converted image contains only two colors, which are converted into binary values. After the image conversion, a threshold filter is applied using the ability to manually adjust the maximum and minimum threshold values for each component of the color model. When conducting the experiment, the manual settings of threshold filter were changed in real time, on a video stream for previously unprepared environment. In order to reduce the visual noise during automatic measurements, there may be a need to install additional light sources or use bright water coloring, but during semi-automatic measurements, the resulting images can be sent to the server for further analysis and processing. Figures 9 and 10 show the original and filtered image at different camera positions.

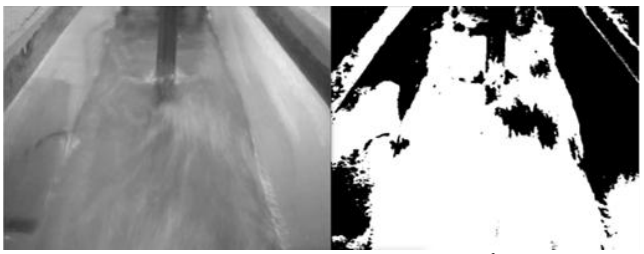

Fig. 9. Captured images of the incident wave: a) original image, b) filtered image

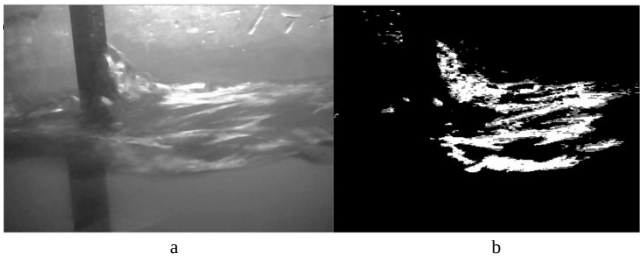

Fig. 10. Captured images of incident wave by camera placed beside the obstacle: a) original image, b) filtered image

Based on the results of experiments authors created remote monitoring system of flow velocity in open channels. Technical implementation is based on the Raspberry Pi 3B microprocessor platform based on the ARM architecture. Its advantages are: availability of hardware parts, the ability to scale, the convenience of configuring, and use of open-source and free software repositories.

On the platform, the Apache Web server, the SSH server and the FTP server based on the Vsftpd module were configured, and the video capturing capability was implemented with the Motion module. Combination of these protocols and applications allows not only to transmit measurement data remotely but also to remotely reconfigure the device, send control signals to any other elements connected to the server. The system used a client-server architecture, but it was decided to abandon the client part as a separate application, since it allows you to measure or make changes to the system only from individual clients and a limited number of devices. Therefore, a Web-SCADA system was created based on html, php, javascript, which allows access from anywhere in the world and from any device that has a browser.

Technical implementation of the Web-SCADA system is based on the use of Dynamic DNS technology, since the SCADA web-page is stored on a microprocessor platform that is connected to the Internet via a router. Port forwarding was configured when accessed via HTTP port 80, which allows you to access the page not only from the local network but from anywhere in the world.

2. Conclusion

As a result of experimental studies, the dependencies between the hydrodynamic parameters of the turbulence zones around the semi-immersed artificial obstacles in the open stream and the velocity of water and were discovered. Based on the results of the experiment, a combined hydrodynamic-optical measurement method was developed and a technical implementation of the measuring complex in the form of a server and Web-SCADA system was created, allowing remote reliable operational monitoring of the measurement parameters.

Further research is planned to investigate measuring the velocity distribution not only in height but also in the width of the flow profile as well as measuring the profile of the channel, for switching from measuring the velocity to measuring the flow in open stream.

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Prof. Volodymyr Drevetskiy
e-mail: westra@rv.uar.net

Vice president of Engineering Academy of Ukraine, Head of Automation, electrical and computer-integrated technologies department (NUWEE).
Main scientific direction – development of methods and devices for continuous automatic monitoring of physical and mechanical parameters of Newtonian and non-Newtonian fluids, as well as quality of oil products. Author of over 200 scientific papers, including 51 patents, most of which are implemented in production.

M.Sc. Roman Muran
e-mail: muranroman@gmail.com

Postgraduate student of the Department of Automation, electrical and computer-integrated technologies (NUWEE).

otrzymano/received: 29.07.2018 *przyjęto do druku/accepted: 15.09.2018*

DOI: 10.5604/01.3001.0012.5274

INSTRUMENT DESIGN FOR CYBER RISK ASSESSMENT IN INSURABILITY VERIFICATION

David Nicolas Bartolini[1], Andreas Ahrens[2], Jelena Zascerinska[2]
[1]Universidad Politécnica de Madrid, [2]Hochschule Wismar, University of Applied Sciences, Technology, Business and Design

Abstract. *Cyber risk assessment for insurability verification has been paid a lot of research interest as cyber insurance represents a new dynamic segment of market with considerable growth potential for insurers. As customer's practices and processes consistently lead to the final overall result, customer's behaviour has to be described in detail. The aim of the present paper is to design an instrument (questionnaire) for customer's cyber risk assessment in insurability verification. The method for building an instrument (questionnaire) is empirical research. Empirical research is based on use of empirical evidence. A questionnaire with 11 questions is proposed.*

Keywords: cyber risk management, cyber insurance, information security, data protection

PROJEKTOWANIE INSTRUMENTÓW PRZEZNACZONYCH DO OCENY ZAGROŻENIA RYZYKA CYBERNETYCZNEGO W WERYFIKACJI UBEZPIECZALNOŚCI

Streszczenie. *Ocena ryzyka związana z bezpieczeństwem cybernetycznym jest przedmiotem dużego zainteresowania badawczego, ze względu na to, że bezpieczeństwo cybernetyczne stanowi nowy, dynamiczny segment rynku o znacznym potencjale wzrostu dla ubezpieczycieli. Ponieważ praktyki i procesy klienta w ciągły sposób wpływają na końcową ocenę, zachowanie klienta musi być szczegółowo opisane. Celem niniejszego artykułu jest opracowanie instrumentu (kwestionariusza) do oceny ryzyka cybernetycznego klienta w ramach weryfikacji ubezpieczenia. Metoda budowy instrumentu (kwestionariusz) to badania empiryczne. Badania empiryczne opierają się na wykorzystaniu dowodów empirycznych. Zaproponowano kwestionariusz składający się z 11 pytań.*

Słowa kluczowe: zarządzenie ryzykiem cybernetycznym, ubezpieczenie cybernetyczne, bezpieczeństwo informacji, ochrona danych

Introduction

Cyber risk assessment for insurability verification has been paid a lot of research interest as cyber insurance represents a new dynamic segment of market with considerable growth potential for insurers. Companies estimate a premium potential of at least 700 million euros in Germany by the end of 2018. Many companies, especially small and medium-sized ones, continue to underestimate risks associated with using the Internet. In large companies, safety management is in general better trained in comparison to medium-sized companies. But further challenges for companies are regulatory challenges in the context of General Data Protection Regulation (GDPR) and requirements of the IT security law, among others for operators of critical infrastructures. The global network creates problems that have gained significance under the term *cyber risks*. Any company connected to the Internet is vulnerable. Attacks on Sony, Google, Amazon and German Bundestag show the dimensions. Thus, a number of approaches, methods, tools and instruments have been developed for organisation's cyber risk assessment in insurability verification. However, as customer's practices and processes in an organisation consistently lead to the final overall result, customer's behavior has to be described in detail. Assessment combines information security relevant standards such as ISO 27001, NIST, BSI Standard, Cobit, etc. and enables cyber security assessment. Cybersecurity is "the process of protecting information through prevention" [10]. Cyber events can have financial, operational, legal and reputational implications. Cyber incidents can have a significant impact on corporate capital. Costs may include forensic investigations, PR campaigns, legal fees and court fees, consumer credit monitoring, technology changes and comprehensive recovery measures [2]. Cybersecurity therefore needs to be integrated across the enterprise as part of corporate governance processes, information security, business continuity and third-party risk management. Cybersecurity roles and processes referred to in the assessment may have separate roles within the security group (or outsourced) or may be part of broader roles in an organisation. As IT security experts point out that it has become impossible to prevent data breaches, each organisation is considered to be unique that demands on an individual approach. For these purposes, Cyber Risk Dialogue to identify jointly insurance-relevant customer risks was elaborated [1]. According to Cyber Risk Dialogue [1], a dialogue cannot represent a risk assessment and should also be conducted openly and serve as an exchange between clients and insurers. Cyber Risk Dialogue [1] is based on such an instrument as questionnaire.

The aim of the present paper is to design an instrument (questionnaire) for customer's cyber risk assessment in insurability verification. The method, an instrument (questionnaire) for customer's cyber risk assessment in insurability verification is built, is identified as empirical research. Empirical research employs the use of empirical evidence, namely gaining knowledge by means of direct and indirect observation or experience.

1. Questionnaire design

The questionnaire is structured according to such domains and maturity levels of the respective customer as Existing certifications, IT security Organisation (IT security and risk management), Awareness for information security, Use of external service providers and contract management, Protection of IT systems, Network protection, Detection of attacks, Data management and storage, Access and access protection, and Physical security.

Each domain and maturity level have characteristics that are classified according to valuation factors. Statements are categorized to assess customer's situation and track common areas across all maturity levels. Components are groups of similar statements to facilitate or comprehensively organize the handling of assessment. Based on a total of 38 questions (according to [5–11]), the questionnaire could be filled in with the findings from the risk dialogue by the risk engineer. This questionnaire is assessed by the Cyber Risk Engineer. This assessment provides the insurer, and risk engineer, with a repeatable, reproducible and measurable process to inform underwriters of client's risks and to assist in verifying insurability of cyber security. Cybersecurity maturity level includes domains, valuation factors, components and individual implementations of measures across four levels of responsiveness to identify specific controls and practices. Each maturity level contains a descriptive characteristic or a characteristic. Each of the questions contains four different answer options, which correspond to the respective risk situation of customer. Risk Engineer determines which category client's current practices best suit. All statements in each domain and in all included levels must be answered and classified qualitatively to achieve a best possible maturity of this domain. Risk Engineer can determine a maturity level of customer in each area, but assessment is not intended to determine a general maturity level

of cyber security only based on these 38 questions in an equally weighted form. On the one hand, domains which do not apply to the respective customer must be excluded, for example if outsourcing is not carried out. Questions or domains that are not applicable to the respective customer have no influence on the determination of specific insurance capability.

In principle, an equivalent quantification of rating can be made from 38 questions. Questionnaire is logically staggered so that a rating can be made based on the respective maturity of answers (between 1 = weak maturity and 4 = strong maturity). This can be calculated using the arithmetic mean formula:

$$\bar{x}_{\text{arithm}} = \frac{1}{n}\sum_{i=1}^{n} x_i = \frac{x_1 + x_2 + \cdots + x_n}{n} \tag{1}$$

If the minimum rating value (> 2.00) is reached, the company is generally insurable.

However, Risk Engineers have incorporated an exception to this fundamental weighting in the risk assessment, since there are 11 show stopper topics as shown in Table 1 within the questions or domains, which must be considered separately.

Inherent risk profile and company's maturity may change over time as threats, vulnerabilities and operating environments change. However, fundamental domains and maturity's levels are a prerequisite for company's cybersecurity, categorized as a show stopper.

2. Show stopper description

The present part of the paper clarifies the choice of 11 questions classified as show stoppers and requirements to their minimum degree of maturity per area:

Does a security organization with defined roles and responsibilities exist?

Table 1. Showstopper

Showstopper / Questions	Minimum rating value
Does a security organization with defined roles and responsibilities exist?	2
Do employees succeed in raising awareness and training on information security and cyber-security?	3
Are there any specifications for the secure basic configuration (hardening) of IT systems?	2
Is malware protection implemented in your company?	2
Are there any procedures for patch and vulnerability management?	3
Are backups regularly performed and tested?	3
How are external accesses secured?	3
Are data transfers over unsecured networks protected?	2
Does the processing of information in the public cloud take place according to the requirements of your own information security?	2
Have password quality requirements been implemented?	2
Have physical security zones been defined?	2

Since customer must take a holistic approach to cyber security, identification of basic roles within a security organization is important.

The entrepreneur is therefore responsible for the organization of IT security in his/her company, but s/he cannot manage the task alone: the development of an IT security organization is necessary [4]. Depending on the company's size, there are distinctive characteristics to be considered. In a small company between 10 to 20 employees, it is difficult to create jobs that deal exclusively with the topic of IT security. Medium-sized companies may have financial means and the need for one or two full-time IT security jobs. International corporations cannot do without an extensive IT security organization.

In general, IT security must be exemplified. Management must make decisions, set precise targets and of course, set a good example for implementation. In addition, IT security must be carried to all company's areas, and it must be made clear that every employee is part of the IT security organization. An IT security officer should be appointed, even if not required by law. This can be an own employee or an external service provider. For core tasks, suitable employees must be appointed and equipped with sufficient skills. This is the only way to enforce the guidelines. Responsible employee must be given a necessary freedom to perform his/her duties adequately. Separation of functions is essential. For example, IT administrator may not be responsible for creating IT security policies at the same time [6]. All employees and executives (including management) must be regularly informed of the importance of compliance with the guidelines (e.g. SOX 2002, COSO 1992). This can be done through training, but better through advanced training or even small IT security competitions.

Do employees succeed in raising awareness and training on information security and cyber-security?

Human beings continue to be the greatest vulnerability in IT and non-digital information security. Whether out of good faith, ignorance or bad faith - confidential company data quickly falls into the wrong hands or the network is infected [14]. For example, phishing mails are a widespread form of social engineering, detection of the fake website, USB sticks left lying on the company's car park or in publicly accessible areas of the company [4], documents such as alleged salary list of the Executive Board or candidates for an upcoming wave of redundancies. There are many technical measures, but ultimately the user remains the weakest link in the chain.

Probably every user has already found such an email in her inbox. They can be used to pretend that you have completed a transaction on eBay, Amazon or PayPal with errors. You should correct this by visiting the site. If users follow this call, they will come across a website that looks very similar to the original. There they are asked to enter passwords or TANs. If now actually functioning Account-data is revealed, the theft starts on the real account.

Detection of the fake website is usually easy, indications are, for example, security certificates expired, faulty or not available at all. URL or domain of the website seem strange, like amazon. tv. There are spelling mistakes in the e-mail and on the website. Also, not to be despised are USB sticks that seem to have been left lying on the company car park or in publicly accessible areas of the company. If the curious finder connects such a stick to the computer, she will catch a sophisticated Malware or Ransomware and possibly infect a large part of the company network. Finally, tempting are the documents contained therein, such as the alleged salary list of the Executive Board or the candidates for an upcoming wave of redundancies. It is assumed that the state-contracted malware Stuxnet also entered the Iranian atomic plant Natanz via USB stick.

However, no matter how an attack takes place or how you assess the threat situation: it is important that companies take themselves out of liability as far as possible and if they have established a comprehensive training and awareness-raising program, claims for damages can be passed on directly to the perpetrator. Incidentally, this is also the only sensible method of protecting oneself against any form of social engineering. There are many technical measures to filter e-mails or control accessed websites, but ultimately the user remains the weakest link in the chain. It is therefore important that companies achieve the required maturity level in risk assessment.

Are there any specifications for the secure basic configuration (hardening) of IT systems?

All measures taken in individual cases can only be effective to a fraction of their effectiveness as long as systems or system components, on which they are based, and respective application

to be secured are not sufficiently robust and built on a system environment that is secured in principle [2, 8]. For example, it is not sufficient to protect a database against unauthorized access if the operating system allows "anonymous" access at any time. Customers need to know and secure concrete operating system architectures as well as the general system and basic services they use.

Is malware protection implemented in your company?

As malicious code is one of the most important tools used by attackers [12], customer must take appropriate countermeasures and reach the minimum maturity level.

Because malicious code is one of the most important tools used by attackers, the customer must take appropriate countermeasures and reach the minimum maturity level. Every company should put together appropriate preventive measures against malware and regulate how it should be handled in the event of a malware infection. In addition to the classic computer viruses, malware also includes Trojan horses, computer worms and malicious software causing Ransomware. A security concept against malware should be developed as a basis for preventing the intrusion of malware into IT systems. Aware of the residual risk, measures must be taken to prevent the intrusion of malicious programs. If a preventive defense is not successful, the intrusion of malware should be detected as early as possible. The consistent application of the measures and constant updating of the technical methods used are essential.

Are there any procedures for patch and vulnerability management?

Since vulnerable software is a risk, a controlled process for patch management must be in place at customer's premises. Patch management is the process that evaluates, controls and installs software updates during operations. This ensures the functionality of used software components, eliminates security gaps and thus increases the stability of the production environment. Use of outdated software and resulting adverse effects on system security can have a negative impact on interruption of business-critical infrastructures, data theft and data integrity, etc. In addition to hardware and software specifications, these include dependencies among each other. By means of a patch management process, company ensures the best possible security process and reduces risk.

Are backups regularly performed and tested?

Regular data backups must be performed to avoid data loss. In most computer systems, these can be largely automated. Rules must be set to determine which data is backed up by whom and when. All users should be informed about the rules for data backup to be able to point out any shortcomings (e. g. too little time interval for their needs) or to be able to make individual additions (e. g. mirroring important data on their own disk). Confidential data should be encrypted before the backup to ensure decryption even after a longer period.

How are external accesses secured?

Remote maintenance of IT systems involves security risks. In case of remote maintenance, a distinction must be made between internal and external maintenance personnel accessing the IT systems [1].

Are data transfers over unsecured networks protected?

In the age of digitalization, data are constantly in motion. They are transferred from one point to the next via different devices. End-to-end encryption is an effective protection measure for communication via e-mail.

Does the processing of information in the public cloud take place according to the requirements of your own information security?

Various alternatives for cloud computing must be developed on a broad scale and subjected to a security analysis adapted to customer's organization. Distinguishing features of the alternatives include, among other things, localities of the data centers, options for restricting the public cloud to specific regions, control options for the data flow and service levels offered [3, 7]. Contracts and service level agreements (SLAs) describe a complete and controllable service to guarantee quality and information security in the public cloud. It is also important to have own audit rights, key figures, migration and above all the regulations for terminating the contractual relationship.

Have password quality requirements been implemented?

Insecure passwords can be found quickly by crackers via simply trying them out (e. g. brute force attack, dictionary attack). The risk of becoming a victim of such an attack can be significantly reduced by users' changing their passwords on a regular basis, paying attention to the security of passwords [6, 9, 10, 11, 13]. A formal management process for the authentication information is required [7].

Have physical security zones been defined?

The Physical Security monitoring area deals with all aspects of secure organizational environment. The monitoring area is divided into two fields, namely Securing Areas, such as Entrance Areas and Rooms, and Securing the Equipment from Theft, Misuse, etc. Entrance controls ensure access to sensitive organizational areas. Technically based solutions are available in the form of terminals up to contactless detection. Earthquakes, tsunami, war or a fire can also have devastating effects. As a result, data and data media should be stored securely, the data center should be securely equipped, and all backup media should be stored at different (but also secured) location [1]. Equally important are various cable connections (power, fiber optic and copper cables for data transmission). The equipment required in a data center, such as air conditioning, emergency generators, UPS, ventilation, water supply, sewage, fire alarm system (incl. smoke detector, fire extinguisher and sprinkler system) and telecommunications must be checked and maintained [4]. Depending on the need for security, replacement systems should also be available. The most important protection against unauthorized persons is the sensitization of employees. To achieve the best level in the maturity model, the lifecycle model (Plan-Do-Check-Act) requires ongoing monitoring and maintenance. Insurability can already be reached (minimum 2) beforehand.

3. Remarks and conclusion

Instrument (questionnaire with 11 questions) has been designed. Depending on the customer's needs and wishes, Risk Engineer can formulate improvements for each domain or across domains. A gap analysis can be created between the current and the target maturity level. Customer can initiate improvements based on the identified gaps. Any organizational or technical weakness can necessitate many strategies and processes that have an enterprise-wide impact. For example, risk engineers' feedback on individual domains that do not reach yet a required maturity can provide insight into new policies, processes, procedures and controls to improve risk management about a risk or the customer's overall cyber-security readiness.

Further work will focus on the one hand on the development potential of loss probabilities in selected industries. This includes possible data mining strategies on collected data breach information's. On the other hand, future cyber insurance products will also have to focus more on the effects of the GDPR. For this reason, data privacy and information security requirements will also be addressed in the further work and the challenges will be worked out, as well as additional and necessary showstopper questions will be developed.

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M.Sc. David Nicolas Bartolini
e-mail: davidnicolas.bartolini@alumnos.upm.es

David Nicolas Bartolini received the Master of Science degree in Business Informatics from University of Wismar, Germany, in 2017. Currently, he is a Ph.D. student at the Polytechnic University of Madrid, Spain. His main field of interest include Cyber Risk Management, Cyber Insurance and Machine Learning.

Prof. Dr.-Ing. habil. Andreas Ahrens
e-mail: andreas.ahrens@hs-wismar.de

Andreas Ahrens received the Dr.-Ing. and Dr.-Ing. habil. degree from the University of Rostock in 2000 and 2003, respectively. In 2008, he became a Professor for Signal and System theory at the Hochschule Wismar, University of Technology, Business and Design, Germany. His main field of interest includes error correcting codes, multiple-input multiple-output systems, iterative detection for both wireline and wireless communication as well as social computing.

Dr. Jelena Zascerinska
e-mail: knezna@inbox.lv

Jeļena Zaščerinska was awarded Dr. Degree from University of Latvia in 2011. In 2012 she became a leading researcher at Centre for Education and Innovation Research, Latvia. She received research grants. In 2012 she was bestowed expert rights by Latvian Council of Science, in 2013 – by Horizon 2020, in 2017 – by National Science Centre, Krakow, Poland. Since 2013 she has been actively acting as Editorial Board Member and Reviewer in international scientific journals.

otrzymano/received: 1.08.2018 *przyjęto do druku/accepted: 15.09.2018*

DOI: 10.5604/01.3001.0012.5275

MULTICRITERION ANALYSIS AND CHOOSING OF THE OPTIMAL ROUTING IN AD-HOC NETWORKS

Valeriy Bezruk, Kyrylo Halchenko
Kharkiv National University of Radioelectronics, Department "Information and Network Engineering"

Abstract*. The paper discusses the practical aspects of application of multicriterion approach to solving the problem of an optimal routing for wireless self-organizing networks. As the initial metrics analyzed convergence time, memory overhead, control overhead, time complexity and communication complexity.*

Keywords. ad-hoc network, routing protocols, optimization.

ANALIZA WIELOKRYTERIALNA I WYBÓR OPTYMALNEJ TRASY ROUTINGU W SIECIACH AD-HOC

Streszczenie*. W artykule omówiono praktyczne aspekty zastosowania podejścia wielokryterialnego do rozwiązania problemu optymalnego trasowania dla bezprzewodowych samoorganizujących się sieci. Jako początkowe metryki analizowano czas zbieżności, narzut pamięci, narzut sterowania, złożoność czasu i złożoność komunikacji.*

Słowa kluczowe: sieci ad-hoc, protokoły routing, optymalizacja

Introduction

Ad-hoc network is a network of self-sustaining, without using a single access point [4]. When creating such networks do not develop any map location of their deployment and previous plans because they are usually small and have limited long enough for the transfer of shared data in the event of such need. Also standard is not limited to the number of devices that may be included in an independent basic service area. Ad-hoc structure is suitable for the rapid deployment of networks. This mode requires minimal equipment: each station must be equipped with a wireless adapter. With this configuration, no need to create network infrastructure. The main disadvantages of ad-hoc mode are limited to the range of the network, limitations imposed on the power devices and the problem of routing with substantial mobility of nodes.

The routing protocols can be classified into three groups: global/proactive, on-demand, reactive and hybrid [1, 5, 7]. In proactive routing protocols the routes to all the destination (or parts of the network) are determined at the start up, and maintained by using a periodic route update process. In reactive protocols routes are determined, when they are required by the source using a route discovery process. Hybrid routing protocols combine the basic properties of the first two classes of protocols into one. That is they are both reactive and proactive in nature.

The large number of routing protocols specific to these networks is an urgent task of choosing the of optimal protocols with using the set of objective quality indicators. They are determined by basic metrics such as convergence time, memory overhead, control overhead, time complexity and communication complexity. The important task also is a choice of the optimal routes in network with using the set of objective quality indicators [2, 3].

It determines the necessity of the use for this purpose methods of multicriterion optimization. Thus, actual are researches of features of application of methods of multicriterion optimization at the decision of tasks of routing in ad-hoc networks. Therefore in this work for solution these tasks it is proposed to use the methods of multicriterion optimization in ad-hoc networks.

In addition, due to the increase in computing capabilities of devices used in Mesh networks, it is possible to implement individual smart protocols and routing methods in self-organizing networks. Firstly, most of advantages multicriteria optimization methods are already used in MANET, but earlier there was increased use of resources of the mesh, due to use compromise complex [6].

1. Choosing of the optimal variants system by multicriteria optimization methods

Let's consider the basic features of a choice of optimum variants of the routing systems with use of methods of multicriterion optimization. Suppose that the system is characterized by a set of objective quality indicators

$$\vec{k}(\phi) = (k_1(\phi), k_2(\phi), \ldots, k_m(\phi)) \quad (1)$$

They determines the influence of the structure s and the parameters vector β of the variant of the system $\phi = (s, \vec{b})$ upon the system quality indicators. Each variant of the system ϕ is mapped from a set of permissible variants Φ_d into the criteria space of estimates $V \in R^m$:

$$V = \vec{K}(\Phi_d) = \{\vec{v} \in R^m \mid \vec{v} = \vec{k}(\phi), \phi \in \Phi_D\}. \quad (2)$$

In this case to each approach ϕ corresponds its particular estimate of the selected quality indicators (1) and, vice versa, to each estimate corresponds an approach. When one can only attain the consistent optimum of introduced objective functions – the optimum according to the Pareto criteria, which implies that each of the indicators can be further improved singly by lowering the remaining quality indicators of the system.

To the Pareto optimum in the criteria space corresponds a set of Pareto-optimal estimates that satisfy the following expression [5, 6]:

$$P(V) = opt_{\geq} V = \{\vec{k}(\phi^0) \in R^m \mid \forall \vec{k}(\phi) \in V : \vec{k}(\phi) \geq \vec{k}(\phi^0)\}. \quad (3)$$

An optimum based on the Pareto criteria can be found either directly according to (2) by the exhaustive search of all permissible variants of the system Φ_D or with the use of special procedures such as the weighting method, methods of operating characteristics. In these methods the decision of the task of multicriterion optimization is taken to some great number of tasks of scalar optimization.

Found of the Pareto-optimal routing protocols and optimal subset routes at the ad-hoc networks has important properties. In choosing the Pareto-optimal variant are eliminated by far the worst routing protocols options for an unconditional preference criterion. Moreover, Pareto-optimal variant of the routing corresponding to the agreed quality indicators introduced optimum (private functions). It means that the extreme value is reached for each of the quality metrics, which may be achieved without deterioration in the quality values of other parameters.

Pareto-optimal routing protocols options, not comparable with each other and therefore are equivalent in terms of the Pareto criterion. Therefore, each of them may be used in solving special problems of routing based on a minimum power input devices, a minimum of overhead information or complexity of the algorithm that will uniformly load the link corresponding to the traffic types of the required quality of service. If there is the need for a single selection routing, this may be applied different methods of narrowing down to a single subset of Pareto options. This methods base on the value functions, the lexicographical approach, theory of fuzzy sets and other [2, 3]. In this methods the additional information is used from the experience experts.

The process of choosing optimal variants of routing includes such stages: setting the initial set of the system variants; separation of the permissible set of variants with regard of limitations on the network structure and parameters, limitation on the value of the quality indicators; choice of the subset of Pareto-optimal variants; choice of a single variant. The choosing of optimal design solutions by multicriterion optimization methods was implemented in a software package, based on Java.

It is not difficult to see that they correspond to the agreed optimum Pareto quality indicators (the minimum possible values of one quality indicator at a given fixed values of another indicator). This boundary is also a chart of the exchange of quality indicators, which shows how the potentially achievable value of one of the quality indicators depends on the value of another indicator.

The resulting subset of Pareto-optimal route variants can be used to organize multi-path routing and to select the optimal routes for transmitting the appropriate traffic with the required quality of service.

This raises the question: does it make sense to make a choice based on the unconditional criterion of preference (Pareto criterion), when further to choose a single route when faced to introduce conditional preference criterion. In justification of expediency of introduction of a stage of Pareto-optimal variants finding it is necessary to note:

- the use of the unconditional criterion of preference (UCP) makes it possible to find all Pareto-optimal routes, while discarding all certainly the worst route options,
- the use of UCP makes it possible to find the best possible values of each of the indicators of quality and the relationship between them,
- even if when choosing a single route option you have to enter a conditional preference criterion, it is better to enter all sorts of skills at a later stage of selection.

Methodology of choosing of the optimal of the routing protocols and optimal routes by multicriterion optimization methods was used for the decision of the different tasks of the designing in the area telecommunications taking into account totality of quality indicators. It is tasks of choice of optimal speech codecs and optimal types of modulation in the telecommunications systems, optimal structure and parameters of radio networks and transport networks and also radiotechnologies in mobile communication networks.

2. Consider given methods in routing process

Practical features of the solution of the specified multicriterion routing problem are considered using the example of a fragment of the communication network (Fig. 1).

The model of the network under investigation consists of twelve nodes linked by lossy communication [3]. We will consider the following quality on line:

- packet delay time,
- the level of packet of service indicators, which characterize each communication loss,
- cost of using the communication line.

We will assume that the packet delay time is determined mainly by the length of the communication lines. The level of packet loss depends on the loss model introduced in each line. The cost of using the line depends on the delay time on the line, the amount of loss and intensity of use. The research was conducted in the Network Simulator software package.

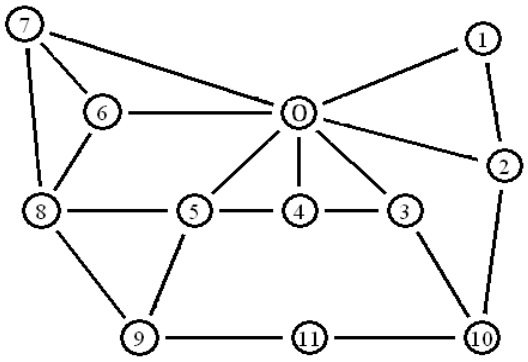

Fig. 1. The example of a fragment of the communication network

For description of investigated network and choice of optimal variant of routing the mathematical model was used in a kind $\{X,F\} \to x^*$ [7]. Here $X = \{x\}$ – set of routes on the network graph $G = (V,E)$; $F(x)$ – objective function of choice of the routes; x^* – optimal variant of the routing.

In case of the multicriteria approach to the choosing of the optimal routes on the set X it is given the vector of the objective function:

$$\vec{F}(x) = (F_1(x), \ldots F_j(x), \ldots F_m(x)) \tag{4}$$

Components of this function determine the values of quality routes indicators. The variant of the route $x^* \in X$ is Pareto-optimal route if another route $x \in X$ doesn't exist, order to perform inequality $F_j(x^*) \le F_j(\tilde{x}), j = 1,...,m,$ where at least one of the inequalities is strict [4]. When selecting a subset of the Pareto-optimal routes there was dropped a certainly worst variant in terms of the absolute criteria of preference. Pareto-optimal alternatives of the routes are equivalent to the Pareto criteria and could be used for organizing multipath routing in the multi-service telecommunication networks.

Network analysis shows that for each destination node there are many options to choose the route directly. These variants are presented in the criteria space of the two quality indicators – k_1 (delay time of packets transmission) and k_2 (the level of packets loss) (Fig. 2). Subset of the Pareto-optimal alternatives routes corresponds to the left lower border which includes three variants; they are marked (▲).

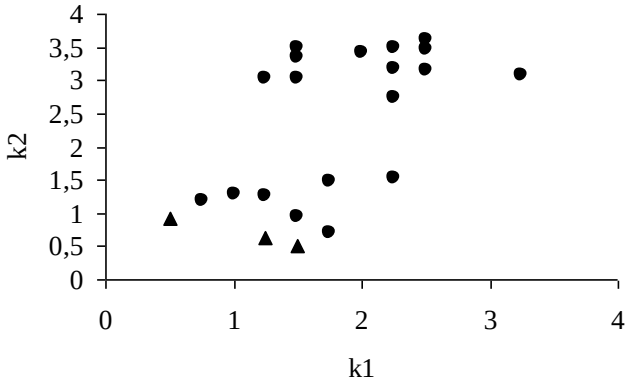

Fig. 2. Presenting of the variants of the routes in the criterial space of the two quality indicators

The resulting Pareto-optimal alternative routes can be used for organizing multipath routing in ad-hoc networks when using MPLS technology. It will allow to provide a load balancing and a traffic management and to provide given quality-of-service taking into account the set of the quality indicators.

Various methods based on attraction of some additional subjective information in the form of experts' judgments can be used for narrowing the Pareto set to the unique design solution. Theoretical and practical aspects of choosing the preferable version of routing protocols taking into account the totality of quality indices and experts' judgments based on hierarchical analysis method are considered. Scientific novelty of work consists in the application of hierarchy analysis method for comparative analysis and selection of a preferred version of routing protocols taking into account a set of indicators of quality and judgments of experts [3].

The hierarchical analysis method consists in decomposition of the problem of choosing a single project variant of a certain system for several levels and obtaining expert judgments on pair comparisons of various elements of the choice problem. As a result of processing the obtained numerical data according to a certain mathematical procedure receive components of the global priority vector that characterize the priority of choosing the versions of the projected system and determine the choice of the preferred design variant of the system.

The principle of comparative judgments of experts in the hierarchical analysis method is that the objects of the choice problem are compared by experts in pairs in importance, in particular, the system variants and quality indicators are compared. Estimates of paired comparisons of elements are found using subjective judgments of experts on the scale of relative importance of the elements. The results of paired comparisons are reduced to the matrix form. Next, the matrices of paired comparisons of different elements of the hierarchy are processed. From the mathematical point of view, this processing task is reduced to the calculation of the main eigenvector of the matrix of paired comparisons, which after normalization becomes the priority vector of the elements at the corresponding hierarchy level.

Matrixes of pair comparisons of system variants are found separately in relation to each indicator of system quality. On the basis of these matrices, the components of the corresponding main eigenvectors and priority vectors are calculated with respect to the quality indicators. Using this data, the values of the components of the global priority vector are calculated. The preferred version of the system is selected for the maximum value of the global priority vector components.

An example of choosing the preferred routing protocol from the set of existing variants of routing protocols taking into account three quality indicators is considered. Matrixes of pair comparisons of routing protocol variants are found separately in relation to each indicator of quality. On the basis of these matrices, the components of the corresponding main eigenvectors and priority vectors are calculated with respect to the quality indicators. Using this data, the values of the components of the global priority vector are calculated. The preferred version of the routing protocol is selected for the maximum value of the global priority vector components.

The comparison of the routing options routing according to the known OSPF Protocol. In the existing algorithm OSPF dynamic routing Protocol status (quality route) is defined by three characteristics: latency, throughput and reliability. However, only one of the quality metrics is selected and used for routing.

We illustrate the proposed multi-criteria approach to route selection and the approach to route selection based on the OSPF Protocol.

When using the multi-criteria approach, the set of Pareto-optimal routes, which is used in the organization of multi-path routing, the load lines are more uniform, there are no large overloads on individual communication lines, unlike OSPF routing. As a result, there is a gain of a multicriteria approach when taking into account the losses of packets and the cost of using communication lines with respect to the OSPF Protocol. Although OSPF will win in terms of a time delay, as he had chosen the path of only one indicator of quality.

The use of a variety of Pareto-optimal route options creates a more uniform load of lines, in addition, each route takes into account all the quality indicators and is the agreed optimum. Figure 3 shows that the multi-criteria approach takes into account and optimizes (minimizes) all quality indicators equally in a compromise (uniform) consideration of the importance of all quality indicators.

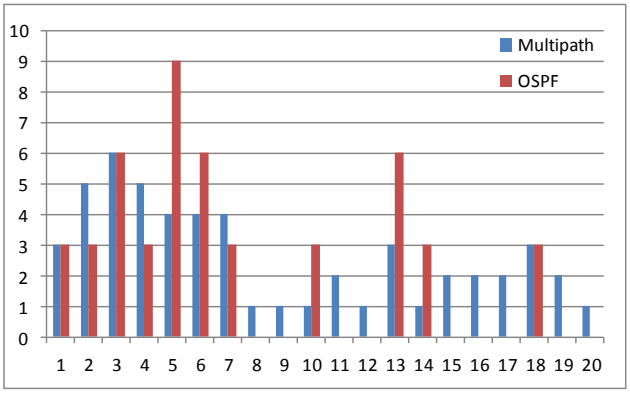

Fig. 3. The load of the lines using a set of Pareto-optimal routes (multipath routing) and OSPF routes

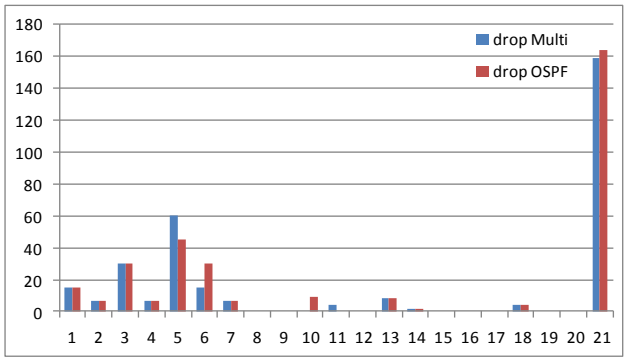

Fig. 4. Comparison of the multicriteria approach with the importance factors (0.3;0.3;0.4) and the OSPF Protocol for the packet loss on those routes

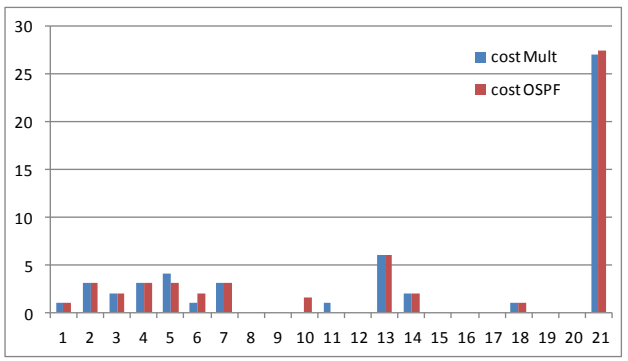

Fig. 5. Comparison of the multicriteria approach with the importance factors (0.3;0.3;0.4) and the OSPF Protocol for the cost of the selected routes

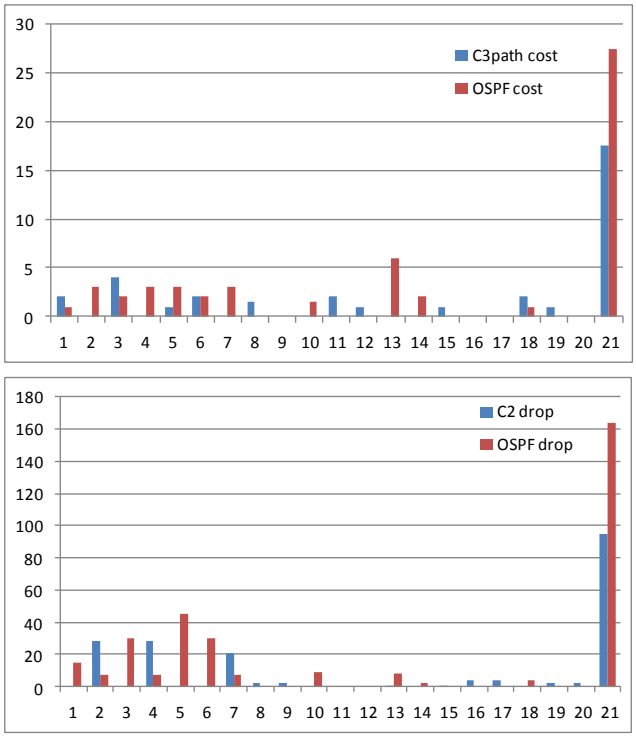

Fig. 6. Shows a comparison of the multicriteria approach with the importance coefficients(0.1;0.1;0.8), (0.1;0.8;0.1) and OSPF Protocol on the cost of selected routes and packet loss on these routes

With the introduction of conditional preference criterion, that is, the allocation of a more important quality indicator, relative to other possible from the set of Pareto- optimality routes to select a single option. When allocating from the point of view of the importance of a quality indicator, reflecting the cost of use of communication lines, are the routes corresponding to the coefficients of importance (0.1;0.1;0.8). When allocating from the point of view of the importance of quality score, reflecting the level of losses of packets are received routes that match the coefficients of importance (0.1;0.8;0.1).

3. Conclusions

1) Review of the existing routing protocols in ad-hoc networks is performed.
2) Methodology of choosing of the optimal of the routing protocols and optimal routes by the multicriteria optimization methods is obtained.
3) Software package for the multicriterion choice of optimal design decisions are proposed.
4) Results of the comparative analysis of the existing routing protocols based on the proposed methodology are discussed.
5) Practical features of the solution of the multicriteria routing problem are considered.
6) Pareto-optimal alternative routes can be used for the organizing multipath routing at the ad-hoc networks.
7) Examples of the problems of choice of the preferred version for different types of routing protocols are considered.
8) In comparsion with OSPF detected strong efficiency in lines loading on Pareto-optimal multicriteria routes.

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Prof. Valeriy Bezruk
e-mail: valerii.bezruk@nure.ua

Graduated from Kharkiv Institute of Radio Electronics, Ukraine (major "Radio engineering") in 1973. In 2004 he received the degree of Doctor of Technology and in 2005 he obtained the academic rank of professor. In 2009 he was elected as the head of Communication Networks department of Kharkiv National University of Radio Electronics. Scientific interests: signal recognition, probability modeling and multicriteria optimization of systems.

M.Sc. Kirill Halchenko
e-mail: kyrylo.halchenko@nure.ua

Graduated from Kharkiv National University of Radio Electronics, Ukraine (major "Informational Comunication Networks") in 2015. From 2015 - Postgraduate of Kharkiv National University of Radio Electronics. Scientific interests: network routing services, automated program interfaces services.

otrzymano/received: 15.03.2018 *przyjęto do druku/accepted: 15.09.2018*

DOI: 10.5604/01.3001.0012.5276

MODELS AND METHODS OF PROCESSING OF INFORMATION ON LOADS OF ACOUSTIC SIGNALS IN TECHNICAL DIAGNOSTIC SYSTEMS

Artem Sharko
National Technical University of Kherson, Faculty of Cybernetics and Systems Engineering

Abstract. *The paper presents one-dimensional discrete-continuous model of power spectrum estimation of the acoustic emission signal, that allows filtering the oscillating components of the acoustic emission signals. The mathematical formalism describing the environment was discussed, initiating the signals of acoustic emission. The problem of spectral analysis and synthesis of acoustic emission signals was solved with the help of Fourier transform. The dependence of acoustic vibrations spectra on the size of the medium parameters and microstructure has been discussed, as well.*

Keywords: acoustic wave modeling, discretization

MODELE I METODY PRZETWARZANIA INFORMACJI DLA SYGNAŁÓW AKUSTYCZNYCH W SYSTEMACH DIAGNOSTYKI TECHNICZNEJ

Streszczenie. *W artykule przedstawiony jednowymiarowy, dyskretno-ciągły model wyznaczania energii widma sygnału akustycznego, który pozwala na filtrowanie jego składowych widmowych. Rozwiązano formalizm matematyczny opisujący środowisko, inicjujący emisję sygnałów akustycznych, w którym problem analizy widmowej i syntezy emisji sygnałów akustycznych został rozwiązany z pomocą transformaty Fouriera. Przedyskutowano także wpływ widma wibracji akustycznych na wielkość parametrów ośrodka i jego mikrostrukturę.*

Słowa kluczowe: modelowanie fali akustycznej, dyskretyzacja

Introduction

The method of acoustic emission (AE) allows to conduct researches of kinetics by volume structural alteration on the different stages of materials deformation in real time. Physical nature of acoustic origin emission in materials is related to the processes of deformation and destruction [4, 5, 13, 17]. Models of the data processing in the system of determining defects by AE methods are based on the concepts of continuum environment and the continuum theory of dislocations, where the acoustic emission signal is indicative for a number of processes of the defect structure [2, 3, 12]. These processes are related to the movement of the dislocation the transition from elastic to plastic deformations, the extension of the dislocation loops and the annihilation of the separate sections of the structure [11, 15, 16].

The relevance of studying the energy spectrum of acoustic emission (AE) signals of nanoscale objects is explained by the importance of solving questions concerning the characteristics of propagation of acoustic oscillations preceding the destruction of materials. To solve the problems of analysis and synthesis of materials with the given properties, a well-developed hierarchy of mathematical models is needed.

The generalized continua of the mechanics of a deformed solid are based on the concepts of the representative volume of the medium and the inclusion of rotational degrees of freedom. Models are constructed as deductive, so that their results act as consequences of axioms or postulates of a single system of assumptions. This provides the possibility of a consistent classification of theories according to the selected characteristics.

Mathematical models of data processing in system of definition of imperfections by AE methodare based on the discrete representations and the models of a continuous medium and the continual theory of the acoustic wave distribution where AE signal characterizes the variety of processes of defective structure of materials development.

Violation of the internal structure of materials initiates the occurrence of AE signals and their further propagation in an elastic medium. Dislocations are transformed into a far field, which propagates in the form of a wave packet independently at the speed of elastic waves in the absence of a stress source.

The main tasks of the paper are: development of the mathematical models of explaining mechanism of emission accumulation on the basis of the developing defects energy concepts; obtainment of the analytical expressions of interrelation of fracture parameters with the characteristics of AE signals through the functions of the applied tension.

1. Formalization of the problem

Theoretical explanation of the change in the structure of nanoscale objects develops in two ways: use of discrete models and continual ones. A characteristic feature of the energy spectrum of AE signal is the dual mechanism for the formation of AE signals: the discrete nature of structural changes and the continuous propagation of acoustic waves. All this makes it urgent to develop mathematical models of media with a microstructure.

In the model of a continuous medium in the form of a linear chain, the atoms interact by means of paired central forces connecting atoms and directed along a straight line connecting the centers of atoms. The instantaneous model of a continuous medium is based on the fact that the interaction between atoms remains paired, but it is realized through forces and moments. In the structural model of a continuous medium, its motion in space is described not by the coordinates and velocities of individual particles, but by the scalar density field and the vector field of velocities.

Behavior of this cell under load is characterized by interaction with the environment and is described by kinematic variables. Such models include, as information parameters of the structure, the dimensions and shape of the particles, on which the modulus of elasticity depends.

2. Results and discussion

One of the most important elements of this apparatus of mathematical physics is the concept of a quasi-continuum, which allows one to consider discrete and continuous models within the framework of a single formalism.

By a quasi-continuum we mean a one-dimensional x-space and a class of admissible functions defined on it (Fig. 1).

It will assume that $a = const$, independent of n. The value of the function at the nodes is denoted by $u(n)$. At points $x = na$, the function $u(x)$ takes on the values $u(na)$ which are the shifts of the oscillating point [9].

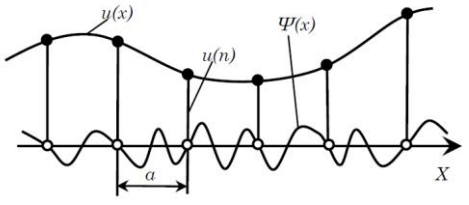

Fig. 1. One-dimensional quasicontinuum

The elementary one-dimensional model of a discrete non-local microstructure can be presented in the form of an unlimited linear chain of the pointwise masses connected with elastic connections Ψ (Fig. 2).

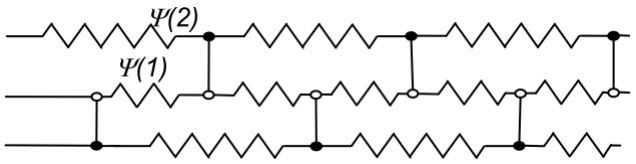

Fig. 2. Model of the discrete simple homogeneous structure: ○ – cooperating atoms of the basic chain; ● – the nearest neighbours

The potential energy of such a chain is a functional from a field of displacement $u(n)$, causing elastic oscillations in the environment of [10].

$$\Phi = \Phi_0 + \sum_n \Phi(n)u(n) + \frac{1}{2}\sum_{n,n'} \Phi(n,n')u(n)u(n') + \\ + \frac{1}{3!}\sum_{n,n',n''} \Phi(n,n',n'')u(n)u(n')u(n'') + \ldots \tag{1}$$

The difference of kinetic energy T and a potential energy Φ defines Lagrange function L. If medium particles are effected by exterior forces $q(n,t)$ Lagrange function in harmonious approach expresses law of energy conservation and takes a form

$$L = \frac{m}{2}\sum_n \dot{u}^2(n,t) - \frac{1}{2}\sum_{n,n'} \Phi(n,n')u(n,t)u(n',t) + \\ + \sum_n q(n,t)u(n,t) \tag{2}$$

Model parameters $\Phi(n)$, $\Phi(n, n')$, $\Phi(n, n', n'')$ are force constants. The force constants, defining the properties of such discrete model, are parameters of elastic connections between the particles.

The representation of function of one argument $\Phi(n)$ defines the elastic connections in a homogeneous linear chain.

$$\Phi(n) = \Phi(-n) \tag{3}$$

If $\Phi(n)$ is distinct from zero for $n > N$ each particle can cooperate with *N-neighbours* on the right and with *N-neighbours* on the left.

Taking into account Lagrange function the equation of an particles oscillated motion a linear chain will be the following

$$m\ddot{u}(n,t) + \sum_{n'} \Phi(n,n')u(n',t) = q(n,t) \tag{4}$$

In the real mechanical systems long-range action is always limited by medium damping.

$$\Phi(n) = -\Psi(n) \qquad n \neq 0 \tag{5}$$

Taking this fact into account for the two particles n and n' value of a potential energy Φ equals

$$\Phi = \frac{1}{2}\sum_{n,n'} \Phi(n,n')u(n)u(n') \tag{6}$$

The kinetic energy of such pointwise masses chain for displacement $u(n,t)$, which depends on time equals

$$T = \frac{m}{2}\sum_n \dot{u}^2(n,t) \tag{7}$$

The elementary model of a complicated medium can be presented as a linear chain divided into elementary cells, each of which consists of two masses connected by elastic connections (Fig. 3).

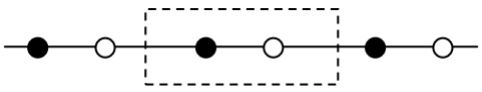

Fig. 3. Model of the discrete complicated structure

In this case the equation of the particles *of n-th* cell movement will be the following

$$m_j\ddot{\omega}(n,j) + \sum_{n'j'} \Phi(n-n',j,j')\omega(n',j') = f(n,j) \tag{8}$$

where n – cell number, m_j *(j=1,2)* – a mass of particles in a cell, *f(n, j)* – exterior force, $\omega(n, j)$ – displacement *of j-th* particle in *n-th* cell.

The wave of constant intensity can be the source of energy, which is lost at sudden decrease of rigidity. The wave concluded in an elastic forerunner leave from the front of destruction.

At metal straining the distance between the atoms under the influence of exterior forces varies, lines and the planes passing through atoms bent and at the expense of these facts the crystalline lattice is distorted. Elimination of the exterior forces between atoms again takes place in a crystalline lattice, and the material completely fills the volume it occupies.

Dislocations happen in places where the energy of activation, which is necessary for their formation, is reduced owing to the concentration of tension.

The energy demanded for the formation of the dislocation of one interatomic distance equals the energy, which is necessary for the formation of one vacant place in a lattice. In lack of other dislocations or imperfections it will move.

The transition from a discrete model to a continuum is done by extra-polarization of the functions given at discrete points by continuous fields of shifts and micro-turns. Depending on the number of expansion terms, we can consider different approximations of the discrete model of the structure of the medium and build a hierarchy of continual models.

The presence of internal connections between translational and rotational properties of a continuous medium is manifested in their connection with oscillatory properties.

In the mechanics of a continuous medium, the figure, which limits the region of structural changes during the initial stage of crack formation, has rotational symmetry if it passes into itself with all rotations. An analogue of such models is Cosserat model (Fig. 4).

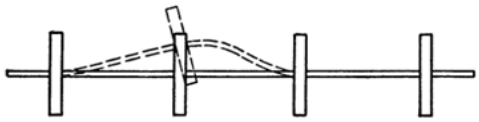

Fig. 4. Cosserat model

For this, in the model of a continuous medium that initiates the occurrence of AE signals (*Fig.* 5), it is necessary to introduce variables: relative displacement of particles inside the cell (9) and displacement of the cell center of mass (10) .

$$\eta(n) = \frac{m_1\xi_1 w(n,1) + m_2\xi_2 w(n,2)}{I} \tag{9}$$

$$u(n) = \frac{1}{m}\left[m_1 w(n,1) + m_2 w(n,2)\right] \tag{10}$$

where m_1 and m_2 are the masses of the atoms in the cell, I is the moment of the cell inertia, ξ_1 and ξ_2 are the coordinates of the particles in the cell with correspondence to the coordinate of the mass center, $m = m_1 + m_2$, $I = m_1\xi_1^2 + m_2\xi_2^2$.

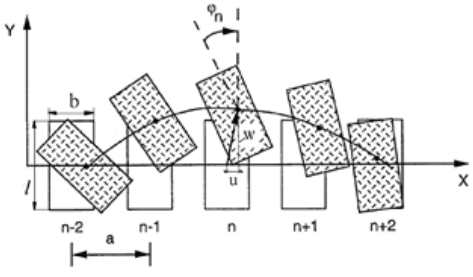

Fig. 5. Model for initiating acoustic emission signals

Equation of motion

$$m\ddot{u}(n)+\sum_{n'}\Phi^{00}(n-n')\eta(n')+\sum_{n'}\Phi^{01}(n-n')\eta(n')=q(n) \quad (11)$$

$$I\ddot{\eta}(n)+\sum_{n'}\Phi^{10}(n-n')\eta(n')+\sum_{n'}\Phi^{11}(n-n')\eta(n')=\mu(n) \quad (12)$$

Here, the matrix $\Phi^{ss'}(n)$ (s, s' = 0, 1) is coordinatewise expressed in terms of the power constants Φ (n, j, j') of the precursors of AE signal [8].

The use of information and structural modeling to analyze the spectrum of AE signals of precursors of occurrence of internal stresses in a material is based on Fourier transforms of AE signals.

Fourier transform preserves the signal energy. It is meaningful only for signals of finite duration, the energy of which is finite. The spectrum of such initial signals rapidly approaches zero. These provisions are in full accordance with the physical meaning of the acoustic emission phenomenon.

The graph of the complex numbers argument values is the phase spectrum, and the modulus graph is the amplitude spectrum. One of the main properties of Fourier transform is the independence of the amplitude spectrum from the time shift of the signal, since when the function moves only its phase spectrum changes.

Fourier image of a real signal has symmetry: the amplitude spectrum is always an even function. This allows us to reduce complex functions and their Fourier-images to simpler ones. The spectrum of the total time function is equal to the sum of the spectra of its components. In Fourier transform AE signal is distributed to a basis of sines and cosines of different frequencies.

When constructing the model of the energy acoustic emission signals spectrum, the following assumptions are introduced:

- locality, i.e. limiting of structural changes in the environment;
- dynamism of processes;
- the signal to the radiation point is a pulsed Poisson process;
- Fourier transform of AE signal has stationary characteristics.

The displacement of elementary masses caused by structural changes in a one-dimensional chain of particles connected by elastic bonds $\Psi(x)$ initiates a propagating wave:

$$u(x,t)=Ae^{i(kx-\omega t)} \quad (13)$$

The coefficients of Fourier transform are found by computing the scalar product of the signal with complex exponentials:

$$F(\omega)=\int_{-\infty}^{+\infty} f(t)e^{-i\omega t}dt \quad (14)$$

where $f(t)$ is the signal, $F(\omega)$ is Fourier transform.

The shape of the propagating AE signal depends not only on the displacement time t, but also on the frequency ω. Therefore, in addition to the displacement functions in the time $u(t)$, we should consider their Fourier-images $u(\omega)$ related by the relations:

Their Fourier-images $u(\omega)$ related by the relation:

$$u(\omega)=\int u(t)e^{i\omega t}dt \quad (15)$$

$$u(t)=\frac{1}{2\pi}\int u(\omega)e^{-i\omega t}d\omega \quad (16)$$

Fourier transform has a number of drawbacks due to the fact that the individual features of the signals cause minor changes in the frequency image and are smoothed over the entire frequency axis.

Part of the problem of spectral analysis and synthesis of AE signals can be solved by means of a window Fourier transform:

$$F(\Omega,b)=\int_{-\infty}^{+\infty} f(t)\omega(t-b)e^{-j\Omega t}dt \quad (17)$$

In this case, the operation of multiplying a signal by a window ($t-b$), which is a local function moving along the time axis, is used. Then the transformation becomes time-dependent and the frequency-time description of the signal is realized.

3. Fourier-transform experimental data

The results of experimental studies on the establishment of the interconnection between the appearance of AE signals and the parameters of the force field for various loading stages of St3 (Fig. 6, 7).

Identification of structural features of material damage accumulation from AE data was carried out on the basis of an analysis of the degree of deformation of samples obtained from tests on a breakaway machine UM5.

Transformer oil was used as the contact material between the AE converters and the sample. The measuring unit used broadband sensors to the AF-15 acoustic and emission instrument. The information and measuring system used in the experiment provided the indication, registration and pre-processing of AE signals with their further storage in the memory of computer for subsequent post-processing of the received data and their real-time visualization using the RIGOL DS1052E Digital oscilloscope.

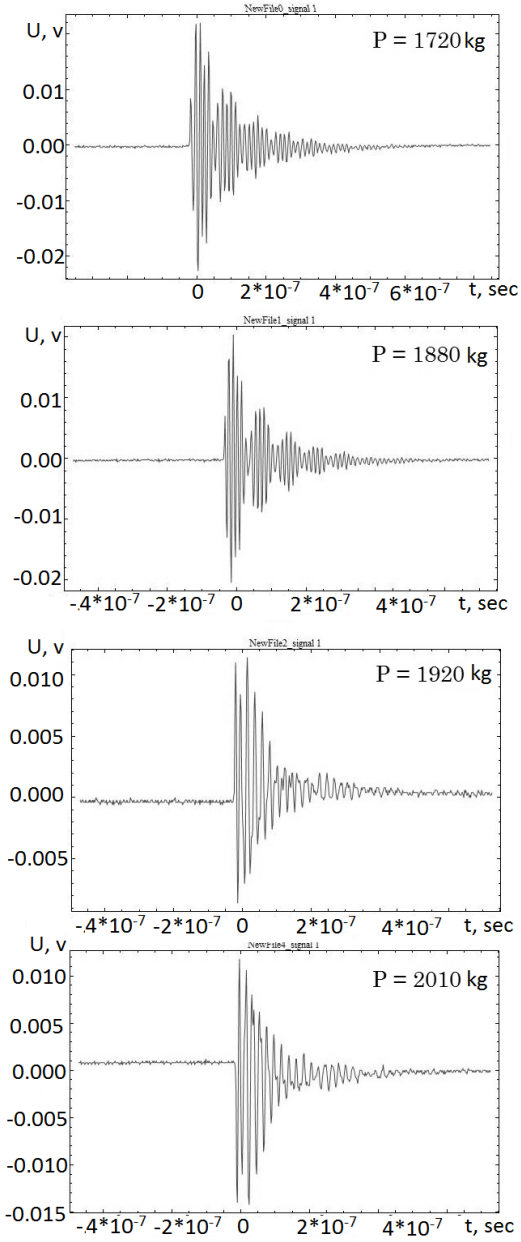

Fig. 6. Amplitude time distribution of spectral density of AE signals, under various loads

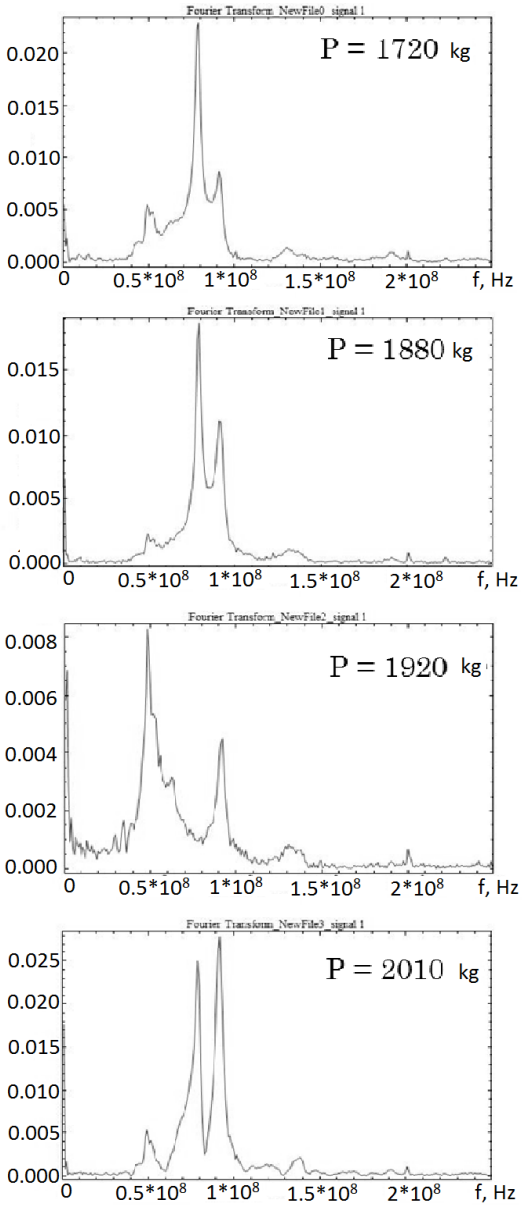

Fig. 7. Fourier-transform experimental data

When processing the experimental data, Mathematica 9.0 computer mathematics system and algorithms for working with numerical data arrays were used: finding the maximum (minimum) elements of the array, sorting the data of the array by the characteristic, combining the data, spline interpolation.

The density distribution of AE signals was determined by calculating the ratio of the number of intersections of the zero level of AE signal form to the time of its existence. The effect of a significant decrease in the distribution density of AE signals with increasing load is detected and quantitatively confirmed.

4. Conclusions

Compression of AE signal in time leads to an expansion of its spectrum, while shifting of AE signal in time, causes a phase shift of the spectrum proportional to the frequency. At the same time, the fundamental condition of translational and rotational invariance is observed in accordance with transformations of AE signal.

The presented results of the theoretical and experimental study of the energy spectrum of acoustic emission (AE) signals in the models of a continuous medium, the informational parameters of which are the operators of elastic energy, showed that the violation of internal bonds between translational and rotational properties of the continuous medium model in the form of a diatomic cell connected by elastic bonds initiates the oscillatory properties of the precursors of the destruction of materials of structures that are under load.

In the information and structural model of precursors of the appearance of acoustic emission signals, the oscillations of particles in a cell are characterized by the high-frequency component of AE signal, while the center-of-mass oscillation is characterized by its low-frequency component. Increasing the size and structure of the cell allows, in the extreme case, us to move from a discrete to a continuum model of the medium. The obtained results make it possible to establish the limits of the use of discrete representations of changes in the structure of materials and the continuum model of the propagation of acoustic vibrations in a medium.

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M.Sc. Artem Sharko
e-mail: sharko_artem@ukr.net

Ph.D. graduate at Kherson National Technical University Faculty of Cybernetics and System of Engineering. Research: nondestructive testing, physical information technologies, acoustic emission. He has 16 research publications.

otrzymano/received: 25.08.2018 *przyjęto do druku/accepted: 15.09.2018*

DOI: 10.5604/01.3001.0012.5277

THE CHANCES OF PRECISION ENHANCE FOR ULTRASONIC IMAGING

Tomasz Rymarczyk[1,2], Jan Sikora[1], Przemysław Adamkiewicz[1], Piotr Bożek[1], Michał Gołąbek[1]
[1]Research and Development Center, Netrix S.A., Lublin, [2]University of Economics and Innovation in Lublin

Abstract. *The results of ultrasonic imaging with the aid of an algorithm with the virtual rays is presented in this paper. The signal associated with the virtual rays is calculated as an arithmetical mean value of the signals of the rays surrounding the virtual one. Developed algorithm was tested on synthetic free noise data then polluted synthetic data in order to move for the real measurements. Conclusions about the imaging with new algorithm are not obvious. In same cases the significant improvement was achieved but in some not.*

Keywords: ultrasound tomography, inverse problems, singular value decomposition

SZANSE NA WZROST DOKŁADNOŚCI OBRAZOWANIA ULTRADŹWIĘKOWEGO

Streszczenie. *W pracy przedstawiono rezultaty działania algorytmu obrazowania ultradźwiękowego z dodatkowymi wirtualnymi promieniami. Sygnał odpowiadający wirtualnym promieniom jest wyliczany jako średnia arytmetyczna rzeczywistych sygnałów pomiarowych odpowiadających promieniom otaczającym dany promień wirtualny. Zaproponowany algorytm najpierw przetestowano na danych syntetycznych niezaszumionych, następnie na danych zaszumionych aby następnie przejść do danych pomiarowych. Wnioski na temat tego czy promienie wirtualne mają szanse podnieść jakość obrazowania nie są jednoznaczne. W niektórych przypadkach jakość jest znacznie lepsza a w innych nie.*

Słowa kluczowe: tomografia ultradźwiękowa, zagadnienia odwrotne, rozkład względem wartości osobliwych

Introduction

In nonclassical tomography like Electrical Impedance Tomography (EIT) [3, 7, 15], Capacitance Tomography (CT) [18, 19], Sonic and Ultrasonic or Radio Tomography [8, 13, 14], as well as Magnetic Tomography and classical tomography [1, 2, 11, 12] always there is a lack of information. In this paper, the problem of imaging has been brought to the solution of under or over-determined system of equation. As a rule, when the spatial resolution is high (for example 64×64 pixels) than such a system of equation is under-determined for the set of 32 sensors [14]. There are many methods of the solution, but in this work, the direct solution of system of algebraic equations has been selected as a simplest and most effective one. Such an algebraic system demands the specialized method of the solution, because its condition number is very high [9]. Three different approaches have been taken into account.

The first approach depends on the solution of the under-determined system of equations with the aid of FOCUSS algorithm [4]. On the base of numerical experiments, one can say [16], that too deep under-determination of the system of equations has a bad influence on the quality of the solution. One can expect nice results if the number of unknowns is less than two times bigger than the number of observations.

The second approach is leading to a square system of equations by left side multiplication of under-determined system of equations by transposition of the coefficients matrix. However, such a multiplication rises the matrix coefficient number with the power of two. Particularly such a remark concerns the measurement data. When the coefficient number is very high than difficulties with the solution are also very high [9].

The clue of the research presented in this paper, is the third approach. The key point of this approach is such a formulation of the problem in order to, in natural way, increase the number of observations. The simplest method is to reduce the number of pixels (unknowns) in which the density function is sought. Not always reduction of pixels is acceptable. That is why the authors suggest introduction of not existing measurements so called the virtual measurements and associated with them the virtual rays.

All above mentioned cases will be illustrated and discussed in this paper.

Theoretical basis of developed algorithm interested readers could find in the monography [6]. Some interesting details are presented in the paper [16]. It is worth to stress that according to the simplifying assumptions the reflection rays will not be taken into account. That means the transmission mode of the sonic tomography will be used in this paper.

In the third case, the most interesting, from the point of view of this paper is the question, if the only way of retaining overdetermination of the system of equations is the reduction of the pixels number?

Another way (virtual rays) of retaining over-determination of equations will be tested in this paper. Namely, artificially increasing the number of observations will be considered. The number of additional artificial observations strictly depends on the number of real sonic sensors. But the real sensors could not be increased without restraints, due to their physical size and the cost.

But some authors apply only two sensors set with the object placed on the rotating table. In that way the number of projection angles could be easily increased [10]. Certainly, not always such an approach is possible.

More projection angles, more rows of coefficient matrix. But if the number of projection angles would be too high, that could lead to linearly dependency of the rows, increasing the coefficient number and also increasing the pseudo-rank deficiency of the matrix [9].

The main goal of this paper is proposed algorithm testing with virtual rays on the real data, if the additional, artificial information are able to improve the quality of the images. As was mentioned already such an information are called the virtual information, as the sonic sensor do not exist for them. They are only in our imagination and the virtual signals are calculated on the base of the real measurements. The virtual signals are calculated as an arithmetical mean value of the surrounding ray's measurement.

Numerical experiment will be carried out in two steps. First, we will test the developed algorithm for the synthetic noise free data and next the noised data. The second part of the experiment will be carried out for real measured data. The measured data for different configurations, were obtained with the aid of the sonic tomograph design by NETRIX R&D company [8]. The reconstructions treated as the reference images were carried out with the PICUS 3 Sonic Tomograph software [5].

1. Additional, virtual ray between the real sensors – synthetic data case

One of the possibilities of enhancing the number of observations is to introduce an additional (virtual) rays between the real ones. In such a case the signal which belongs to the virtual ray will be calculated as an average value of the measurements associated with the rays surrounded the virtual one.

In this part of numerical experiment, the same number of sensors as for the real measurements was applied. The measurements were carried out by the NETRIX R&D company from Lublin [17].

In the Fig. 1 an exemplary real ray (the solid lines) and the virtual ones (dashed line) are presented. But in Fig. 2 the distribution of all rays in the region under investigation is shown.

It is worth to notice that the additional, virtual rays cause that the density of the rays inside the region is really high.

In order to be as close as possible to the real laboratory experiment the two closely placed inside objects were selected. Those objects are separated by 4 or 2 pixels as it is shown in Fig. 3. Such an example gives us a chance to investigate the proximity effect.

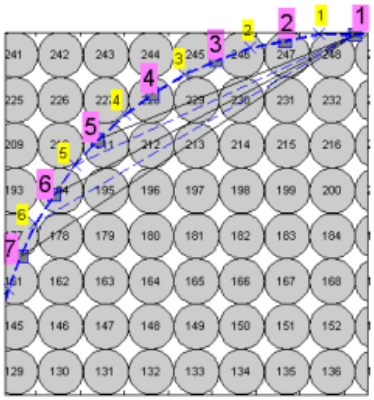

Fig. 1. Real (solid line) and additional rays (dashed line) in the region with a circular pixel

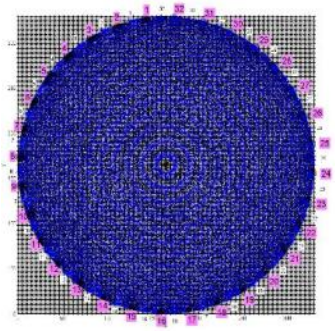

Fig. 2. The 32 sensors on the perimetry of the region and the rays between them for 64×64 pixels discretization

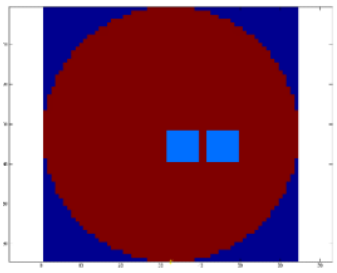

Fig. 3. Model of the region with an object inside splitted into two parts separated by gap 2 pixels wide

As a reference image (see Fig. 4) it was selected an image achieved without of additional-virtual rays with 1% noisy data for the full fan ray after median filtering.

The number of 32 sensors restrict the number of measurements which for the full fan ray is 32×31 = 992. For the spatial resolution 64×64 pixels make 4096 unknowns excluding forbidden pixels visible in the Fig. 3 and Fig. 5 as a blue or black subarea respectively.

So, the imaging problem is reduced to the solution of a generalized (underdetermined) algebraic system of equations. Because the number of observations is less over four times than the number of unknowns, so the system of equations is deeply underdetermind.

The authors experience says that the best results could be achieved when the number of unknowns is not more than two times bigger than the number of observations. In spite of that, the solution by the FOCUSS function [4] gives acceptable results as it is presented in Fig. 4.

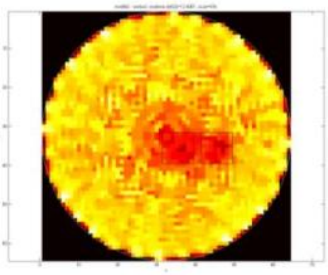

Fig. 4. Image for synthetic data with 1% noise without the virtual ray

Adding the virtual rays, the number of observations rise to 32×(31+30) = 1952, which means two times with respect of the case without of virtual rays. Reducing the ratio of unknowns to measurements by adding the virtual rays causes that the imaging produces much better results as it is shown in Fig. 5. Also, in this case the system of algebraic equations was solved by FOCUSS function and filtered by median filter [20].

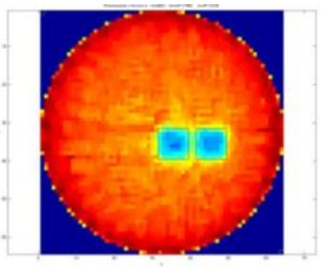

Fig. 5. Image for noise free synthetic data with virtual rays achieved by FOCUSS function

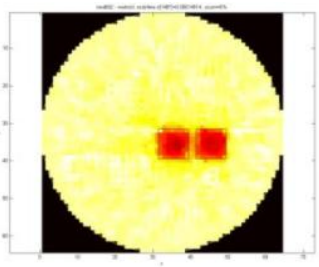

Fig. 6. Image for noise free synthetic data with virtual rays achieved by left multiplication by matrix transposition and SVD decomposition

Comparing the image in the Fig. 4 without of virtual rays with the image in Fig. 5 with the virtual rays one can justifiably say that in this particular case much better results was achieved. Such a conclusion is valid for pollution free data so far.

For the farther comparison, Fig. 6 shows the image which was achieved by left sided multiplication of a transposed coefficient matrix a well as the right-hand side vector and an application of SVD decomposition in order to get the solution. Using the left multiplication, the underdetermined system of equations became the square one. However, bed conditioned and what is more, very often rank deficient, so the solution is only possible by the decomposition method (SVD) [9].

As before, in a similar way the image was gain for synthetic noise free data using the full fan ray and filtered with the median filter. It is visible by comparison of the images in Fig. 5 and Fig. 6, the results are very similar, and is difficult to say which one is better.

Before we will pass to the real data measured in the NETRIX laboratory the algorithm was tested with the synthetic noisy data using the same object with the same obstacles inside. Results are presented in the following figures.

In Fig. 7 for the noisy synthetic data (1% of the noise) two images are presented for the separated object by four and by two pixels. Such an image maybe not ideal one could be compared with the image without the virtual rays (Fig. 4). Now for the noisy data it is not so obvious which algorithm with or without of virtual

rays is better. One thing is obvious. The virtual rays helped to see the gap between the separated obstacles. The gap is deliberately very narrow to see the influence of the proximity effect.

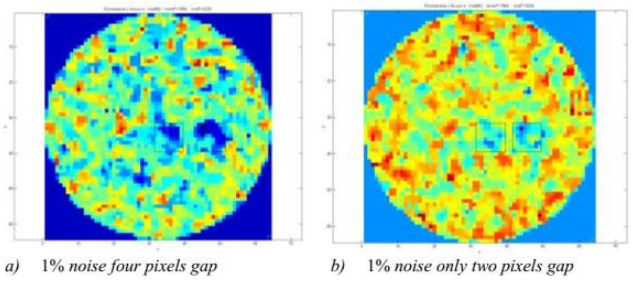

Fig. 7. Images for the noisy synthetic observations

From the other side the background of the image without of virtual rays is calmer what is an obvious advantage.

Conclusion: in case of synthetic data virtualization of rays has some sense. However, their influence on the quality of image, particularly for the noisy data is a little disappointed.

The more vital will be behaviour of the proposed algorithm for the real data which will be presented in the next sections of this paper.

2. Additional, virtual ray between the real sensors – measured data case

Research of influence of virtual rays on the quality of imaging using the synthetic noise free data allow for a bit of optimism. It is not so optimistic as we applied the noisy data. That is why the next step with real life laboratory data will be investigated. Then, could be answered the main question if the virtual rays help improve the quality of the sonic images or do not. The three following cases will be considered.

The first case: three objects – excitation frequency 48 kHz

The measuring set up for the first case is shown in Fig. 8. The arrangement consists of three bottles filled out with an air. One of the bottles is placed in the geometrical centre of the region, where the sensitivity is the smallest. The frequency of excitation is 48 kHz.

Fig. 8. Setup for ultrasonic measurements with the aid of NETRIX tomograph

Fig. 9. Three objects inside the region filled with water

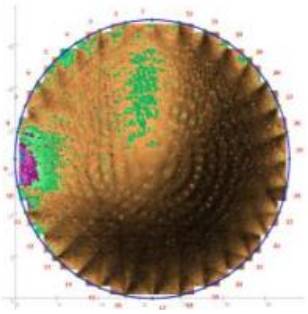

Fig. 10. Reconstruction with the aid of PICUS 3 software [5]

The Phantom of the region is presented in Fig. 9 and the image reconstruction with the aid of software of the Tomograph PICUS 3 [5] is shown in Fig. 10. This image would be treated as a reference image. It is easy to notice that the obstacle in the centre of the region has the worse representation in the reference picture.

The images obtained with the aid of the algorithm with additional virtual rays are presented in the following figures. Images were obtained by three different methods which were described above, for two different spatial resolution: 32×32 pixels and 64×64 pixels.

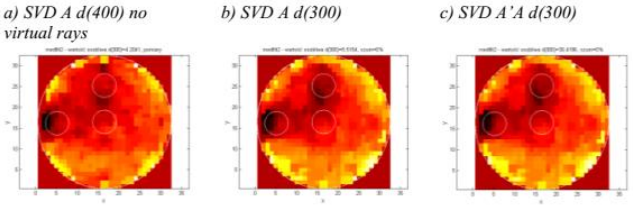

Fig.11. Imaging of the three objects based on laboratory measurements

For the spatial resolution 32×32 pixels in Fig. 11a without of virtual rays and Fig. 11b with virtual rays for different number of singular values were constructed the trial solutions. In Fig. 11c the solution was achieved by left sided multiplication by the coefficients matrix transposition (A'A, where A' means A^T in MATLAB nomenclature [20]).

The differences in the images it is difficult to distinguish. Similarly, to the reference image, the central obstacle is not distinctly represented.

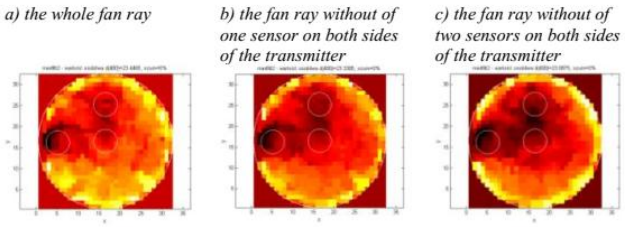

Fig. 12. Influence of the beam width on the imagining

The influence of the wideness of the fun ray on the quality of the image is presented in Fig. 12. The image for the whole fan ray is shown in Fig. 12a. For a narrower fan ray without one sensor on both side of the transmitter is shown in Fig. 12b and slightly narrower the fan ray without of two sensors on both sides of the transmitter in Fig. 12c. As one can see from those images the narrower ray produces slightly better results.

It could be explained by the following fact. The adjacent sensors have the measurements with the highest relative error due to their shortest distance between them. If such measurements would be excluded than the quality of data increase resulting with nicer images.

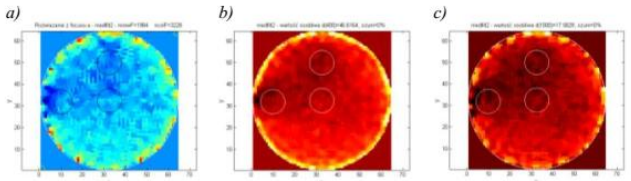

Fig. 13. Images after 2-D median filtering process: a) underdetermined system of equation by FOCUSS, b) SVD solution for the first 400 singular values, c) SVD solution for the first 928 singular values (A'A)

Increasing the spatial resolution do not enhance the quality of the images, as could be observed in Fig. 13. For the same number of observations, the number of unknowns become higher, leading to far worse underdetermination of algebraic system of equations.

The Fig. 13a shows the image obtained by underdetermined system solution. One can see that something happened in the second quarter of the region. A slightly better result was achieved by the solution of the square system of equations for the first 400 singular values and then for 928. As one can see increasing more than two times the number of singular values does not help much (consult Fig. 13c).

The only way to enhance the quality of an image is increasing the number of observations by generating non-existent virtual rays.

The second case: four objects – excitation frequency 48 kHz

As a second case the four internal objects located as it is shown in Fig. 14 has been considered. The next Fig. 15 illustrates the reconstruction results. As before the object placed in the centre of the region has the weakest representation. This image will be a reference one in our experiment.

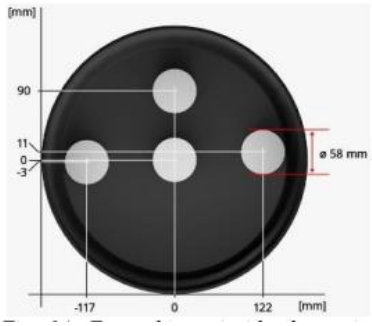

Fig. 14. Four objects inside the region filled with water

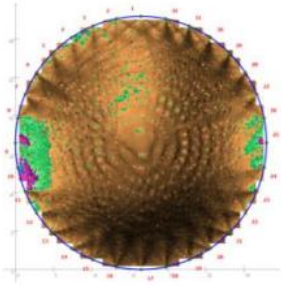

Fig. 15. Reconstruction with the aid of PICUS 3 software [5]

Reconstruction of the four distributed objects are presented in Fig. 16. In Fig. 16a and Fig. 16b the spatial resolution was 32×32 pixels but in Fig. 16c increased up to 64×64. For 32 sensors the lower spatial resolution guarantee overdetermination of the system of algebraic equations. One has got slightly more observations than the unknowns for such spatial resolution. The forbidden pixels inside of the square region which lay outside the circular region are not treated as unknown values. In Fig. 16a image was reconstructed without of virtual rays but in Fig. 16b with the virtual rays. It is very hard to judge which one is better. The authors would like to believe that the second one, because it poses more tranquil background. Increasing the spatial resolution to 64×64 pixels the image deteriorates as it was in previous case (Fig. 13a). Explanation of this phenomenon remain the same.

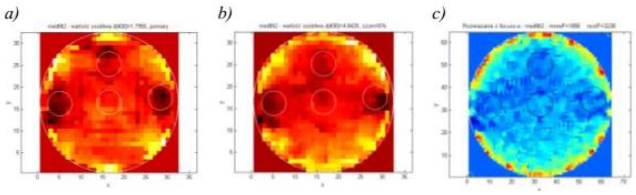

Fig. 16. Reconstruction for the four objects: a) without of virtual rays A d (400), b) with the virtual rays for 32×32 spatial resolution (overdetermined system of equations SVD – A d (400), c) the same case as in b-case but spatial resolution increased to 64×64 driven to underdetermined system of equations solved by FOCUSS

So again, raises the question if for such a number of sensors better resolution is justified as it leads for worse imaging results?

In this case the left side multiplication by the transposition of the coefficient matrix are able to improve a little bit the image but under condition that the number of singular values for trial solution would be properly chosen. In Fig. 17 we can observe the distribution of singular values. At a first glance 500 singular values seems to be the correct one. But in the range of 400 till 500 singular values the curve goes down rapidly. We have to remember that the vertical axis is in a logarithmic scale, so within this range the singular values decreasing significantly. The best results were achieved not for 500 but for 150 singular values (see Fig. 18).

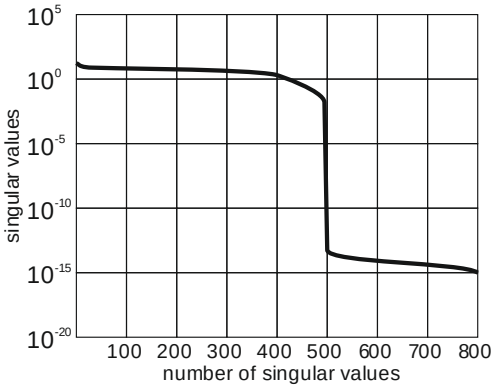

Fig. 17. Singular values distribution

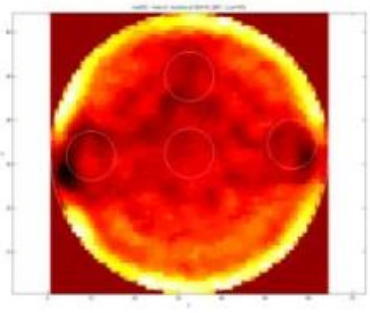

Fig. 18. Image for the four objects and resolution is 64×64 SVD A'A d(150)

The background is calm, and it is an easy to detect the trace of the internal objects, however with a small offset. The problems with the central object remained.

As a general remark in case of measurements is that one has to select the trial solution with a reasonable condition number. It is very hard to define the "reasonable" condition number. It depends on the case considered. By the numerical experiments the authors think that it is rather the dozens but definitely not the thousands.

For the four bottles case the condition number for jump of the singular values is d(1)/d(496) = 1231.7 (consult the Fig. 17). For such a number of singular values the trial solution produces a low-quality image. That is why finally only 150 singular values were selected what gives the condition number equal only 10.58. The results are visible in Fig. 18.

Comparing this result with the reference image (Fig. 15) there is no the central object and also the object placed vertically over the central one has also a very week representation.

The third case: four objects – excitation frequency 400 kHz

As the last experiment the four a smaller than in previous cases, bottles filled in air for excitation of 400 kHz was selected.

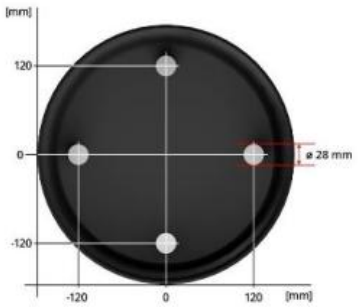

Fig. 19. Four objects location inside the region filled with the water

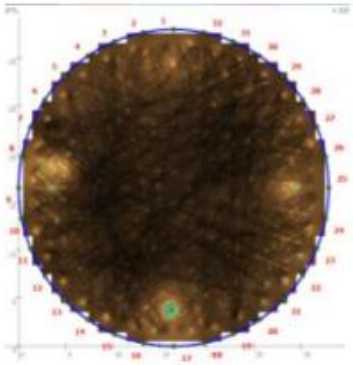

Fig. 20. Reconstruction with the aid of PICUS 3 software [5]

The configuration of internal obstacles is presented in Fig. 19. In spite of that the smaller object is more difficult to identify the reference image is very good. Again, the question is if the proposed algorithm with the virtual rays would be able to produce reasonable image equally good as the reference one.

This time the images are presented in the highest resolution 64×64 pixels. In the Fig. 21 the upper row is showing the raw images but the lower row images after median filtering.

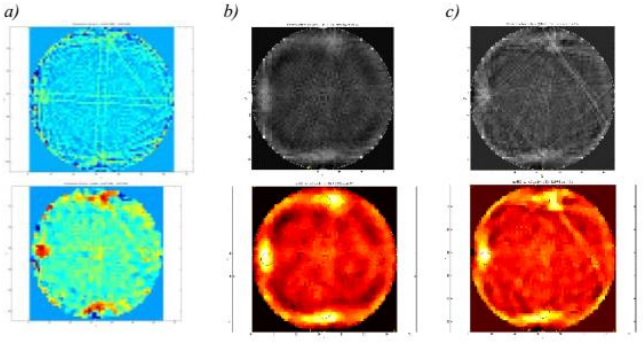

Fig. 21. Images for the virtual rays and four objects from the Fig. 19; upper row the raw images but the lower row images after 2D median filtering a) FOCUSS b) SVD A'A – d(100) c) SVD A'A – d (300)

In the Fig. 21a the image from the solution of under-determined system of equations is shown but the Fig. 21b and Fig. 21c presents the images from the SVD solution for different number of singular values achieved after left side multiplication by transposition of the coefficient matrix.

It is worth to notice that one of the internal objects in the reference image is weaker than the rest ones. For our method as it is seen in Fig. 21, this one is hardly visible at all.

Enlarging the number of singular values does not improve the image (Fig. 22a). So far only the median filtering was applied. But if the image was treated by adaptive Wiener filter [20] we can observe an improvement of the image. Now all four internal objects are visible (see Fig. 22b).

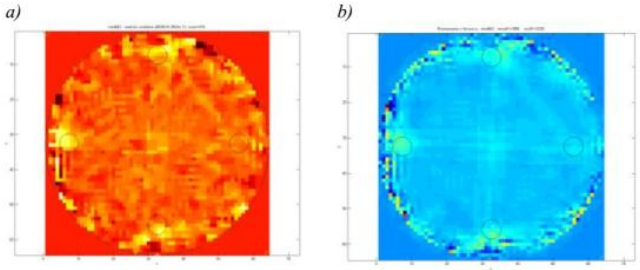

Fig. 22. Image for the four objects from the Fig. 19: a) SVD A'A – d (500), b) FOCUSS filtered with the aid of the adaptive Wiener method [20]

3. Conclusion

In this paper a new method for sonic imaging with virtual rays was presented. Algorithm tested on synthetic noise free data shows significant improvement when the virtual rays were engaged.

However noised data reveal sensitivity of the new algorithm on the noisy data. Merely 1% noise was able to distort significantly the image.

That was not good perspective for the real application of the algorithm. So, the most important was the behaviour of the proposed algorithm in the second part of experiment, with the real data.

The results are not as obvious and not unambiguous as one could expect. For some experiment, improvement could be visible but for the other rather not.

That is why, according the authors opinion, this algorithm based on a very strong simplifying assumptions like for example not taking into account reflecting signals, has reached the end of its ability.

The further sonic imaging improvement could be reached due to relaxing some of the strongest simplifying assumptions.

It will depend on the ability of the measurement, if we would be able to measure the reflecting signals inside the region. Such an ability allows to move from the transition mode to the reflecting mode. Authors believe that it helps to get much more precise images.

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Ph.D. Eng. Tomasz Rymarczyk
e-mail: tomasz@rymarczyk.com

He is the director in Research and Development Center in Netrix S.A. and the director of the Institute of Computer Science and Innovative Technologies in the University of Economics and Innovation, Lublin, Poland. He worked in many companies and institutes developing innovative projects and managing teams of employees. His research area focuses on the application of non-invasive imaging techniques, electrical tomography, image reconstruction, numerical modelling, image processing and analysis, process tomography, software engineering, knowledge engineering, artificial intelligence and computer measurement systems.

Prof. Jan Sikora
e-mail: sik59@wp.pl

Prof. Jan Sikora (PhD. DSc. Eng.) graduated from Warsaw University of Technology Faculty of Electrical Engineering. During 44 years of professional work he has proceeded all grades, including the position of full professor at his alma mater. Since 1998 he has worked for the Institute of Electrical Engineering in Warsaw. In 2008, he has joined Electrical Engineering and Computer Science Faculty in Lublin University of Technology. During 2001-2004 he has worked as a Senior Research Fellow at University College London in the prof. S. Arridge's Group of Optical Tomography.

Ph.D. Przemysław Adamkiewicz
e-mail: p.adamkiewicz@netrix.com.pl

He is a doctor of physics, graduate of Maria Curie-Sklodowska University in Lublin. He is a head of the R&D Department at Netrix S.A. His research area focuses on electrical impedance tomography, electrical capacitance tomography, image reconstruction, forward problem, inverse problem, numerical modelling, image analysis and computer measurement systems.

M.Sc. Eng. Piotr Bożek
e-mail: piotr.bozek@netrix.com.pl

Piotr Bożek is graduated form Lublin University of Technology, faculty of Electrical Engineering and Computer Science (Specialty: Intelligent Technologies in Electrical Engineering). Currently is working on projects of computerized tomography in the NETRIX S.A. Research and Development Center.

M.Sc. Eng. Michał Gołąbek
e-mail: michal.golabek@netrix.com.pl

Michał Gołąbek is graduated form Lublin University of Technology, faculty of Electrical Engineering and Computer Science (Specialty: microprocessor Drives in industrial automation). At present he is constructor of tomographic equipment in NETRIX S.A. Research and Development Center.

otrzymano/received: 25.08.2018 *przyjęto do druku/accepted: 15.09.2018*

DOI: 10.5604/01.3001.0012.5279

ELECTRICAL RESISTANCE TOMOGRAPH FOR DISTRIBUTED MEASUREMENTS FOR FLOOD EMBANKMENT

Tomasz Rymarczyk[1,2], Paweł Tchórzewski[1], Przemysław Adamkiewicz[1], Jan Sikora[1]
[1]Research and Development Center, Netrix S.A., Lublin, [2]University of Economics and Innovation in Lublin

Abstract. *In this paper the terrain electrical resistance tomograph was presented. Its aim is to verify the repeatability of test results by eliminating laboratory equipment, and to validate the use of simple and cheap electronics to the structure of the ERT. Electrical resistance tomography, which is based on measuring potential difference, can be used to calculate conductivity*

Keywords: electrical resistance tomography; sensors; measurements

ELEKTRYCZNY TOMOGRAF REZYSTANCYJNY DO POMIARÓW ROZPROSZONYCH DLA WAŁÓW PRZECIWPOWODZIOWYCH

Streszczenie. *W niniejszym artykule przedstawiono konstrukcję tomografu rezystancyjnego. Jego celem jest weryfikacja powtarzalności wyników badań poprzez wyeliminowanie sprzętu laboratoryjnego oraz potwierdzenie zastosowania prostej i taniej elektroniki do struktury ERT. Do obliczenia przewodnictwa można wykorzystać elektryczną tomografię rezystancyjną, która opiera się na pomiarze różnicy potencjałów*

Słowa kluczowe: tomografia rezystancyjna, sensory, pomiary

Introduction

Electrical tomography (ET) is known that the inverse problem is nonlinear and highly ill-posed [5,10–12]. Electrical Resistance tomography (ERT) is a geophysical technique in which DC electrical current is injected into the ground between one pair of electrodes and the voltage is measured between another pair. ERT involves placing electrodes on the examined object. In this work, there was created a device after achieving good research results of measurements. Its aim was to verify the repeatability of test results by eliminating laboratory equipment, and to validate the use of simple and cheap electronics. The ERT equipment consists of some separated modules: current generator, measure block, multiplexer and controller. The data acquisition system collects the measured voltage from electrode and then the data is processed. The problem is the low level of measured values which should be measured quite accurately and in a very short time. ERT involves placing electrodes on the examined object [1, 2]. Different methods can be used to reconstruct the image in the optimization process [3, 4, 6–8].

1. Measurement system

The ERT solution should make ERT measurements for reconstruction of resistive distribution at big areas (tens of meters) with of conducting media. The ERT equipment consists of some separated modules: current generator, measure block, multiplexer and controller. These modules should adapt to high voltages (about 250 V) and high currents (about 3 A). There should be possibility to connect more than one multiplexer to this system. The designed modules should be supervised and served by a single controller. A schematic diagram of the system is presented in Fig. 1.

The ERT solution should make ERT measurements for reconstruction of resistive distribution at big areas (tens of meters) with of conducting media [9, 10]. The ERT equipment consists of some separated modules: current generator, measure block, multiplexer and controller (Fig. 2 and Fig. 3). These modules should adapt to high voltages (about 250 V) and high currents (about 3 A). There should be possibility to connect more than one multiplexer to this system. The designed modules should be supervised and served by a single controller. The signal power amplifier as a finished device is also located in the 2U housing.

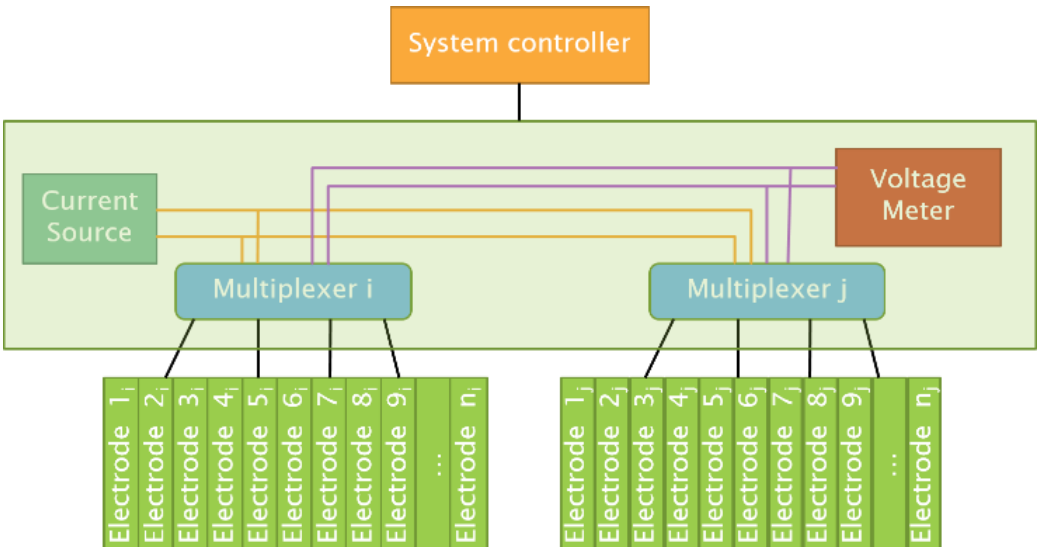

Fig. 1. The ERT measurement system schematic diagram

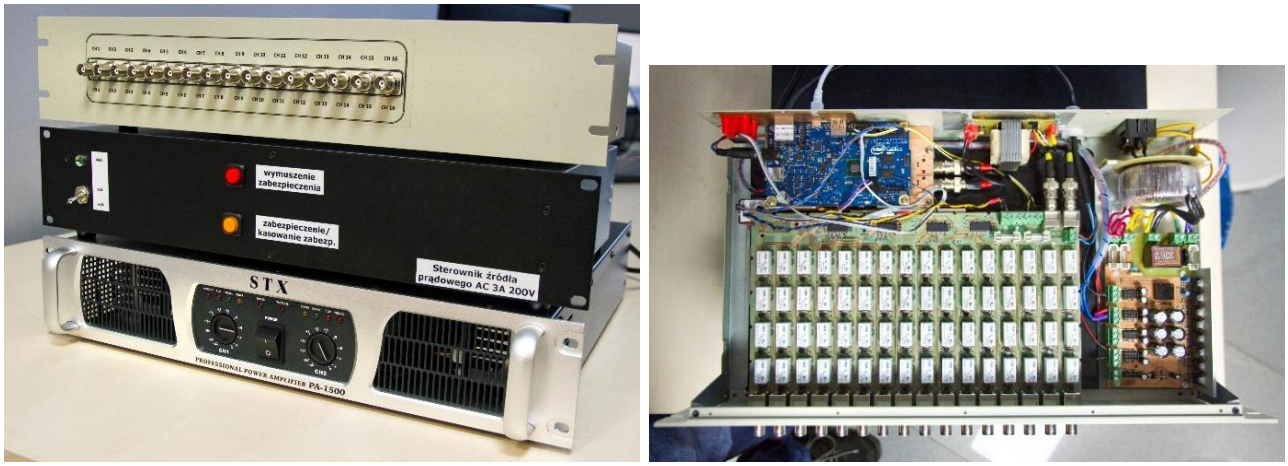

Fig. 2. ERT device

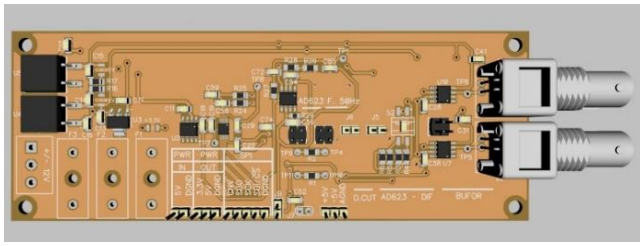

Fig. 3. ADC module

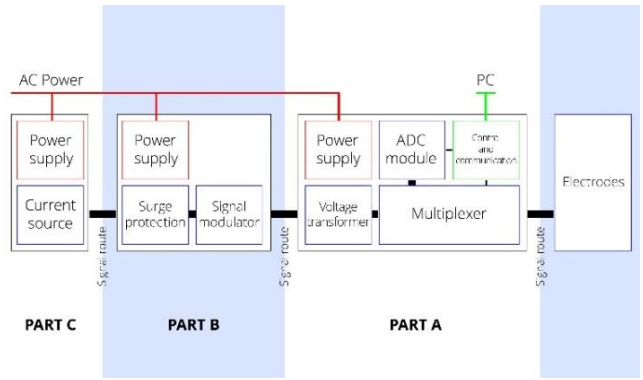

Fig. 4. System scheme

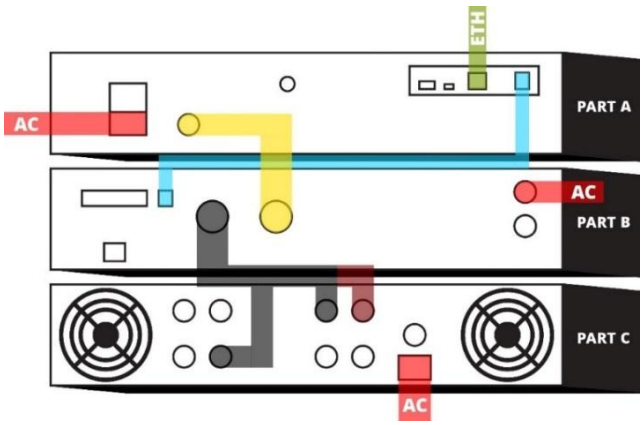

Fig. 5. Connections between back panels of scanner's central unit

The device consists of 3 central unit modules (Fig. 5) and a set of measuring electrodes. External connection diagram is presented in Fig. 4.

Part A is equipped with multiplexer as well as with control and communication circuitry. On its back-panel IEC 60320 power socket with on/off switch, excitation signal cable connected to part B, and a voltage transformer's knob can be found as well as following sockets:

- USB ("USB Host", not used),
- microUSB ("USB Client", for optional direct communication with a computer),
- Ethernet ("LAN", for control of the device and for obtaining measurement data),
- RJ-11 ("UART", for communication with part B).

Front panel is equipped with 16 BNC sockets for measuring electrodes.

Part B (AC current source controller) consists of excitation signal modulator and surge protection unit. Front panel is equipped with lever power switch, status diode and 2 back-lit buttons for manual toggling of surge protection. Back panel consists of following sockets:

- USB-B ("USB 2.0", diagnostic, for firmware update),
- DB25 ("control", not used),
- RJ-11 ("UART", for communication with part A),
- Plug-in 7-pin ("to an audio amplifier", connected to part C),
- Plug-in 3-pin ("galvanically isolated output", output for part A),
- fuse mount ("230V 50Hz 15VA").

Additionally, there's a fixed AC power cable.

Part C (current source) has been enclosed in audio amplifier chassis. Back-lit power switch and two unused knobs can be found on the front panel. On the back one there are multiple sockets, mostly unused with the exception of:

- female XLR (lower "Bridge input", used for connection with part B),
- two red clamp sockets ("Bridge +"; connecting with part B, red cable with left one and black cable with right one accordingly),
- IEC 60320 power socket ("AC in"),
- Fuse mount ("Main fuse").

2. Communication protocol

The basics of communication were made using MQTT v. 3.1.1 protocol. Broker's IP address and local area network settings are fixed in firmware of the central unit. Its uncompiled form is attached to this manual. The device uses MQTT default port 1883. Every command addressed to the device may receive and realized in monitoring mode. In standby mode device monitors communication, the whole time. During operation it switches to monitoring mode for a brief moment between measuring cycles.

Every successfully received command is confirmed with a reply published most commonly in the same topic. After performing starting sequence and establishing network connection the device acquires time information from www.nist.gov. Next, it tries to connect to MQTT broker and in case of success it subscribes identified topics. It also uses topics NX02json (returns the measurement results there) and NX02status (returns device status and last will message) for publication. After subscribing the topics tomography scanner turns into standby mode. It is needed to select key parameters or the device will return the error message in topic NX02status, for example: "Measurement method not chosen". If broker maintains settings as a retained type messages the device will behave accordingly without any assist. In case of unsuccessful connection tomography scanner restarts its network, service and tries again. It is possible to obtain detailed error information with the USB serial port (mini-USB cable).

After performing the whole measurement cycle tomography scanner publishes JSON formatted data frame in NX02json topic according to following pattern:

{„time": „aa", „dev_id":"NXbbbbbVcccc", „electrodes":"16",
„samples":"dd", „frequency":"ee", „method":"f",
„Wggg":"hh.hhhh", …, „Wggg":"hh.hhhh"}

where:
aa – time of cycle start in Unix Timestamp,
bbbbb – device number,
cccc – firmware version,
dd – amount of measurements of instantaneous value used to calculate the RMS value,
ee – frequency of excitation current,
f – measuring method,
ggg – order number of a single measurement result,
hh.hhhh – value of a single measurement result.

3. Model and image reconstruction

The example of the flood embankment is given in Fig. 6. The examples of different inserted electrodes into the embankments were presented in Fig. 7. The measurement system with the EIT device, transfer data to the cloud computing and image reconstruction was presented in Fig. 8.

In examples reported below, several EIT numerical measurement models of the flood embankment were presented. The conductivity of searched objects is unknown. The embankment with 16 electrodes, simulated areas inside (geometrical mesh, original and reconstruction model) was presented in Fig. 9.

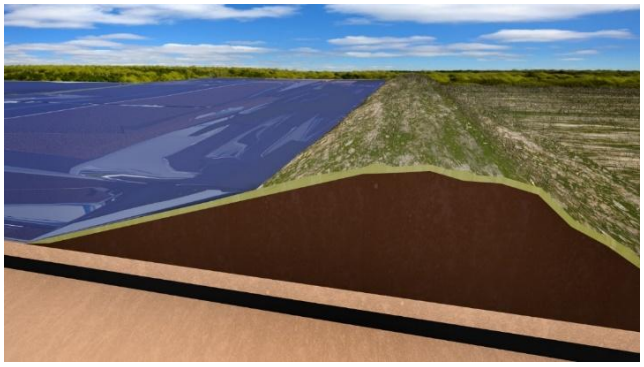

Fig. 6. The example of the flood embankment

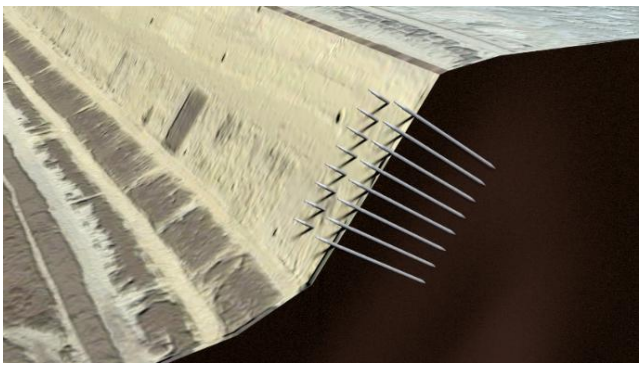

Fig. 7. The examples of electrodes

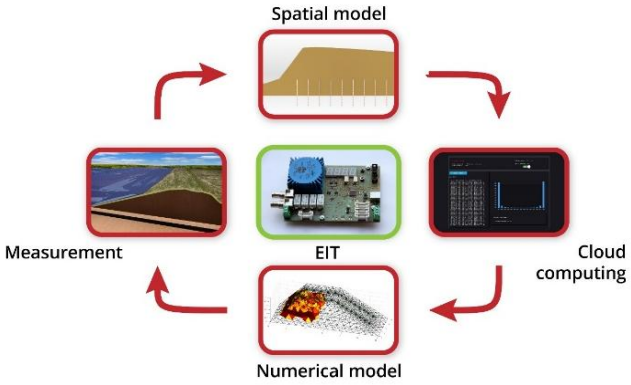

Fig. 8. The measurement system

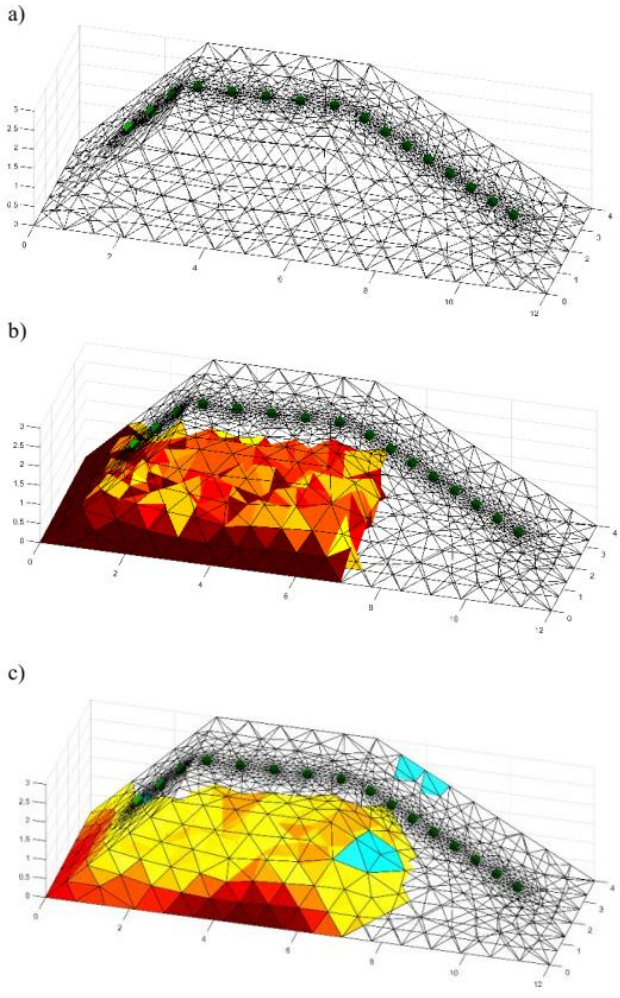

Fig. 9. The embankment: a) mesh model, b) model of object, c) Gauss-Newton with Laplace regularization

4. Conclusion

This article presents the ERT system for tomographic measurements in the real environment. The presented solution was based on electrical resistance tomography. The design of the measuring system has been presented. Basic information about the constructed model system has been given. The concept of measuring equipment for data acquisition has been described. Electrical resistivity tomography was used to calculate the conductivity, which is based on the measurement of the potential difference.

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Ph.D. Eng. Tomasz Rymarczyk
e-mail: tomasz@rymarczyk.com

He is the director in Research and Development Center in Netrix S.A. and the director of the Institute of Computer Science and Innovative Technologies in the University of Economics and Innovation, Lublin, Poland.. He worked in many companies and institutes developing innovative projects and managing teams of employees. His research area focuses on the application of non-invasive imaging techniques, electrical tomography, image reconstruction, numerical modelling, image processing and analysis, process tomography, software engineering, knowledge engineering, artificial intelligence and computer measurement systems.

M.Sc. Paweł Tchórzewski
e-mail: pawel.tchorzewski@netrix.com.pl

He is a software developer in Research and Development Department in Netrix S.A. Currently, he is working on numerical methods in boundary value problems for partial differential equations and image reconstruction in electrical tomography. He graduated in physics at Maria Curie-Sklodowska University in Lublin.

Ph.D. Przemysław Adamkiewicz
e-mail: p.adamkiewicz@netrix.com.pl

He is a doctor of physics, graduate of Maria Curie-Sklodowska University in Lublin. He is a head of the R&D Department at Netrix S.A. His research area focuses on electrical impedance tomography, electrical capacitance tomography, image reconstruction, forward problem, inverse problem, numerical modelling, image analysis and computer measurement systems.

Prof. Jan Sikora
e-mail: sik59@wp.pl

He graduated from the Faculty of Electrical Engineering of the Warsaw University of Technology. During his 34 years of professional work, he has earned all grades, titles and positions at his home university, including the position of full professor. He has been associated since 1998 with the Institute of Electrical Engineering in Warsaw. In the years 2001-2004, he worked as a senior research fellow at the University College London in the Group of Optical Tomography. S.R. Arridge. He was employed at the Faculty of Electrical Engineering and Computer Science. Actually, he works in the R&D Department at Netrix S.A.

otrzymano/received: 10.07.2018 *przyjęto do druku/accepted: 15.09.2018*

DOI: 10.5604/01.3001.0012.5280

MANUFACTURING PLANNING AND CONTROL SYSTEM USING TOMOGRAPHIC SENSORS

Konrad Niderla[1], **Tomasz Rymarczyk**[1,2], **Jan Sikora**[1]
[1]Research and Development Center, Netrix S.A., Lublin, [2]University of Economics and Innovation in Lublin

Abstract. *The article presents an idea of a production process control system. Advanced automation and control of production processes play a key role in maintaining competitiveness. The proposed solution consists of sensor networks for measurement process parameters, production resources and equipment state. The system uses wired and wireless communication, which gives possibility to acquisition data from existing in enterprise sensors and systems as well as acquisition data from new systems and sensors used to measure all processes, starting from production preparation to the final product. The solution contains process tomography sensors based on electrical capacitance tomography, electrical impedance tomography and ultrasound tomography. The use of tomographic methods enables to manage the intelligent structure of the companies in terms of processes and products. Industrial tomography enables observation of physical and chemical phenomena without the need to penetrate inside. It will enable the optimization and auto-optimization of design processes and production. Such solutions can operate autonomously, monitor and control measurements. All sensors return to the system continuous data about state of processes in some technologically closed objects like fermenters. Process tomography can also be used to acquisition data about a flow of liquids and loose ingredients in pipeline based on transport systems. Data acquired from sensors are collected in data warehouses in order to future processing and building the knowledge base. The results of the data analysis are showed in user control panels and are used directly in the control of the production process to increase the efficiency and quality of the products. Control methods cover issues related to the processing of data obtained from various sensors located at nodes. Monitoring takes place within the scope of acquired and processed data and parameter automation.*

Keywords: process tomography, manufacturing execution system, production control system

SYSTEM PLANOWANIA I KONTROLI PRODUKCJI Z WYKORZYSTANIEM CZUJNIKÓW TOMOGRAFICZNYCH

Streszczenie*. W artykule przedstawiono ideę systemu kontroli procesu produkcyjnego. Zaawansowana automatyzacja i kontrola procesów produkcyjnych odgrywają kluczową rolę w utrzymaniu konkurencyjności. Proponowane rozwiązanie składa się z sieci czujników do pomiaru parametrów procesu, zasobów produkcyjnych i stanu wyposażenia. System wykorzystuje komunikację przewodową i bezprzewodową, która umożliwia pozyskiwanie danych z istniejących w przedsiębiorstwach czujników i systemów, a także pozyskiwanie danych z nowych systemów i czujników używanych do pomiaru wszystkich procesów, począwszy od przygotowania produkcji do produktu końcowego. Rozwiązanie zawiera czujniki tomografii procesowej oparte na elektrycznej tomografii pojemnościowej, elektrycznej tomografii impedancyjnej i tomografii ultradźwiękowej. Zastosowanie metod tomograficznych umożliwia zarządzanie inteligentną strukturą firm pod względem procesów i produktów. Tomografia przemysłowa umożliwia obserwację zjawisk fizycznych i chemicznych bez potrzeby penetracji wewnątrz. Umożliwi to optymalizację i automatyczną procesów projektowych i produkcji. Takie rozwiązania mogą działać autonomicznie, monitorować i kontrolować pomiary. Wszystkie czujniki przekazują do systemu ciągłe dane o stanie procesów w niektórych technologicznie zamkniętych obiektach, takich jak fermentory. Tomografia procesowa może być również wykorzystywana do pozyskiwania danych o przepływie płynów i luźnych składników w rurociągu w oparciu o systemy transportowe. Dane uzyskane z czujników gromadzone są w hurtowniach danych w celu ich dalszego przetwarzania i budowania bazy wiedzy. Wyniki analizy danych są wyświetlane w panelach sterowania użytkownika i są wykorzystywane bezpośrednio w kontroli procesu produkcyjnego w celu zwiększenia wydajności i jakości produktów. Metody kontroli obejmują zagadnienia związane z przetwarzaniem danych uzyskanych z różnych czujników zlokalizowanych w węzłach. Monitorowanie odbywa się w ramach pozyskanej i przetwarzanej automatyzacji danych i parametrów.*

Słowa kluczowe: tomografia procesowa, system realizacji produkcji, system kontroli produkcji

Introduction

First Information Technology systems in the world were used in enterprises in 1960's when early computers appeared. Firstly, systems cover small parts of operating space, like ROP systems (Reorder Point), which were charge of replenishment of stock when inventory drops down to zero. Later, systems grow up, MRP (Material requirement planning) was built with cooperation between J.I. Case – manufacturer of tractors and IBM. Those kinds of systems were charge of planning material demand in production process. Next step, MPC systems (Manufacturing planning and control) were built. Those systems gave the possibility of collecting data in storages. Of course, from our point of view every system was very primitive, technological limitations like small amount of memory, mass storage problems – we didn't know hard drives, we knew magnetic tapes, lack of processors – which were slow, had limitations, for example first processors couldn't calculate square root. Systems were very expensive and big, difficult to use, they needed a lot of stuff who had mastered a technique [10]. In 70's systems and IT companies were developing. In 1972 five IBM's workers founded SAP company, and one year later completes its first accounting system [24]. In August 1977 was founded Oracle, in 1979 they started selling first relational database systems (in fact it was version number two) [4]. In 80's works were conducted on second generation of systems, like MRP-II (Manufacturing resource planning). MRP-II included stock reporting as well as production and procurement scheduling and cost reporting. New abbreviation CIM (computer integrated manufacturing) was introduced in the middle of 80's. The CIM model introduced a concept of integration all kinds of electronic data processing application in all enterprise's divisions connected with production, starting from design department to quality control, although implementation often failed due to complexity, lack of standardization and technologies [17]. Next type of IT systems is called ERP (Enterprise resource planning). The term was used by the Gartner Group in 1990 first time. ERP systems attempts to integrated processes and data in organization. The data are stored in a single database. The database stores, shares and manages data from different departments [6]. In practice the name ERP is more ambition than system really is, because usually they are administrative, automation accountant tasks and material management systems. Gap between ERP and lower level systems like MRP-II in CIM model was filled by MES systems (Manufacturing execution system). First time term MES was promulgate in 1992 by AMR Research Inc. The MES systems are based on functionality for planning, execution and control production process, as well as act MES must react in real time in case of interrupt. MES systems were overtaken by ERP, because ERP systems are helping business executive with financial decisions. The plant level executives, who had to take important decisions, can't rely on business information. Crucial data comes from the plant, and plays significant role in process optimization, thus MES systems are becoming important software in manufacturing ecosystems [28].

To meets modern challenges production control systems should satisfy the following requirements [8]:

- enterprise integration: cooperating enterprises should integrate related management systems to effectively and efficiently exchange information,
- distributed organization: enterprises should integrate knowledge transfer between parts of company as well as between cooperating companies,
- heterogeneous environment: cooperating companies usually have different organizational and information systems; new age environment should integrate them,
- interoperability: different systems means different platforms, programming languages, data format, models,
- open and dynamic structure: integration new or removing existing subsystem should be prepared rapidly, without disturbances for working environment,
- cooperation: enterprise should cooperate with suppliers and customers for materials, supplies, parts fabrication, product commercialization etc.,
- integration of humans with software and hardware: computers must be integrated with humans on the whole product life cycle,
- Agility: agile means ability to rapidly adapting to new situation. In manufacturing environment this new situation can be connected with customers' requirements or e.g. new equipment features,
- Scalability: operational space and resources should be able to expand without breaking of existing organizational connections,
- fault tolerant: The system has to be fault tolerant on all working levels. It should minimize bad impact of failures, detect it and recover system.

In recent years technology has evolved. We have available new equipment and software. Almost everyone has a smartphone in their pocket, a computer and a tablet on their desk. We can use cheap sensors and hardware, RFID, Beacons, Internet of Things are very fashionable words. We have access to Cloud Computing technology which offer on demand almost unlimited computing power and storage space, but also, we can use cognitive services which can be helpful to process huge amount of data. The whole electronic world is more accessible, it gives new possibilities in building MES systems. We can collect data from large number of various sensors, Cloud computing and Big Data allows us to store and process collected data. Increase technology also has a big impact on the development of process tomography. We can build smaller, cheaper and more useful device as well as smarter, faster and more accurate algorithms. At the same time, customers' requirements are constantly growing. They needs customized products, shorter production time, possibility to making changes, higher quality and lower price. World continuously changing, then we have to build systems significantly more elastic and more responsive for customers' needs. The above expectations and possibilities can meet in a common point.

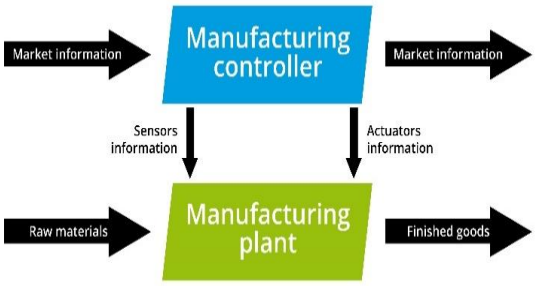

Fig. 1. Manufacturing control model

In this paper we propose production control system that will meet users' and management's needs, will be able to collect the right data, process it using the latest solutions, and return the results to both processes and users. The distributed and open architecture of the solution should allow use of a wide range of sensors and measuring and executive devices, including process tomography systems. The solution should also enable dynamic adaptation to changing conditions and needs e.g. the need to add new sensors.

1. System background

According to Baker, factory control is charge of conduct production process to make desired product from manufacturing resources and information. Manufacturing control model was presented on [1]. Baker wrote that system should decide what to produce, how much to produce, when production is to be finished, what resources to use, how and when use them and make them available, when to release jobs into the factory, which job to release, job routing, and operation sequencing [1]. Single central factory controller has difficulty to deal with complexity coming from production system (e.g. complexity of data management, uncertainty connected with demand and resources availability, lags between events and relevant information processing, real-time constraints). Popular solution for these kinds of problems is separation of responsibilities into several decisional entities, introducing a non-centralized control system. In our case non-centralized means division of a global control process based on a selected splitting criterion e.g. functional [27]. Functional horizontal division was defined by Association of German Engineers, that works on MES Systems in details. In their guideline VDI 5600 they define 3-levels manufacturing company structure. As can be seen from, business management is represented by ERP systems, production management is represented by MES system, and finally production level is represented by workplaces, machines and equipment. Manufacturing execution systems are subject of work for a lot of organizations. They are trying to specify standards which can help implement system in manufacturing enterprises. To define common functionality, MES functions specified by different standards was presented in Table 1 [25]. There was selected four standards: Manufacturing Execution Solution Association MESA [16], Normenarbeitsgemeinschaft für Meß und Regeltechnik in der chemischen Industrie NAMUR [18], VDI-Kompetenzfeld Informationstechnik [11], National Institute of Standards NIST [2].

As you can see on the Table 1, all considered standards have defined areas connected with detailed planning, quality management, master data management. Other functionality is described in three or less number of specification. This may indicate that these functions are specific to selected industries. The MES system occupies a central position in a manufacturing company. According to VDI, MES is charge of nine areas: detailed planning and control, information management, quality management, human resources management, production facility management, performance analysis, data collection and material management. MES is capable of exchanging information between the business level and the production level. The production level includes complex machines and subsystems for production tasks, which are involved in production process. Production equipment generate data which MES system uses to represent the actual state. From this point of view, production control system should integrate equipment, machines and exchange data in way which enable control over production subsystems [11].

Table 1. MES Functions

	MESA	NAMUR	VDI	NIST
Labour Management	X		X	
Requirements Planning		X		
Gross Planning		X		
Detailed Planning	X	X	X	X
Quality Management	X	X	X	X
Prod. Inventory Management	X	X		X
Resource Management	X		X	X
Equipment Management	X		X	X
Manufacturing Control	X	X		
Traceability/Genealogy	X			X
Production Reporting	X		X	X
Machine Control	X			
Production Data Acquisition	X		X	X
Master Data Management	X	X	X	X

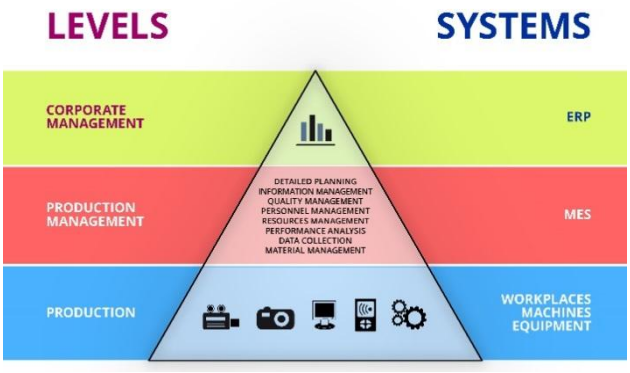

Fig. 2 VDI-5600 Manufacturing company levels model

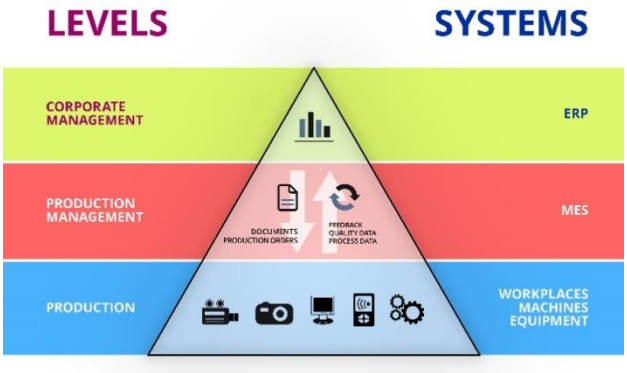

Fig. 3. Vertical system communication

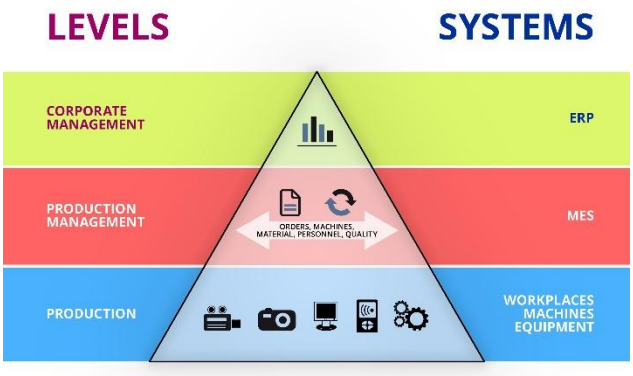

Fig. 4. Horizontal system communication

2. Distributed system

Manufacturing companies often have very complex and complicated operational processes, additionally it happens that operations are extended over many partnership companies which make smaller parts of products or plays role in a part of production processes. To stay on the market firms should change dynamically products, and have always fast reaction to disturbances. This need forces the use of systems with high level interactions and integration, at the same time with great flexibility for changes in configuration or components. This requirement meets distributed systems sometime called collaborative automated production systems. These systems have several special features [13]:

- A complex problem is divided into several small problems, using a distributed approach, with the development of intelligent building blocks, i.e. control units.
- Each control unit is autonomous, having its own objectives, knowledge and skills, and encapsulating intelligent functions, however, none of them has a global view of the system.
- The global decisions (e.g. the scheduling, monitoring and diagnosis) are determinate by more than one control unit, i.e. the control units need to work together, interacting in a collaborative way to reach a production decision.
- Some control units are connected to physical automation devices, such as sensors, robots and CNC machines.

We have a number of tools to implement this kind of systems. Agents, holons, webservices and microservices can be used. As communication protocols very popular are JSON (JavaScript Object Notation) [5] and XML (eXtensible Markup Language) [29], and for aggregate events MQTT (MQ Telemetry Transport) [9] protocol can be used. Agents are autonomous, intelligent, adaptive and cooperative objects, the most suitable definition for agents is: "An autonomous component that represents physical or logical objects in the system, capable to act in order to achieve its goals, and being able to interact with other agents, when it does not possess knowledge and skills to reach alone its objectives" [14]. The word “holon” was proposed by Koestler in 1971. This is combination of Greek words “holos” and “on”. Greek word “holos” meaning whole and the Greek suffix “on” meaning particle od part like proton or neutron. Holon can function as part another object and at the same time it is autonomous whole [8]. Holonic manufacturing system idea was proposed in 1990. HMS contains autonomous building blocks called holons, They have ability to transforming, transporting, storing and validation information or physical objects. Holons cooperate each other during the process, in order to achieve production goals. The holon in HMS must enable features [7]:

- autonomy: Each holon must be able to create, control and monitor the execution of its own plans and/or strategies, and to take suitable corrective actions against its own malfunctions,
- cooperation: Holons must be able to negotiate and execute mutually acceptable plans and take mutual actions against malfunctions,
- openness: The system must be able to accommodate the incorporation of new holons, the removal of existing holons, or modification of the functional capabilities of existing holons, with minimal human intervention, where holons or their functions may be supplied by a variety of diverse sources.

Web service is data source or application accessible via HTTP (HypeText Transfer Protocol) or its encrypted version HTTPS (HyperText Transport Protocol Secure) protocols. Opposite to WebApplication webservices are designed to communicate with other programs, not users. The most popular webservice protocol is SOAP (Simple Object Access

Protocol) – add a header to XML message before it is transferred over HTTP [3].

Microservice is module which supports a specific business goal, and uses well defined interface to communicate with other sets of services. Microservices architecture is an approach to developing a single application as a set of small services, each running in its own process and communicating with lightweight protocol [21].

3. System idea

Whole system idea was presented on Fig. 5. According to VDI 5600 guideline, system is divided horizontally in three main operational levels. The first level contains business systems, working in manufacturing company, it includes customer web portal, external information systems like ERP, web and mobile platform. First level already contains internal information systems like mobile production supervising application and other systems used in the enterprise. Business applications communicate with second level application via data services like WebApi, WebServices, WCF services, with use any communication formats and protocols like JSON, XML MQTT etc.

Data services should be projected as façade for master data service, this will allow to add any chosen communication method. Second level a larger number of elements. The start components of the system are Goals agent. The primary functions of Goals agent are asking data store about commissions queue, checking resources availability, knowledge about products and finally send commissions to Automation and customization product service. Goals agent ask Expert system service about expert's knowledge about product's production process. Expert system collects expert knowledge, questions and answers about production process. This data will be used in future to optimization production process. Goals agent also takes data from supplier's databases, HR system, warehouse system and data about production needs. Automation and customization product service prepare production process, divide commissions to smaller atomic parts and send to Plant floor objects. Plant flor objects we can define as services connected with physical factory equipment like sensors, actuators, PLC, CNC machines as well as data readers from transport equipment, measurement systems, RFID gates etc. As a plant floor object could be installed process tomography equipment to measure process parameters in closed production objects like pipelines or chemical reactors. Automation and customization module consists products reference models and adaptive control subsystem. The task of the automation module is to control the manufacturing process and receive process data. Collected data are used to adjust the control system settings. Intelligent measurement module is used to extend the measuring system with additional sensors and devices. This is area where process tomography equipment will be used. Additionally, could be used sensors which are important from production management and business management point of view, but which were not prepared by devices' manufacturers. This module contains measurement subsystem and intelligent sensors controller. Effect agent should collect data about production results, this data is collected in big data service, and after process will be use in future. The analytical engine is based on computational intelligence algorithms. This module takes data, process them, and returns as synthetic information ready to use in future processing. The last described module is communication module. This system's part is charge of data exchanging between production system and external applications like web applications, ERP systems, mobile applications as well as IT systems for control and supervisor production.

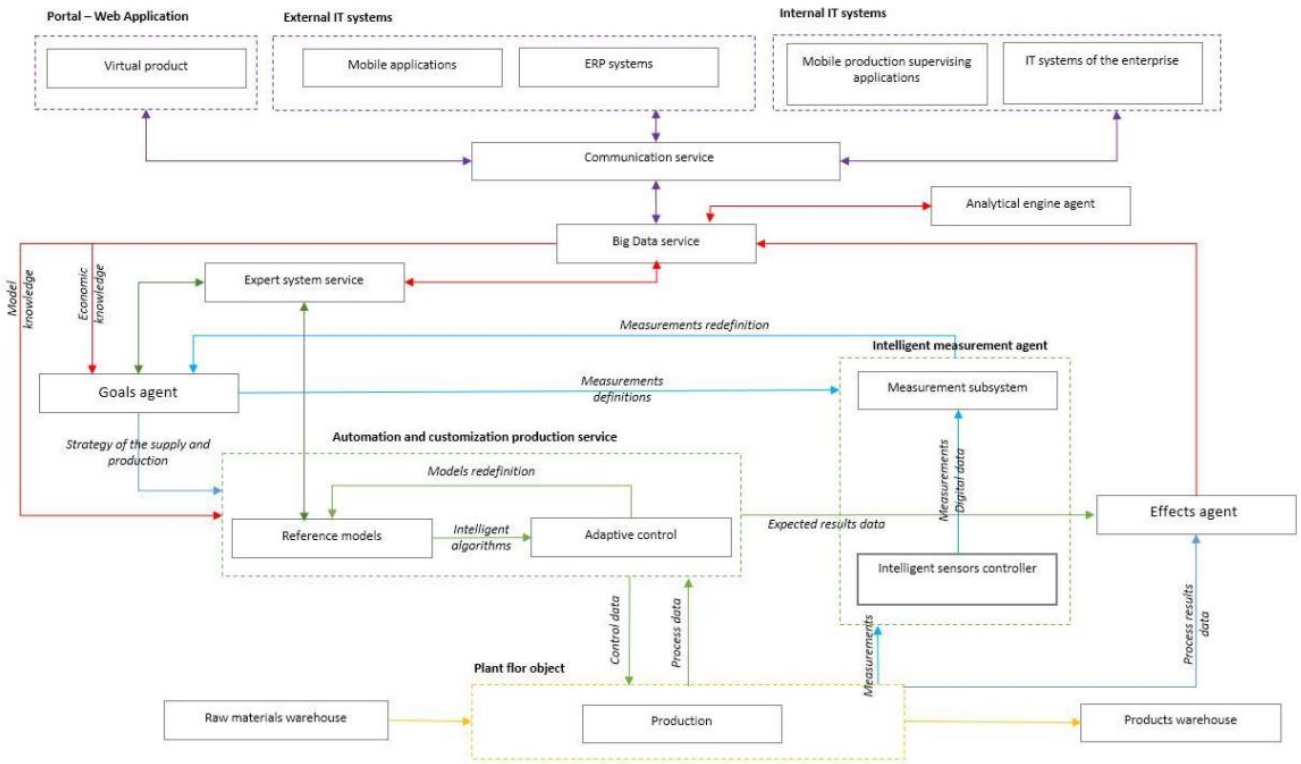

Fig. 5. System idea

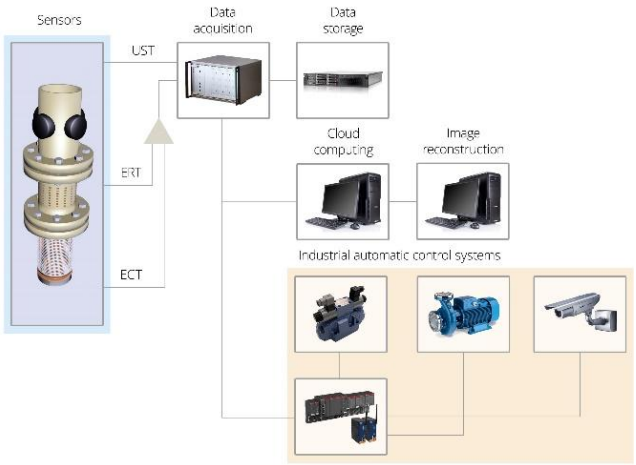

Fig. 6. The data acquisition system

The idea to use tomography to monitoring industrial processes emerged in the nineties. Since then, various tomographic methods have appeared, including: electrical tomography, magnetic, optical, ultrasonic, microwave and radioactive tomography. This concept requires new data processing strategies and a correct extension of the classical control theory, because the latter is not developed enough for a large amount of sensor data and must be created on a non-parametric criterion [12, 15, 19, 20, 22, 23, 26, 30]. Industrial tomography applications are usually a challenge for obtaining spatial distribution data from observations beyond the boundary of the process. Sensor networks with the feedback loops are the fundamental elements of the production control. Here, the future belongs to distributed sensors and imaging (Fig. 6).

4. Examples

Algorithms manual control and automatic cover issues related to the processing of data obtained from various sensors located at key nodes of the system. Supervision and control is in the range of acquired and processed data and device parameters implementing automation such as servo valves, pumps supply and rotary flow, etc. The primary / main feature of the use of methods of wireless is to obtain important information about the process and the state of the installation in real time by persons having strategic importance in the management and technical supervision. The Solution of the diagram of a multiphase flows system is presented in Fig. 7. Figure 8 shows the example of the image reconstruction by ECT, UT and EIT.

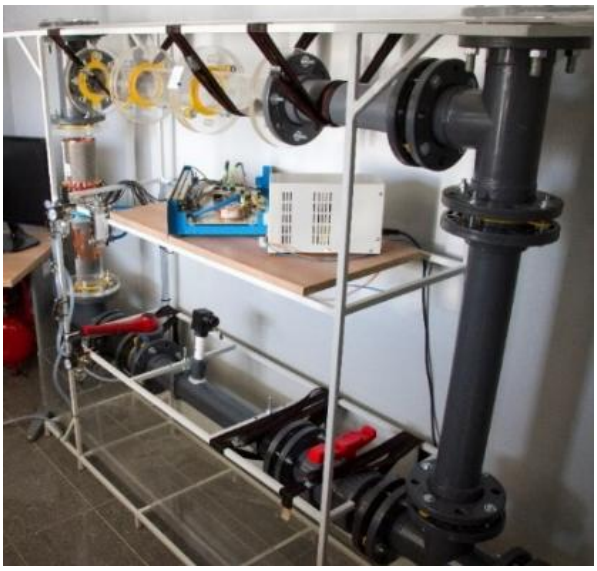

Fig. 7. Tomographic measurement system

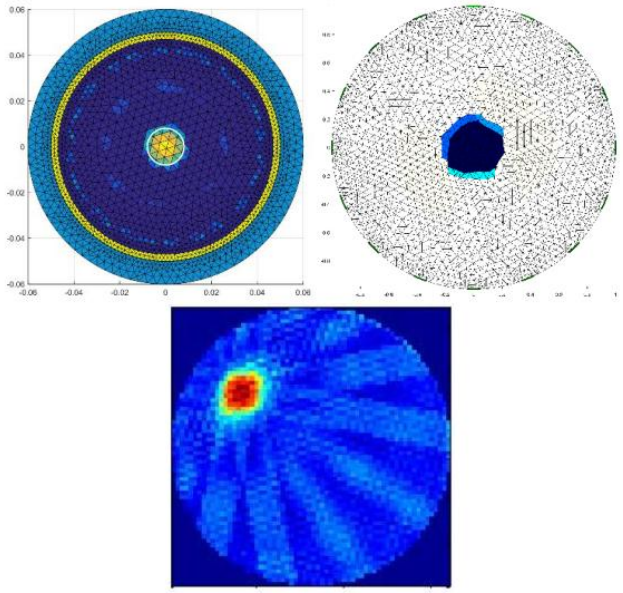

Fig. 8. Example of the image reconstruction by ECT, EIT and UST

5. Conclusion

In this work, there was presented the control and steering in cyber-physical system based on an idea of a production process control system and tomographic sensors. They were made virtual arrays equipped with active elements, control algorithms of manual and automatic. Running an application for processing and data obtained from various sensors disposed at key nodes installation. Supervision and control is in the range of acquired and processed data and parameters of devices implementing automation. A new science will define new mathematical foundations with formalisms to specify, analyze, verify and validate systems that monitor and control physical objects and entities. This system includes new measurement techniques and designs innovative smart measuring devices. The application structure covers a communication interface, unique algorithms for optimization and data analysis algorithms for image reconstruction and process monitoring

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M.Sc. Konrad Niderla
e-mail: konrad.niderla@netrix.com.pl

He manages at Netrix S.A. the programming and research department. In his work he deals with the development of new methods of control and measurement in the field of automation and tomography as well as artificial intelligence.

Ph. D. Eng. Tomasz Rymarczyk
e-mail: tomasz@rymarczyk.com

He is the director in Research and Development Center in Netrix S.A. and the director of the Institute of Computer Science and Innovative Technologies in the University of Economics and Innovation, Lublin, Poland.. He worked in many companies and institutes developing innovative projects and managing teams of employees. His research area focuses on the application of non-invasive imaging techniques, electrical tomography, image reconstruction, numerical modelling, image processing and analysis, process tomography, software engineering, knowledge engineering, artificial intelligence and computer measurement systems.

Prof. Jan Sikora
e-mail: sik59@wp.pl

He graduated from the Faculty of Electrical Engineering of the Warsaw University of Technology. During his 34 years of professional work, he has earned all grades, titles and positions at his home university, including the position of full professor. He has been associated since 1998 with the Institute of Electrical Engineering in Warsaw. In the years 2001–2004, he worked as a senior research fellow at the University College London in the Group of Optical Tomography. S.R. Arridge. He was employed at the Faculty of Electrical Engineering and Computer Science. Actually, he works in the R&D Department at Netrix S.A.

otrzymano/received: 10.07.2018 *przyjęto do druku/accepted: 15.09.2018*

DOI: 10.5604/01.3001.0012.5281

METHODS FOR DETECTION ANALYSIS IN QUALITY CONTROL SYSTEM

Konrad Kania[1], **Tomasz Rymarczyk**[1,2]
[1]Research and Development Center, Netrix S.A., Lublin, [2]University of Economics and Innovation in Lublin

Abstract. *The article contains a description of the quality control system based on optical detection algorithms. It plays an increasingly important in the production process. The development of new systems based on the technology of optical detection methods to a large degree can improve the production process at different stages.*

Keywords: segmentation, image analysis, code book algorithm

METODY DO ANALIZY DETEKCYJNEJ W SYSTEMIE KONTROLI JAKOŚCI

Streszczenie. *Artykuł zawiera opis systemu kontroli jakości oparty na optycznych algorytmach detekcji. Wykrywanie uszkodzeń odgrywa coraz większą rolę w procesie produkcyjnym. Opracowanie nowych systemów opartych na technologiach optycznych metod wykrywania w dużym stopniu może usprawnić proces produkcji na różnych jego etapach.*

Słowa kluczowe: segmentacja, analiza obrazu, algorytm code book

Introduction

Analysis of the data may be used for a process optimization in different ways and it can affect many aspects of a process management. We can detect disturbances in the process, find the causes affecting problems with a quality, and choose optimal settings for the process, comparing different preparation procedures and many others [1,4–9]. The presented application of a image processing concern two problems. Bottle caps and rectangular dark objects were used. Caps are cheap, easy to access and are available in various colours. The rectangle is a shape often found in products as well as squares, circles and ellipse and can be qualified and measured in similar way. In the testing setting there is a camera located over the conveyor belt. Axis of the camera view is perpendicular to the plane of the belt. The speed of the belt was about 16.5 cm per second.

First part of the paper is about detecting caps and determined their orientations. To detected objects set of pictures with an empty scene were used to define common colours of the background. To determine orientation of a cap the algorithm uses the Canny edge segmentation and the image is processed using the discrete convolution trying to match the cap oval pattern to the best extent - this is how the outer cap oval is located and then the interior of the oval is analysed.

Next part is about detecting and measuring rectangular dark objects. Two methods were presented to track the object location. The type of the method is determined by modality of a scene histogram. Whereas to measure the object rotate and translation invariant geometrical moments where used.

The main goal of the research was to find fast segmentation (in the real time) methods due to the requirements of the production processes.

1. Initial operations

1.1. Brightness regularization

Due to a lightening condition in the working space before an analysis of the scene there was applied a regularization of a brightness across the frame. Because the irregularity had stationary character i.e. it does not change over time, used method was based on the least square fitting of a plane to the brightness of the referential image of the empty conveyor belt treated as points in the three dimensional Euclidean space and next subtracting this plane from analysed scenes. The Fig. 1 shows a visualisation of the mentioned irregularity as a tilt in the brightness of the empty belt scene treated as a three dimensional surface, and the Fig. 2 presents the same scene after the regularisation. Removing of the tilt improve significantly global thresholding methods robustness without any additional computational expensive operations.

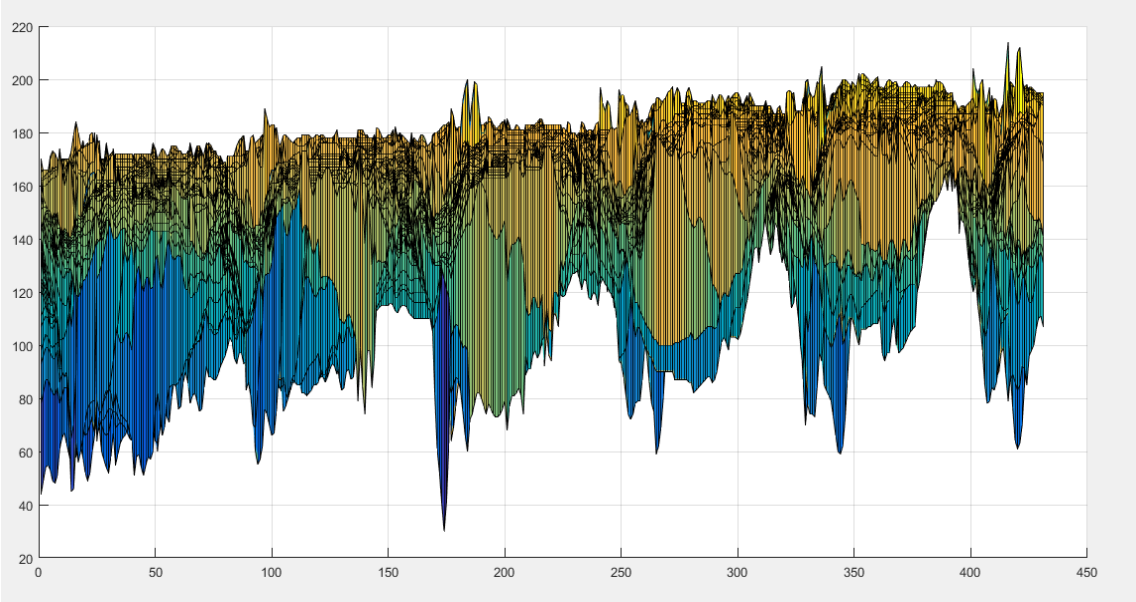

Fig. 1. Brightness irregularity on the scene - side view of 3D surface

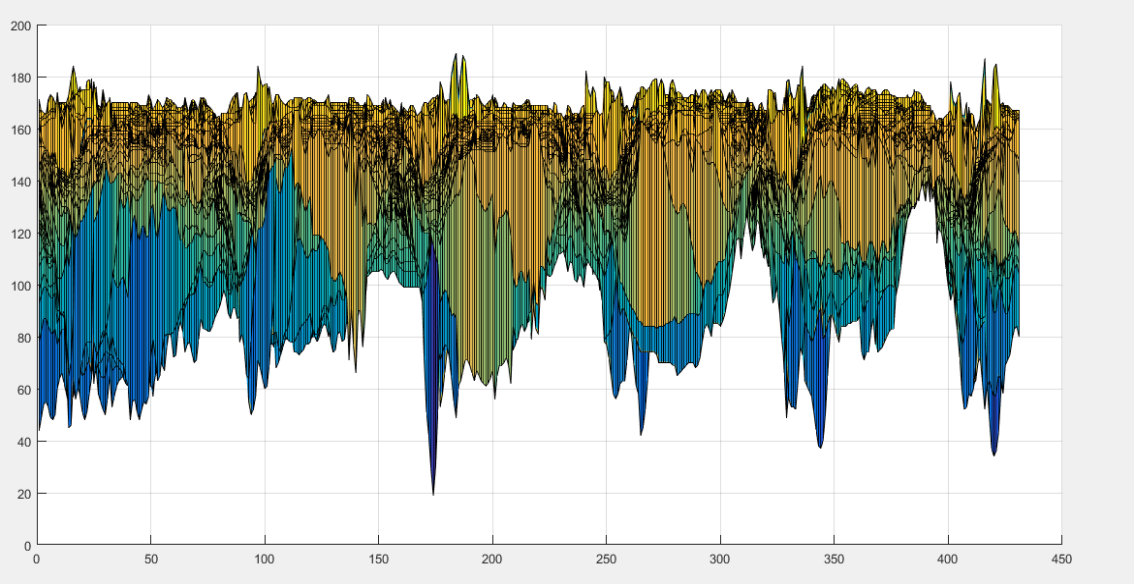

Fig. 2. Brightness after regularization – side view of 3D surface

1.2. Fast localisation of objects on the scene

In optical algorithms we often make an assumption that there is at most one object to analyse on the scene. To ensure that assumption in general conditions we have to split the initial scene, which can contain more than one object, to subscenes where the assumption is fulfilled. Thus we require the segmentation method that can be very inaccurate but has to be fast in splitting the scene, for that task we adapted the Code Book algorithm [2] changing the colour space from RGB to HSV. Because HSV has separated channels for the saturation and the brightness therefore the hue (H channel) is quite resist to lightening conditions and is essential for colours distinguishing. Thus change of the colour space allow to use the absolute value of differences between pixels to distinguish colours and is computationally cheaper than the Euclidean norm. The further most important change concerned the number of analysed pixels. Instead of checking all points on the frame we select just a grid with a distance of thirty pixels between checking points, and about fifteen pixels from edge of the picture to ensure that the grid is centred on the scene. The general purpose of the experiment was to determine how much information we can remove from the original scene and still be able to locate objects on the picture to split the whole image for sub-images containing only one object. The minimum number of points in the grid can be determined in two ways. First of all the minimum number of checking points is bounded by the degradation of entropy of the scene. Graph 4 show the curve of entropy of the scene after reducing it by taking every second pixel from original image (first point on graph) or previously reduced image (for rest of the points). We can see that after fifth point on the graph (where fifth point corresponds to taking every thirty-two pixel of the original image) the entropy decreases drastically due to degeneration of information on the scene. The second way of determination of the number of checking point correspond to the Nyquist–Shannon sampling theorem – radius of caps was about 65 pixels, so the 30 pixels space between checking points met the minimum value of samples (at least two checking point match a cap if it appear on scene) needed to restore the information about location of a cap. It is worth to notice that this is also the theoretical boundary for the spaces between objects, smaller gaps cause that separated objects are detected as one. Due to introduced changes, developed algorithm generate location marks map at the speed of about 1500 frames per second which meets our requirements for execution time. Fig. 3 shows example scene with the grid of analysed points. Location markers plot on the right show which points of the grid were recognized as a foreground. Based on that markers the rectangular sub-scenes with exactly one object are extracted and are shown on the bottom of the Fig. 3. Figure 4 presents the entropy degradation in the reduced scene.

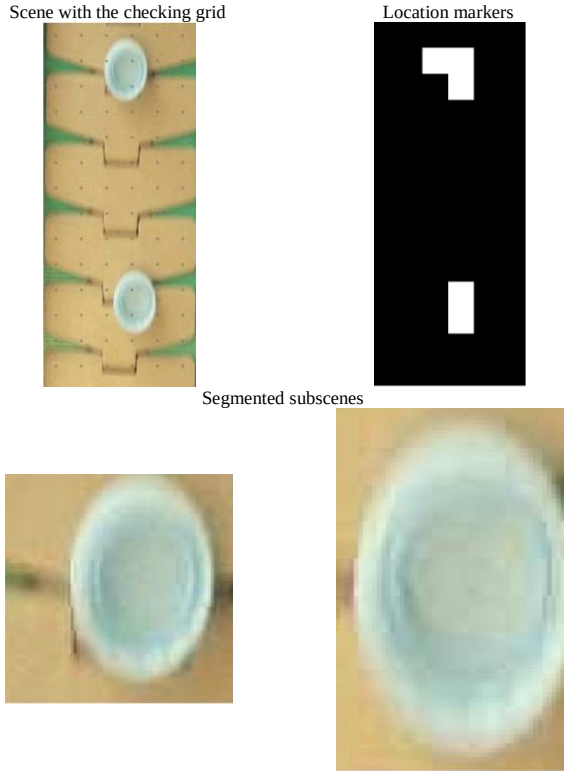

Fig. 3. Example of result of scene splitting algorithm

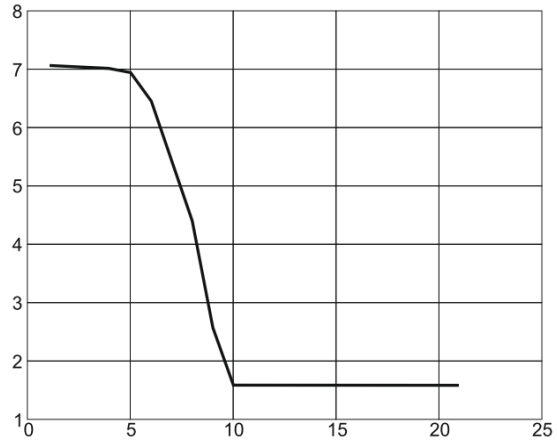

Fig. 4. Entropy degradation in the reduced scene

2. Determination of an orientation of a cap

Using the method for splitting the scene for the sub-scenes we create an application to define which side of a cap laying on the conveyor belt is visible.

Algorithm take sub-scene and (using the two-dimensional convolution) search for an oval of a cap on a scene of edges segmented by the Canny detector. Next the space inside the founded oval is analysed: if the number of pixels inside the oval do not exceed the fixed threshold then its mean that a cap is thread down. If the threshold is exceeded then it is mean that a cap is thread up. Figure 5 shows an example result of a sub-scene processing. In the upper left there are edges obtained by Canny detector and marked rectangle points place of the strongest response to the searched oval. In upper right there is shown the shape of oval mask. Bottom left presents extracted interior of the oval and the bottom right shows original image. The header REVERSED mean that a cap was recognised as thread up. Tested effectiveness of method was 94% (From 500 tested caps 19 was classified wrong as reversed and one was wrong classified as not reversed).

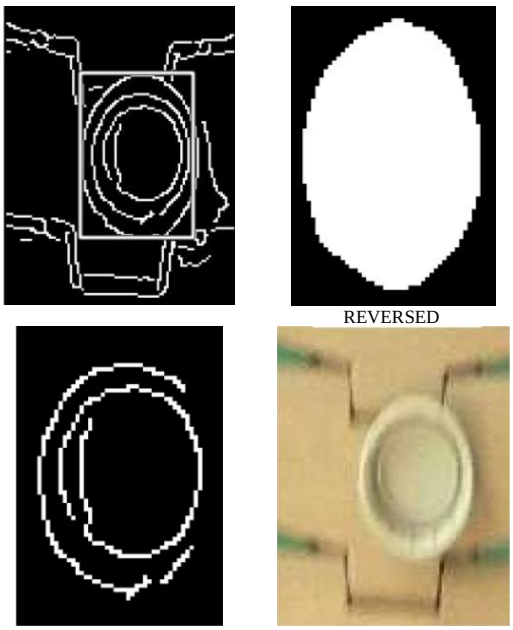

Fig. 5. Example of result of the algorithm for determination of an orientation of a cap

3. Segmentation of dark objects and measurements of dimensions based on rotate invariant geometrical moments

The next algorithm that we develop can be used to black object segmentation and also assuming that it has a shape of the rectangle the application measures dimensions of that object. For testing we used rectangular black phantoms printed by a 3D printer (in the case of bimodal histogram) and phantoms made of a black rubber (in the uni-modal case).

3.1. The case of bimodal histogram

If the histogram of the scene is bimodal then for the segmentation process we can use two global thresholds. The lower one is fixed on some small value to separate far too dark objects. The higher threshold is variable and it is adapting to the position of local maximum of the histogram of analysed scene that correspond to the mode of the searching object. To determine the value of that threshold we use a histogram of referential image of empty conveyor belt and the higher threshold is defined as

$$T_{high} = \arg\max(S_c(H_i - \alpha H_{ref})) \quad (1)$$

where H_i and H_{ref} are smoothed histograms of the current scene and the referential image respectively, $\boldsymbol{\alpha}$ is a fixed scalar bigger than 1 where a typical value is in the interval [1.5;2.1], $S_c(X)$ is a cumulative sum of the vector X.

Comparison of thresholding methods are shown in the Fig. 6. There are three different scenes binarized by: the Otsu's algorithm (first column), the iterative algorithm proposed by Gonzalez and Woods [3] (second column) and presented method before any additional filtering (last column of the figure).

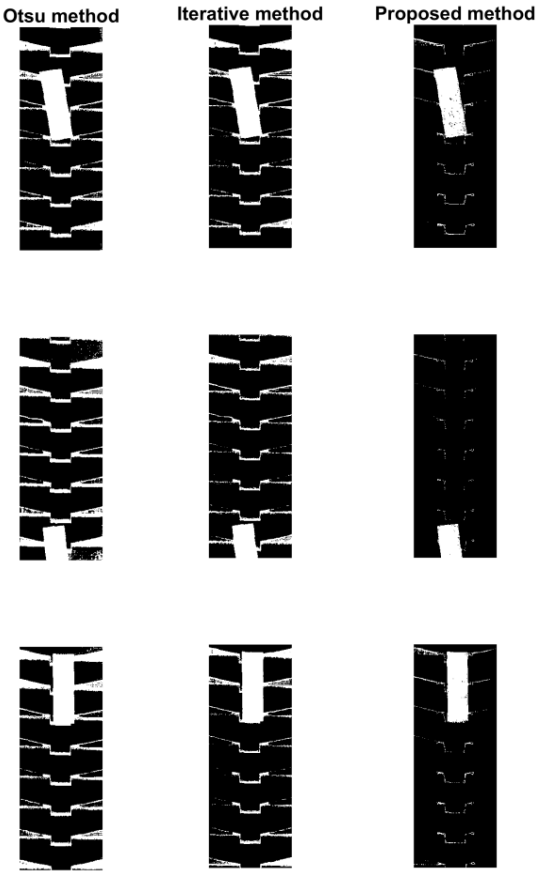

Fig. 6. Thresholding methods comparison

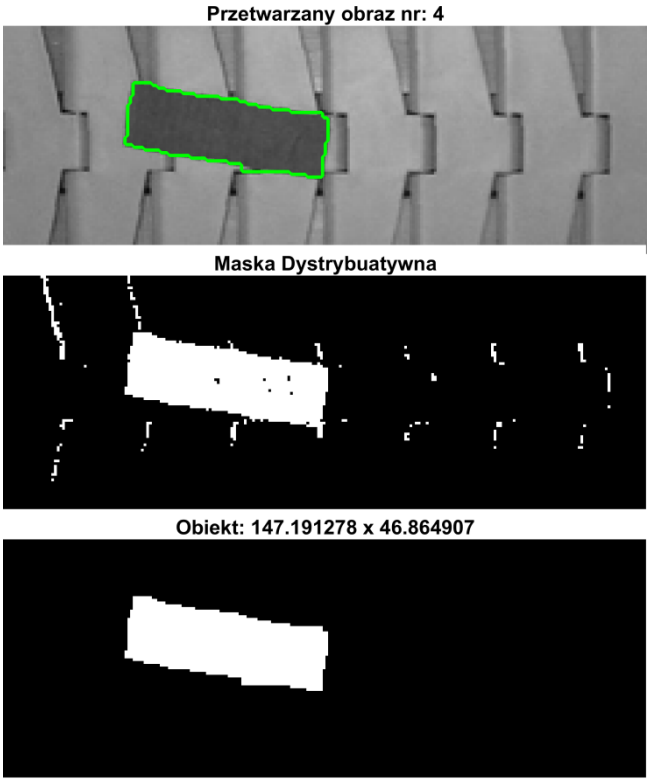

Fig. 7. Example of result of bimodal segmentation and measurements of dimensions

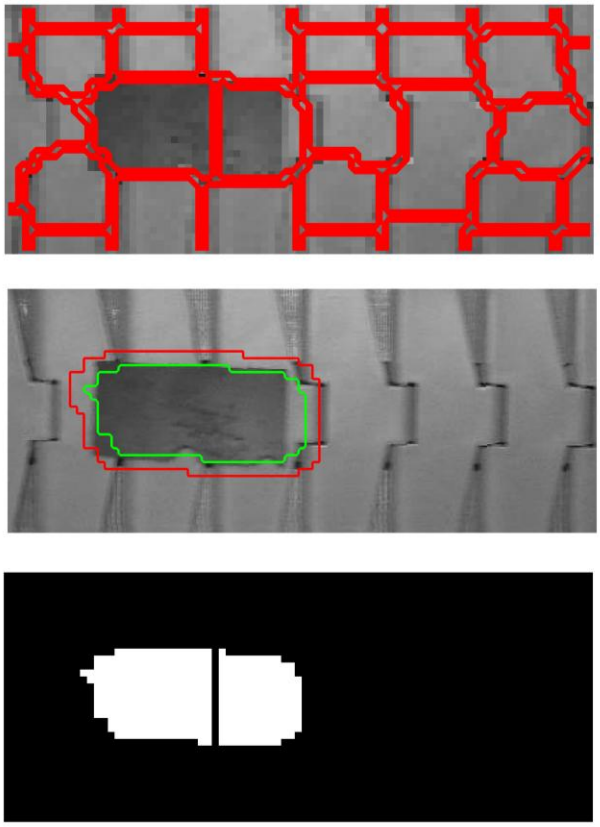

Fig. 8. Example of result of uni-modal segmentation

To remove noises after initial thresholding (middle plot of the Fig. 7) we scale down the binary mask (with the scale factor 2) and then we use standard morphological operation like opening (for further noise reduction) and closing (to obtain more convex shape on the mask). Bottom plot of the Fig. 7 shows the final mask, a boundary of a founded object is marked by the green line in the original grey-scale image in the top plot of the Fig. 7. When the segmentation process is complete we treated the founded shape as a set of points on the two dimensional plane and compute second order geometrical moments invariant to translations and rotations and base of that moment we can determine the dimensions of the object assuming that it is approximately rectangle-shaped according to the equations

$$T_{high} = \arg\max(S_c(H_i - \alpha H_{ref})) \quad (2)$$

for a < b. Where ϕ_1 and ϕ_2 are rotate and translation invariant moments [3] of a segmented shape and a parameter k is a scalar depending on the measured shapes. For rectangles $k = \sqrt{6}$ but for example for ellipses $k = 2\sqrt{2}$.

3.2. Segmentation in a case of uni-modal histogram

The method presented in the previous section is not suitable for the situation when the histogram of the analysed scene is uni-modal. In that case we cannot use the global thresholding even the adaptive one and we have to use some methods of local segmentation. In our method we computed morphological gradient of the image and applied median filter. After filtering we used the watershed segmentation (Matlab 2015b implementation of Meyer algorithm). Due to the shape of the segmented object we could scale down the picture with the factor of 5 without degradation of the entropy and process far less pixels which speed up watersheding and decrease the number of regions to inspect, moreover after downscaling distribution of the regions are more consistent due to degradation of gaps between belt plates to boundaries of regions. For segmentation the regions we use just a fixed threshold for the mean brightness within the region. After thresholding we scale up the mask back to the original size of the picture obtaining the fine approximation of the minimal region containing the searched object. Example of result is shown in the Fig. 8. Upper image is a visualisation of watershed segmentation, segmented regions are shown in the bottom part and in the middle there is the original scene, marked green line is the boundary of merged (by morphological closure) regions from the bottom mask rescaled to the original resolution, red line is the same region boundary but with the additional padding. Founded boundaries can be next used for example as the initial contour for the level set method if the accuracy of the segmentation is more desired than its speed.

4. Conclusion

Presented algorithm and methods show that the problems of detection and localisation of objects on the production line can be solved with the relatively easy way and according to that simplicity the systems of optical detection can be cheap and very fast. Another noticeable fact is that we can perform some mathematical operations to the scene to improve quality of detection without modifying conditions of the production environment. Used methods show also the advantages of applying reductions to the analysed frames for relevant acceleration of computations without decreasing the quality of detection results.

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Eng. Konrad Kania
e-mail: konrad.kania@netrix.com.pl

A graduate of the Lublin University of Technology. He specializes in applications of mathematics with particular emphasis on tomography reconstruction techniques. Currently, he prepares and implements algorithms for the analysis of measurement data in capacitive and ultrasonic tomography at Netrix S.A.

Ph.D. Eng. Tomasz Rymarczyk
e-mail: tomasz@rymarczyk.com

He is the director in Research and Development Center in Netrix S.A. and the director of the Institute of Computer Science and Innovative Technologies in the University of Economics and Innovation, Lublin, Poland. He worked in many companies and institutes developing innovative projects and managing teams of employees. His research area focuses on the application of non-invasive imaging techniques, electrical tomography, image reconstruction, numerical modelling, image processing and analysis, process tomography, software engineering, knowledge engineering, artificial intelligence and computer measurement systems.

otrzymano/received: 10.07.2018 *przyjęto do druku/accepted: 15.09.2018*

DOI: 10.5604/01.3001.0012.5282

NEURAL NETWORK AND CONVOLUTIONAL ALGORITH TO EXTRACT SHAPES BY E-MEDICUS APPLICATION

Tomasz Rymarczyk[1,2], **Barbara Stefaniak**[1], **Przemysław Adamkiewicz**[1]
[1]Research and Development Center, Netrix S.A., Lublin, [2]University of Economics and Innovation in Lublin

Abstract. *The solution shows the architecture of the system collecting and analyzing data. There was tried to develop algorithms to image segmentation. These algorithms are needed to identify arbitrary number of phases for the segmentation problem. With the use of algorithms such as the level set method, neural networks and deep learning methods, it can obtain a quicker diagnosis and automatically marking areas of the interest region in medical images.*

Keywords: image analysis, level set method, artificial intelligence algorithms

SIEĆ NEURONOWA I ALGORYTM KONWOLUCYJNY DO WYODRĘBNIANIA KSZTAŁTÓW W SYSTEMIE E-MEDICUS

Streszczenie. *Rozwiązanie pokazuje architekturę systemu zbierającego i analizującego dane. Opracowano algorytmy segmentacji obrazu. Algorytmy te są potrzebne do identyfikacji dowolnej liczby faz dla problemu segmentacji. Dzięki zastosowaniu algorytmów, takich jak metoda zbiorów poziomicowych, sieci neuronowych i metody głębokiego uczenia się, można uzyskać szybszą diagnozę i automatyczne oznaczanie obszarów w regionie zainteresowania w obrazach medycznych.*

Słowa kluczowe: analiza obrazu, metoda zbirów poziomicowych, algorytmy sztucznej inteligencji

Introduction

In medical clinical research and practice, imaging has become an essential part to diagnose and to study anatomy and function of the human body. The image data is of immense practical importance in medical informatics. Through continuous improvement of algorithms, we come to reduce the noise in the medical image. The proposed algorithms have been used to real pictures with promising results in the medical images segmentation. With the use of modern algorithms, the physician is able to obtain a quicker diagnosis. By automatically marking areas of interest you will notice all the changes in medical images [1–7]. E-Medicus system consists of artificial intelligence algorithms, segmentation algorithms, framework, agents, topological algorithms, databases, visualization systems and user interface.

Medical image segmentation, which aims at automated extraction of object boundary features, plays a fundamental role in understanding image content for searching and mining in medical image archives. A challenging problem is to segment regions with boundary insufficiencies, i.e., missing edges and/or lack of texture contrast between regions of interest (ROIs) and background. Lately, much interest has been raised in the medical imaging community about segmentation algorithms that use active contours or surfaces. In e-Medicus system, the segmentation algorithms were used, such as neural networks, deep learning, algorithm Beyesa, level set method, fuzzy sets and algorithm k-means (Fig. 1).

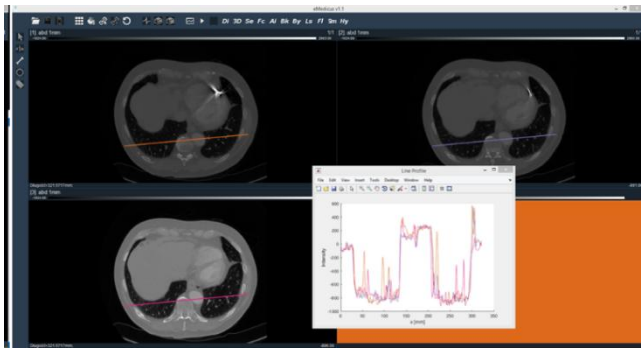

Fig. 1: Examples in e-Medicus system

1. Processing and analysis of data images

Processing and analysis of medical images includes image creation and reconstruction, image restore, image enhancement, image compression and storage, visualization [10–14]. In this work the image segmentation and analysis by artificial algorithms (such as neural networks and deep learning) and level set methods are presented.

The level set method tracks the motion of an interface by embedding the interface as the zero-level set of the signed distance function [8, 9, 13, 14]. The idea is merely to define a smooth function $\phi(x,t)$, that represents the interface as the set where $\phi(x,t)=0$. The motion is analyzed by the convection the ϕ values (levels) with the velocity field. The Hamilton-Jacobi equation of the form:

$$\frac{\partial \phi}{\partial t} + \mathbf{v}\,\nabla\phi = 0 \tag{1}$$

where **v** is the velocity on the interface.
The numerical algorithm is following:
from the level set function (initial) at a time level t, find necessary interface information,

- calculate the velocity,
- extend velocity,
- update the level set function,
- reinitialization.
- check convergence.

In Fig. 2, the level set method to compare two images and select differences between them was presented.

The artificial neural network (ANN) imitates the action of the human brain. It consists of neurons – which are the counterparts of nerve cells. Individual neurons are interconnected by creating a network. An artificial neural network usually consists of many types of neurons that exchange information between themselves. Neurons in the network can be grouped into so-called layers. There are hidden layers between the input layer and the output layer. Networks of this design are the popular variant of the ANN called multilayer perceptron networks (MLP). The characteristic feature of multilayer perceptrons is that the neurons in the same layer do not have connections between them.

The common feature of Machine Learning methods is that they can be used to teach computers in a manner that is analogous to how people learn by example. One of the Machine Learning techniques is Deep Learning, which is usually associated with Convolutional Neural Networks (CNN). Describing the extraordinary neural network workflow as "deep" distinguishes CNN model from the well-known Artificial Neural Networks (ANN) shallow architecture. Deep learning takes place if the neural network structure contains so-called convolutional layers and pooling layers. Another difference is the amount of hidden layers.

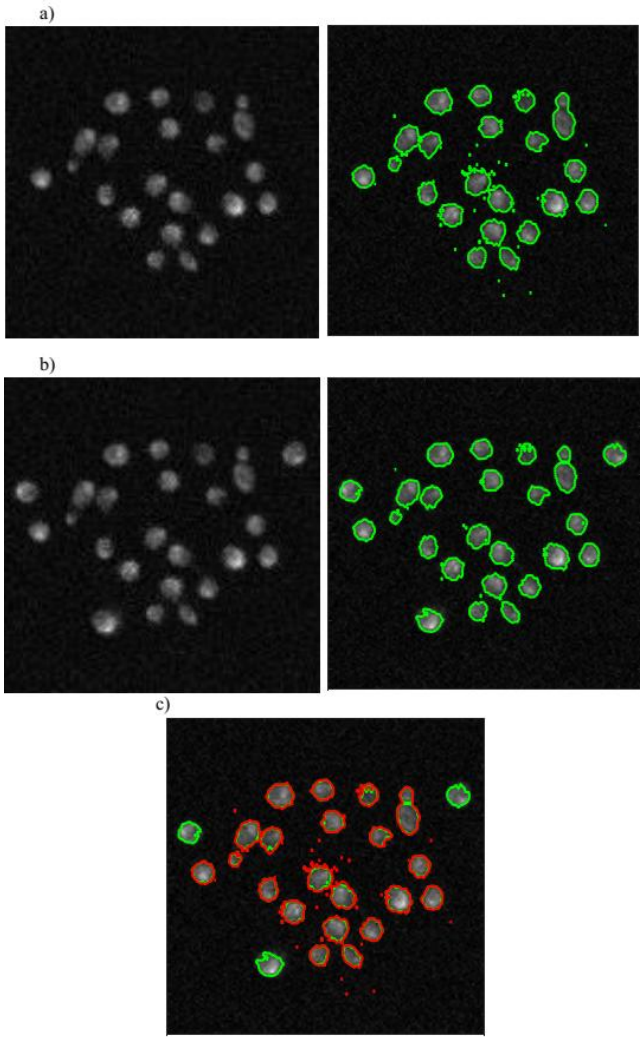

Fig. 2. Level set method – comparison of images: a) image 1, b) image 2, c) differences

While typical ANNs usually contain no more than 2–3 hidden layers, CNN can have them more than a hundred. Significant advantage of deep learning models is their ability to learn features directly from the data. It means that the training process is conducted automatically, without the need for manual feature extraction. To make it possible and efficient the CNN must be trained by using large sets of labelled data [4].

1.1. Neural network to recognize shapes

In our example, 11749 geometric figures were generated, such as: square, circle, rectangle, ellipse, for which all moments of inertia and variance were determined after developing the object's edge into polar coordinates. A neural network was created for which the input data are moments and variance of previously interchangeable flat figures. The output data are belonged to a particular class of figures. We rely on binary photos (Fig. 3).
The network has two layers. The number of layers are calculated from the formulas:

$$nf = \left\lfloor \sqrt{(ld+2)*n} \right\rfloor, \tag{2}$$

$$ns = ld \left\lfloor \frac{\sqrt{n}}{ld+2} \right\rfloor, \tag{3}$$

where *nf* – number of neurons in the first layer, *ns* – the number of neurons in the second layer, *ld*–number of input variables, *n*–number of the set.

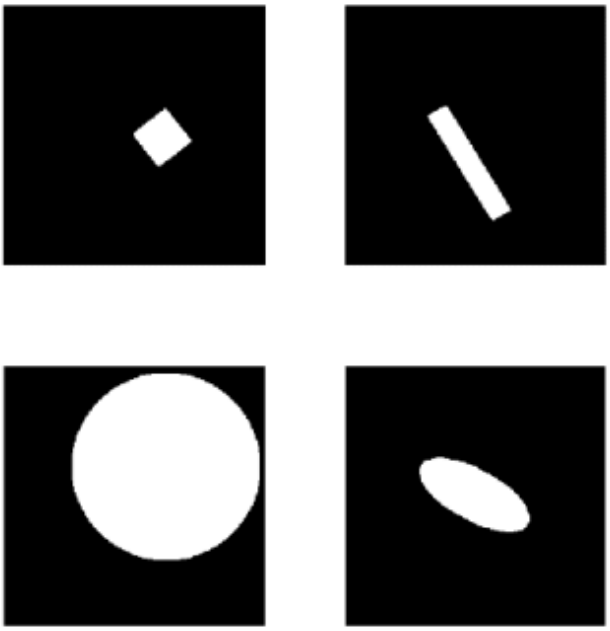

Fig.3. Shapes of the binary photos

The method to update weights and free words on the basis of trial and error was chosen as a conjugate gradient method – "trainscg". The validation threshold from 6 to 7 has been changed. For learning, 0.7, 0.15 and 0.15 of the set were used as a training, testing and validation set respectively. By minimizing the cross-entropy, the object sought the best classification. Science ended after 1135 iterations. The criterion for retaining science was to reach the validation threshold (network overriding was avoided). As a visualization of the results, a gradient and classification chart on the whole set is used (Fig.4).

Neural network gained 93.7% correctness in classification. The first class represents ellipses, the second circle, the third rectangle, and the fourth are squares. It can be noticed that the given network unmistakably classifies districts (as the object was a circle it was qualified as a circle).

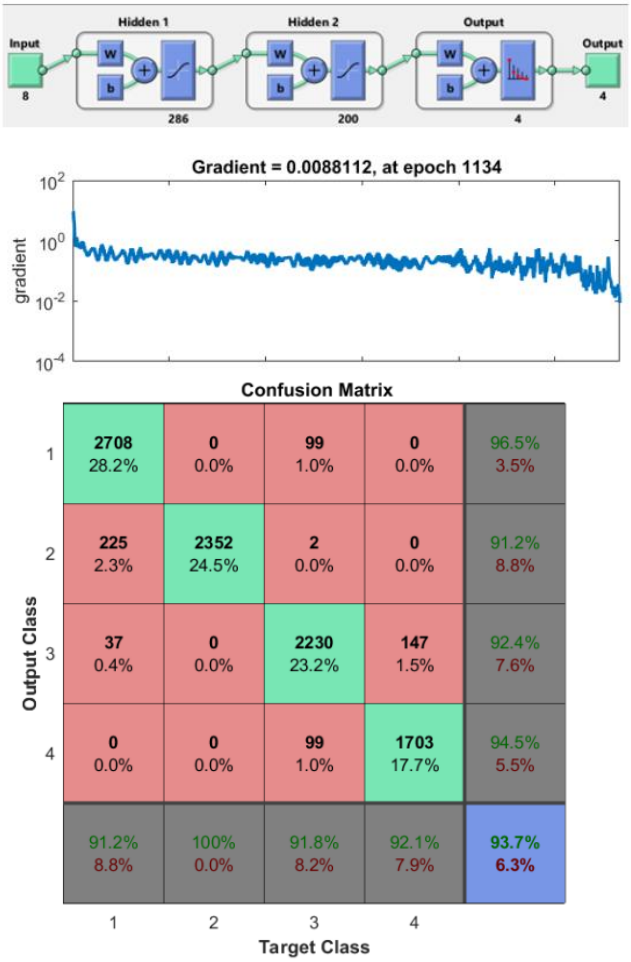

Fig. 4. Neural networks

1.2. Convolutional networks to extract shapes

Based on the emulsion images, a binary mask with clearly emphasized circles is marked in Fig. 5.

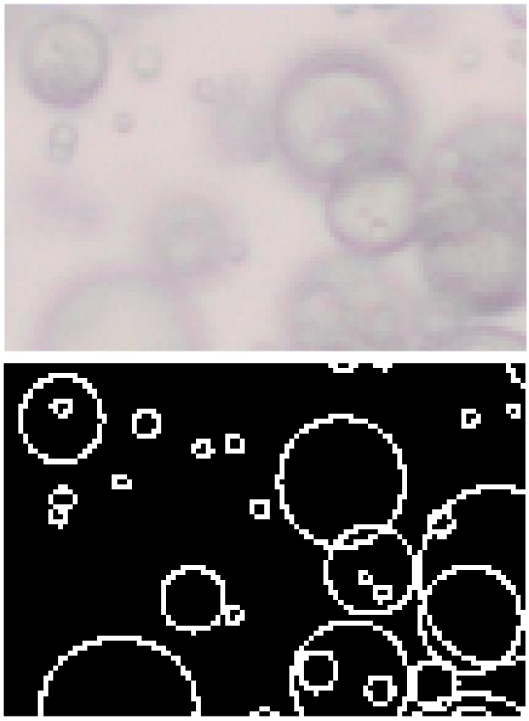

Fig. 5. Image with a binary mask with clearly marked circles

We use a two-layer network, both layers are based on 3×3 size convolution filters. The first layer has 5, the second 10 neurons.

Below, we consider convolutional networks without pooling (without reducing the matrix n-times by selecting the maximum from n × n blocks), a 4-layer network with neuron numbers of 10, 8, 5, 4 respectively for the first, second, etc. layers. At the entrance there is a 24 × 36 size photo, It gets a 16 × 28 size mask. Two approaches to the formulas for the activation function are presented.

Activation function I:

$$F(IMG) = \begin{cases} x, x > \overline{IMG} \\ 0, x < \overline{IMG} \end{cases},$$

where x is the value for individual pixels.

Activation function II:

$$F(IMG) = \begin{cases} \begin{cases} x, x < quantile(IMG, 0.3) \\ 0, x \geq quantile(IMG, 0.3) \end{cases}, & \text{var(IMG)} > prog, \\ \frac{\text{IMG}}{255}, & \text{var(IMG)} \leq \text{prog}, \end{cases}$$

where prog = $3.4393 \cdot 10^{-5}$.

The threshold was selected experimentally as a 10% quantum from the condition of all generated drawings.

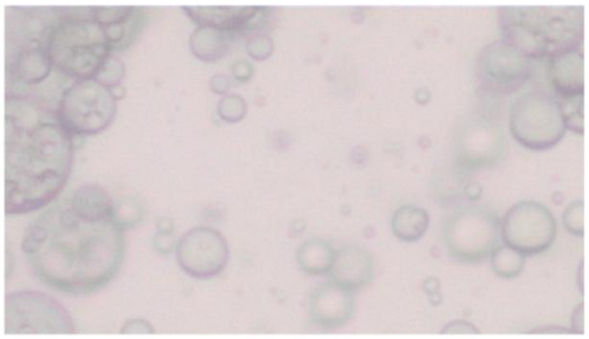

Fig. 6. The original image

Fig. 7. The results of the convolutional network – visualization I

Fig. 8. The results of the convolutional network – visualization II

The presented pictures are examples of the results of the convolutional network (Fig. 7 and Fig. 8) with the first activation function for the original photo (Fig. 6). It maps the block over a 24×36 size moving by a vector $\{16,28\}$, so it do not play back the edges at the moment. We give up this activation function because, as it turns out, pictures that do not contain circles are reproduced as white noise.

For the second activation function, the results was received after two iterations in Fig. 9. For time reasons, only the second iteration. Changing the activation function may reduce or even remove the white noise that occurred earlier. Assigning a constant value of 0 for the $IMG \leq prog$ would reset the part of the image that contains only a part of the circle or a very small circle.

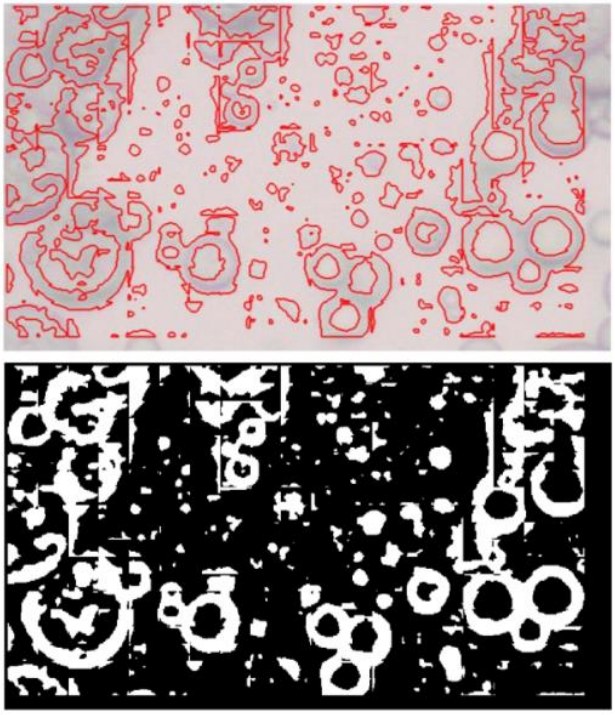

Fig. 9. The result for the activation function II

2. Conclusion

In medical clinical research and practice, imaging has become an essential part to diagnose and to study anatomy and function of the human body. The proposed algorithms have been used to real pictures with promising results in the medical images segmentation. With the use of modern algorithms, the physician is able to obtain a quicker diagnosis and to enable comparing the figures. By automatically marking areas of interest it will notice all the changes in medical images. In this work, the effective algorithms (such as the level set methods, neural networks and convolutional neural networks) to analysis and compare medical images were developed.

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Ph.D. Eng. Tomasz Rymarczyk
e-mail: tomasz@rymarczyk.com

He is the director in Research and Development Center in Netrix S.A. and the director of the Institute of Computer Science and Innovative Technologies in the University of Economics and Innovation, Lublin, Poland.. He worked in many companies and institutes developing innovative projects and managing teams of employees. His research area focuses on the application of non-invasive imaging techniques, electrical tomography, image reconstruction, numerical modelling, image processing and analysis, process tomography, software engineering, knowledge engineering, artificial intelligence and computer measurement systems.

Ph.D. Przemysław Adamkiewicz
e-mail: p.adamkiewicz@netrix.com.pl

He is a doctor of physics, graduate of Maria Curie-Sklodowska University in Lublin. He is a head of the R&D Department at Netrix S.A. His research area focuses on electrical impedance tomography, electrical capacitance tomography, image reconstruction, forward problem, inverse problem, numerical modelling, image analysis and computer measurement systems..

otrzymano/received: 10.07.2018 *przyjęto do druku/accepted: 15.09.2018*

DOI: 10.5604/01.3001.0012.5283

DESIGN OF DATA ANALYSIS SYSTEMS FOR BUSINESS PROCESS AUTOMATION

Tomasz Rymarczyk[1,2], Tomasz Cieplak[3], Grzegorz Kłosowski[3], Paweł Rymarczyk[1]
[1]Research and Development Center, Netrix S.A., Lublin, [2]University of Economics and Innovation in Lublin, [3]Lublin University of Technology, Faculty of Management, Department of Organization of Enterprise

Abstract. *The paper deals with the design of data analysis systems for business process automation. The main goal of the project is to develop an innovative system for analyzing multisource data, business data mining processes, and as a result the creation and sharing of new improved procedures and solutions.*

Keywords: Smart system, Multi-source Data, Agent Based Modelling

PROJEKTOWANIE SYSTEMÓW ANALIZY DANYCH DO AUTOMATYZACJI PROCESÓW BIZNESOWYCH

Streszczenie. *Artykuł dotyczy projektowania systemów analizy danych do automatyzacji procesów biznesowych. Głównym celem projektu jest opracowanie innowacyjnego systemu do analizy danych wieloźródłowych, procesów eksploracji danych biznesowych, a co za tym idzie tworzenie i udostępnianie nowych ulepszonych procedur i rozwiązań.*

Słowa kluczowe: inteligentne systemy, dane wieloźródłowe, modelowanie agentowe

Introduction

In this paper, the concept of an information system for analysis, preservation, optimization and generating innovative business data mining processes was presented. In modern and complex business world, companies must develop pioneering ways to distinguish themselves from other market players by becoming more cooperative, effective, precise, flexible and agile. They need to be capable to quickly reply to market requirements and alterations. Depending on the company's competitive advantage which may be a novelty, price, outstanding web content, or presence in social media, specific online strategies should be applied to achieve the desired market. Many companies have observed that the data they preserve and how they utilize it can build their market advantage. Data and information are turn into primary resources for many organizations [6]. For example, Walmart's databases located in cloud are estimated to contain overall more than 40 PB and process 2.5 PB of data every hour consisting information about customer behaviour and preferences, network and device activity, and market trends data [17]. Business models are based on data from external sources, data warehouses and web resources. They create a process base that is a resource for computational intelligence algorithms. The functionality of intelligent decision support and business process modelling is the management of strategic information, the analysis of information coming from the immediate and indirect business environment and influencing its strategic development. Traditional approach to systems development is concentrated on building applications, not services. Systems built that way are not flexible and are difficult to scale [19]. Nowadays, one of the major issues is that how to capture users' frequently changing needs and expectations and to support those with dynamic business processes. Moreover, analytical systems design must take into consideration that there are multiple channels of data that may need to be accessed and incorporated for further exploration. One of key characteristics of cloud is on-demand and secure access to scalable data exploration resources. Recently, main players of cloud-based services market introduced wide range of tools for data scientists. They enable analytical systems to aggregate a number of services with computing algorithms that are capable to provide dynamic solutions of data analysis tasks. Cloud-based analytical systems provide unlimited access to various data types and sources. It gives us an ability to process high volume and wide variety of data with high velocity and veracity, which means Big Data solutions.

The emergence of new technologies and tools of data collection and manipulation now opens areas of research on understanding customers-business relations and interactions. Conventional user interest modelling approaches are not created for integrating and studying interests from multiple sources, therefore, they are not very successful for obtaining comparatively complete description of user interests in the dispersed conditions. In this context data acquired from sources like social networks, digital journalism, mobile telephony, online gaming, online shopping, etc. empower business analysts to find more precise explanation of phenomena's driving contemporary business [5]. This process can be strongly empowered by AI methods. According to Gartner, Inc. report [4] for several next years main concern of IT companies will be creation of systems supported by artificial intelligence that can be applied in one form or another. Another important technological trend mentioned in the report is called "digital twins". This term occurs more frequently with progression of digitalization of our life but also digitalization of places, processes and "things". The process of "digital twins" development will offer productive space for new event-driven business processes and digitally enabled business models as well as ecosystems. Thanks to technological advancement, such systems will be able to provide a coherent set of components that will act as a living organism. In most cases, an intelligent system is able to percept and act to altering conditions as well as collect and deposit information in its memory and learn from prior experiences and knowledge. What is crucial, intelligent system is being able to adapt its actions to implement new tasks and achieve its pre-determined or developing objectives. Intelligent actions of those systems include listening and responding to participants, inspecting the markets, collecting and analysing data, creating and broadcasting knowledge, learning, and efficient decision making.

1. Smart system – design remarks

A diagram of system's data flow is shown on Fig. 1.

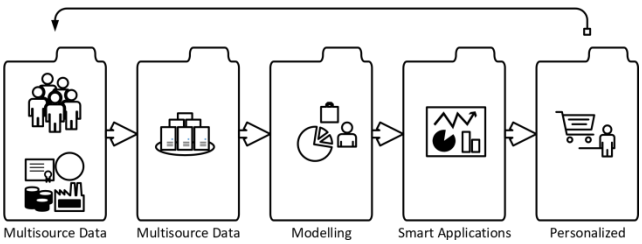

Fig. 1. Multi-source smart application data flow pipeline

Proposed approach involves following steps: data sources determination (mandatory – user's feedback and reactions on propositions sent by the system) as well as representing key information (e.g., entities, relations, events, sentiments); accumulating information from multiple sources, identifying inter-

document relationships, and storing the information in a structured knowledge databases; exploring and filtering existing data including entities, relations, and events, building analytical models and then identifying system efficiency with appropriate simulation methods (e.g. agent based modelling); upon on selected model suited for user's needs, an adequate type of application will be served to system's user.

A. Multi-source information integration

Perception of any particular state (e.g. purchase decision) involves incorporating many bits of information. In case of user interests, they are typically spread in various systems on the Web. This information has numerous attributes as a rule cases and is gained from multiple data sources within multiple time periods. Consumers' purchasing decision is stimulated by their knowledge about the brand, which includes innovativeness, impression of the brand, self-perceived brand value from web content, and e-WOM from social media [10]. State evaluators' understanding and preference will obviously affect the outcome of information integration, and therefore impact the understanding generated for a given state. Process of a multisource data analysis demands an accurate and precise data integration with evaluator's effect deprived. A learning-based information integration approach, which embeds the fuzzy least squares support vector machine (FLS-SVM) technique, was described in a research [15]. In the cited research, a state can be assessed through incorporating an inference acquired information and analyzing correlated data sources. In series of experiments it was shown that the suggested method has a precision learning capability depending on evaluators' skill in the information incorporation for producing awareness for a state. Another method of user interest modelling based on multisource personal information fusion and semantic reasoning was presented in a research [16]. Authors give different fusion strategies for interest data from multiple sources. Moreover, investigation on the semantic relationship between users' explicit interests and implicit interests by reasoning through concept granularity was presented. Authors gave illustrative examples based on multiple sources on the Web (e.g. microblog system Twitter, social network sites Facebook and LinkedIn, personal homepage, etc.) showing that offered approach is possibly effective.

B. Simulation modelling

Leaving aside a diversity of analyzed data and their huge number the smart applications are still very complex to design. Based on the above-mentioned statements the application design can be based on interactions of system actors. Following assumptions of essential functionality are made: all actors can exchange information with each other to understand continuously changing social situation; outgoing motives are generated to help other actors to understand the preferences and important factors in the decision-making process; at the same time respond to incoming motives from other actors to update its own attitude to the process [18]. In such scenario many dynamics and discrete events take place. Understanding a particular system is difficult without appropriate modelling method – a way of solving problems that occur inside the real system. Mentioned system consists of a number of dynamic processes that occur between actors of the system. Also, the actor's state is dynamic and changes in time as well as under interaction with environment. Analytical or static modelling solution for dynamic system does not always exist or may be very hard to find [3]. Nowadays, multi-agent simulation is increasingly being promoted – and used – as a tool to study the dynamics in various kinds of systems where human behaviour plays a critical role [9]. That's why, as a best solution, Agent Based Modelling (ABM) can be taken under consideration. Application of ABM allows system optimization prior its implementation.

C. Agent Based Modelling

Agent-based model (ABM) is a bottom-up methodology and has advantages in modelling complex systems. It has capability to symbolize the macro-level dynamics of a system by gathering individual behaviours and interactions among agents at the micro-level. ABM has been applied to engineering, sociology, economics, and management fields. Agent based modelling treats system as a collection of independent decision making objects so-called agents. Each agent separately evaluates its state and makes decisions on the foundation of a set of instructions. Agents may perform various actions suitable for the system they symbolise — for instance: producing, consuming, or selling. Recurring competitive relations among agents are a characteristic of agent-based modelling, which depend on the power of computers to investigate dynamics without application of pure mathematical methods [2].

Upon the research paradigm of study depicted on Fig. 2, a simplified agent-based model to study factors affecting consumers' adoption decision in multiple brands competition was developed. The modelling solution was based on a framework developed by Wander Jager. Understanding these decisions allows one's to say which factors ultimately affects brand's market share. The model simplification limits factors to a self-perceived value (price, rating, quality), a self-perceived utility from online information, e-WOM and social media [8]. In case of the self-perceived value, buyers often evaluate the value of a product by searching its online information, which includes price, online rating, quality ranking, etc. [12]. Wordof-mouth (WOM) is an important aspect that can influence consumers' opinion of a product and promote product diffusion [1].

Though, typical WOM is limited to social communication margins, and the influence weakens quickly over time and space [11]. The online review (e-WOM) performs a more significant role in consumers' purchase decision as the online groups are becoming more widespread and persistent. Buyers can easily retrieve the online evaluations in social network to reach first-hand data about the product [22]. The empirical investigation works also implies that there occurs a positive association between e-WOM and sales yield.

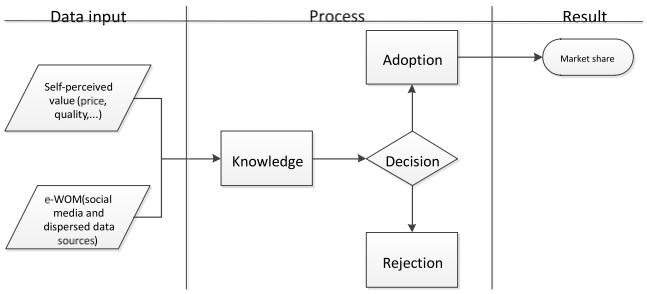

Fig. 2. Simplified model of factors affecting consumers' adoption decision in multiple brands competition

D. Simulation study

The agent-based model gives possibility of system observation, where consumers make decisions and adopt a brand upon its price, services, products quality and information taken from WOM and e-WOM sources. Often, customers may lack necessary product data, even after discussing with off-line groups. Often, customers may face a lack of necessary product data, even after discussing with off-line groups (WOM). They possibly will enter an online society to investigate relevant information, which can decrease an uncertainty and prevent incongruities between presumed and actual product functioning. Therefore, e-WOM communications are likely to have strongly effect opinion and purchase intent when customers meet new goods [7]. On the other hand, the more e-WOM is being searched, the less it is being utilized in the final purchase decision [20]. The online reviewing

system can act as an amplifier of information received through WOM, but also if e-WOM is also negative, it will have strong negative effect on customers' purchase decisions [14]. Taking into account information given by Liu [13], in the particular simulation model the scale-free network was employed to represent the interindividual interactions in the population to provide diversity of individuals in searching and information dissemination ability.

The calibrated consumer agent population to lead several simulations was used. Simulations were carried out to test market shares evolutions with a variant e-WOM level of information and different levels of perception of feedback (influenced by a number of searches). The following section reports these simulations and interpretations of the obtained results.

The interface of simulation system is shown in Fig. 3. All computational experiments were conducted in the same environment. The proof-of-concept of investigated approach was programmed in NetLogo 6.0.2 environment [21] on standard laptop (Intel core i7-5500U, CPU 2.4 GHz, and 16 GB of RAM), with Microsoft Windows 10 operating system.

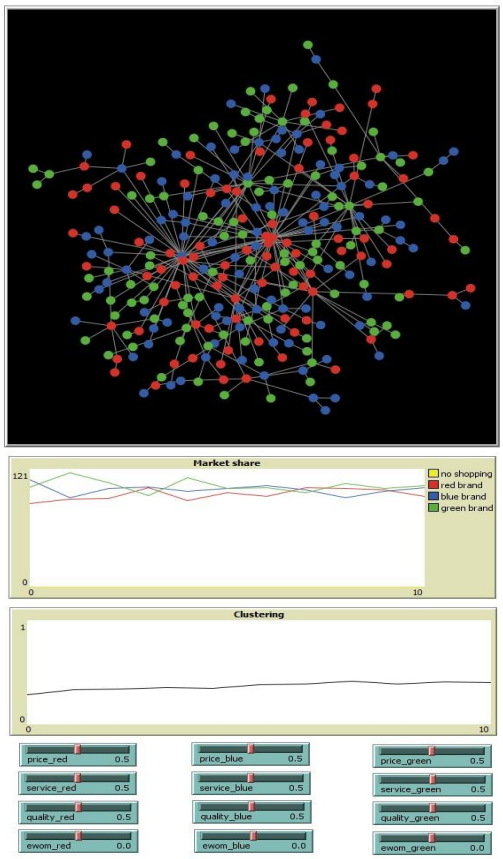

Fig. 3. Interface of the simulation system with depicted equilibrium state of customers' purchase intents

E. Simulations results

The simulation was started by creating a consumer agent population whose individuals have initially set behavioural attitudes intensities, like a preference of product, an ability to receive information from other agents, a level of market exploration. Then agents are gathered together establishing a scale-free network. Two experimentation contexts were tested. The first one was carried without an influence of e-WON on customers' purchase instances, the second included that influence. In both cases simulation contained a population of 300 consumer agents within a virtual market including 3 competing brands. Main parameters ranges of brands and customers agents are shown in Table I. When the simulation progress advances one "tick", consumers will make the purchase decision and trigger the choice event based on their purchase requirements (generated randomly Poisson-distributed integer values).

Consumers can retrieve brand information in WOM, and in the second research' scenario, the off-line WOM is amplified by the influence triggered by e-WOM. After the simulation process starts, the simulation system will run continuously until one hundred of repetition condition is met. In the following three cases of results relative to the evolution of market shares in the virtual market are presented. In the first experiment an initial market situation dominated by one brand was considered. In this case "Red Brand" overcome other brands by a mean of better price in comparison to competitors. The difference was set in an instance of price parameter. For "Red Brand" it was set to level 0.9, were for other brands the price level was 0.5. In such conditions, the mean market share was 0.44% in case of "Red Brand" and other two took almost the same position with 0.28% for each. The summary statistics of the simulation results of case 1 are shown in Table II.

Table I. Agents parameters ranges

	Parameter	Min	Max
Brand	Price	0	1
	Services	0	1
	Quality	0	1
	e-WOM	-0.5	0.5
Customer	WOM influence	0	1
	Perception ability	0	1
	e-WOM search level	1	2

Table II. Descriptive statistics of first case of first experimentation context

Brand	Min	Max	Mean	SD
Red	0.34	0.53	0.44	0,04
Blue	0.22	0.36	0.28	0,03
Green	0.20	0.34	0.28	0,03

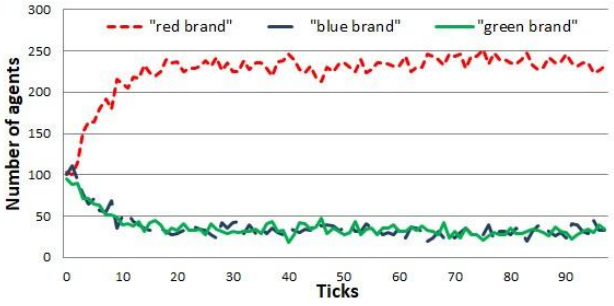

Fig. 4. Interface of the simulation system with depicted equilibrium state of customers' purchase intents

Following two cases describe the influence of the positive e-WOM on the market share. This is the aim of the research to understand how to eliminate information noise to increase the positive e-WOM influence on brand's position on a market. With the first e-WOM influence case, "Red Brand" has a well-developed system of online reviews and opinions about its product. Users were able to find quickly corresponding opinions, so the e-WOM search level was low and equalled 1.0 and e-WOM amplification was set to 0.1. "Blue Brand" has in the same time no information and no positive influence of e-WON on buyers' decisions, trying to conquer the market with lower price level competing with "Red" adversary. With a low diffusion coefficient of the information about "Blue" and "Green" brands over the market participants, "Red Brand" quickly gets almost 75% of market share. This phenomenon is depicted on Fig. 4.

The situation has opposite course when "Red Brand" information quality spread around online community become worse comparing to the previous state. Then users must spend more time and have to search through many more reviews to find sufficient and satisfactory enough information about brand's products. On the other hand, "Blue Brand" is developing much better services and product quality with lower price in contrast to "Red Brand". This situation is represented by the model setting: "Red Brand": price 0.5, services 0.5, quality 0.5, eWOM: 0.1,

e-WOM search level: 2; “Blue Brand”: price 0.9, services 0.9, quality 0.9, e-WOM: 0.0, e-WOM search level: 2. Due to that users can’t rely on the brand’s information collected from Internet, they need to develop a self-perceived value of brands. So, that’s why after some time needed for the user to investigate the market “Blue brand” overcome “Red Brand”. This can be observed on Fig. 5.

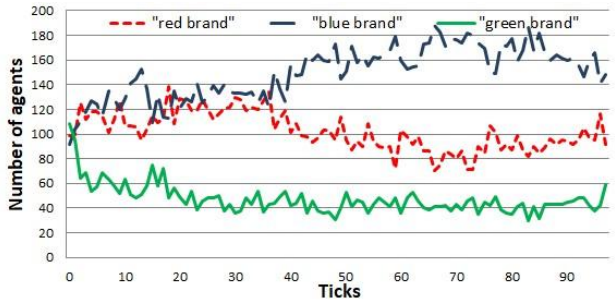

Fig. 5. Interface of the simulation system with depicted equilibrium state of customers’ purchase intents

2. Conclusion

A goal for designed system is better market penetration and long-tail marketing, targeted and personalized recommendation, increased sale and customer satisfaction. To reach this aim, the influence of the information spread over the internet in the form of product’s users’ opinions, reviews or recommendations on customer purchase intents were investigated. The investigation shows that well developed and reliable e-WOM has very high influence on customer’s decisions.

Systems that will be developed in future will be based on research areas containing five critical technical areas – big data sets analytics, text analytics, web analytics, network analytics, and mobile analytics. Characteristics of user’s data can be described as follows: structured web-based, user-generated content, rich network information, unstructured informal customer opinions. Data sources identification gives a potential way for application of different analytical methods like: association rule mining, database segmentation and clustering, anomaly detection, graph mining, social network analysis, text and web analytics, sentiment and affect analysis. Introduction of multi-source, multi-user data analysis allows to develop or reinvent systems for social media monitoring, crowd-sourcing data gathering and monitoring, social and virtual games and better recommender systems.

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Ph.D. Eng. Tomasz Rymarczyk
e-mail: tomasz@rymarczyk.com

He is the director in Research and Development Center in Netrix S.A. and the director of the Institute of Computer Science and Innovative Technologies in the University of Economics and Innovation, Lublin, Poland.. He worked in many companies and institutes developing innovative projects and managing teams of employees. His research area focuses on the application of non-invasive imaging techniques, electrical tomography, image reconstruction, numerical modelling, image processing and analysis, process tomography, software engineering, knowledge engineering, artificial intelligence and computer measurement systems.

Ph.D. Tomasz Cieplak
e-mail: t.cieplak@pollub.pl

Doctor of Engineering, acting assistant professor in the Department of Enterprise Organization in the Faculty of Management, Lublin University of Technology. He has extensive experience in preparing and conducting lectures and training. What's more, he has research experience gained in the prepared doctoral dissertation at Saga University, Japan. The area of research interest is the use model of cloud computing in the enterprise, creating systems based on SOA and the cloud computing model.

Ph.D. Grzegorz Kłosowski
e-mail: g.klosowski@pollub.pl

Assistant Professor in Department of Organization of Enterprise at the Faculty of Management of Lublin University of Technology. The research interests of the author include artificial intelligence, simulation and modeling of engineering and business processes. Leader and participant in several implementation projects. Chairman of the Board of the Special Purpose Vehicle of POLLUB-Invest Ltd., whose purpose is indirect commercialization.

M.Sc. Paweł Rymarczyk
e-mail: pawel.rymarczyk@netrix.com.pl

In 2003, He graduated from IT studies at the University of Information Technology and Management in Rzeszów. In the years 2012-2016 he was a PhD student at the Electrotechnical Institute in Warsaw. Research interests are mainly focused on IT applications.

otrzymano/received: 10.07.2018 *przyjęto do druku/accepted: 15.09.2018*

DOI: 10.5604/01.3001.0012.5284

OVERVIEW OF CURRENTLY USED WIRELESS ELECTRICAL VEHICLE CHARGING SOLUTIONS

Damian Dobrzański
Lublin University of Technology, Faculty of Electrical Engineering and Computer Science, Department of Electrical Machines and Drives

Abstract. *This article describes the current systems for wireless electrical vehicles charging available for use and ideas how to improve efficiency of them, differences between active and passive (static) contactless charging and also institutions and companies which work on development this kind of technology.*

Keywords: wireless charging, electrical vehicles, contactless charging, active charging, EVSE

PRZEGLĄD WYKORZYSTYWANYCH BEZPRZEWODOWYCH SYSTEMÓW ŁADOWANIA POJAZDÓW ELEKTRYCZNYCH

Streszczenie. *Artykuł opisuje aktualnie dostępne systemy bezprzewodowego ładowania pojazdów elektrycznych oraz koncepcje zwiększenia ich sprawności, różnice pomiędzy aktywnym oraz pasywnym (statycznym) ładowaniem bezstykowym a także instytucje i firmy pracujące nad rozwojem tych technologii.*

Słowa kluczowe: ładowanie bezprzewodowe, pojazdy elektryczne, ładowanie bezstykowe, aktywne ładowanie, pojazdy elektryczne

Introduction

In the last few years, the automotive world is turn back to history. It`s really hard to say when and who was built the first electric vehicle but with a lot of probability it was created between 1832–1839 by Robert Anderson [20]. But in 1900 in USA car production was equal 1575 electric vs. 936 petrol car. The most of society doesn`t even know about it and take electric cars for a new gadget, but if we look for dates someone could say "Electric cars is nothing new" and he has the right. As we can see when we are looking at a market, electric vehicles are becoming more popular. All major car producers have or plan to have in their offer electrical models. This kind of revolution brings many advantages like cleaner air with less pollution, higher efficiency of car engine (petrol engine achieves efficiency near to 40% as opposed to electrical engines with efficiency higher than 90%) and finally while using EV (electrical vehicle) we can significantly reduce greenhouse gases. The most important limitation of EV is range which is directly connected to energy density, for example in gasoline this value is 46 MJ/kg and in lithium-ion battery is less than 1 MJ/kg [11]. It only means that we have to fill the battery more often than the petrol car. The most used kind of charging EV is standard electrical plug with cable connected to home socket or using EV fast chargers mounted in parking lots near large-area shop or tank station or less in public places. For now we have four most popular standards of chargers, with different plug and charging power. Driver needs to know where is the charger which is compatible with his car, then park car in range of cable, go out from vehicle, authorize himself in system and connect it to charger to start charging. This solution takes priceless time and is uncomfortable when outside car is bad weather.

This paper is a short overview of few chosen solution which could remedy this, all of them can be described as a wireless vehicle charging system. The aim of the article is to present existing contactless solutions for both individual users as well as for companies and public space.

1. Standards of conventional charging of electric vehicles

The beginnings of the actually existing standard dates back to 2003 when is published by International Electrotechnical Commission (IEC) in IEC 62196 documents. Today all types of wired EV charging should be compatible with requirements described in IEC 62196 standard documentation which is divided to three parts. First – IEC 62196-1 which describes general information about interface between charging station and electric vehicles. Second – IEC 62196-2 describes dimensional compatibility and interchangeability requirements for alternating current (AC) charging and the third – IEC 62196-3 where have been included requirements for direct current (DC) or AC/DC charging [17]. Right now we have four most popular standards based on IEC 62196 which is use to charge electrical vehicles. The first one is 62196 – type 1 – American and 62196 – type 2 – European version of AC charging, second is Combo Charging System (CCS) which is also divided to American and European versions, this standard was first time connected AC and DC fast charging in one plug. The most important different between US and EU types are number of using AC phases this is due to the greater popularity of the three-phase network in Europe. Third is Japanese CHAdeMO-DC fast charging standard and the last one is Tesla Supercharger. The most important technical parameters and differences between them was shown in *Table 1*.

Table 1. The most important parameters of wired charging standards for electrical vehicles [17, 19, 21]

Name	Voltage [V]	Current [A]	Power [kW]	Communication
62196 US	240 AC	80	19.2	PLC
62196 EU	480 AC	63	30.2	PLC
CCS1	500 DC	<400	200	PLC
CCS2	500 DC	<400	200	PLC
CHAdeMO	500 DC	<125	62.5	CAN-bus
Tesla super-charger	480 DC	<250	120	PLC

2. Wireless energy transfer the obsession of Nikola Tesla

First time energy was transferred contactless probably by Nikola Tesla in 1891 to supply lighting bulb, this concept is shown in Figure 1. Two vacuum tubes lighted in an alternating electrostatic field while held in the hand of the experimenter hand. Between two metal plates each being connected to one terminal of the induction coil secondary winding, was created electric field [17]. We can speculate that he did not suspect that his concept will be used after more than 100 years to charge many devices, from smartphones, smartwatches to electrical vehicles. First hands-free wireless charging had its debut in 2002 in Turin and Genoa to charge electrical buses. Contactless power transfer system was made by German company Conductix-Wampfler and it is still working to this day. Since 2009 wireless charging has been divided into two types, passive (stationary) and active (on line charging or charging on move).

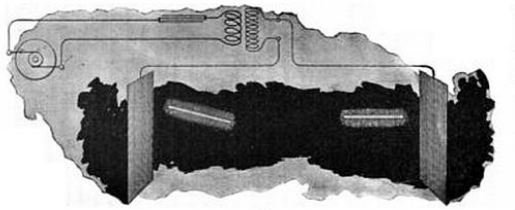

Fig. 1. Tesla`s wireless energy transfer concept [19]

To understand the idea how wireless charging works we need to know what conventional charger is built of. As is shown in Figure 2 we can see two pairs of transistors (S1,S2 and S4,S3 or S5,S6 and S7,S8) for each side of charger, connected to DC bus, in the centre there is a transformer with galvanic isolation. Number of turns on primary and secondary side is strictly related to power of the charger. After transistors there is a low pass filter and a load, depicted by battery symbol. Transistors turn on and off in pairs as below, to deliver power when it is necessary. Transformer is used to achieve the required level of safety The wireless charger isn`t more complicated than typical fast charger. To build this kind of power transmission station we need to replace transformer with galvanic isolation with two coils transmitter (Tx) and receiver (Rx) and design compensation system for each of parts as is shown on Figure 3, rest of the circuit could be similar.

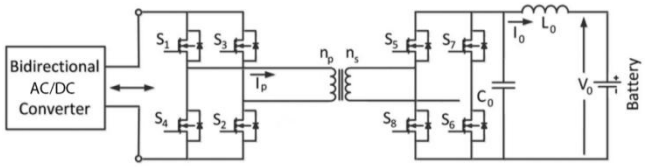

Fig. 2. Bidirectional EV fast charger topology [10]

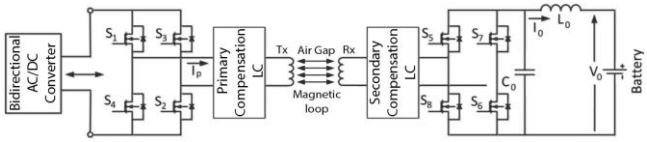

Fig. 3. Bidirectional EV wireless charger topology

In wireless power transfer (WPT) [14] the transmitter and receiver coils together form transformer with larger air gap than it is in conventional charger. The current flowing through to the Tx coil creates an oscillating magnetic field which is passes through the Rx coil. This phenomenon was found and described by Faraday, it`s induces a AC voltage in Rx terminal. Inducted voltage can be used directly or rectified by receiver [6]. In this topology voltage on Rx clamp is rectified by four controllable transistors and deliver to load. Of course each coil should be calculated for assumed power, frequency and voltage. However, designer must be aware of the limitations resulting from this kind of solution. The most important of the aforementioned restrictions is distance between coils which in a three-dimensional coordinate system is defined as the "z-axis" variable, second one is centering of both coils it`s the "x-axis" and "y-axis" variable correlation bad and good configuration was shown in Figure 4. WPT technology is a collective name for any solution which is use to wireless energy transfer, it`s divided to six types for different technology and possible current or possible future applications starting at portable devices charging and ending on biomedical implants or MAGLEV (Magnetic Levitation) trains [1]. The Division and exemplary use are presented in Table 2 and Table 3. Wireless Power Transfer includes technologies like inductive coupling, resonant inductive coupling, capacitive coupling, magnetodynamic coupling, microwaves, light waves.

It should be honestly acknowledged that if the distance between the coils is too large and their arrangement significantly deviates from the central one, charging process could be ineffective or not start at all.

Table 2. The most important parameters of WPT types part 1 [1, 8]

Technology	Inductive Coupling	Resonant Inductive Coupling	Capacitive Coupling
Range	Short	Medium	Short
Directivity	Low	Low	Low
Freq.	Hz-MHz	kHz-GHz	kHz-MHz
Antenna	Wire coils	Tuned coils, lumped resonators	Metal plate electrodes
Current and possible applications	EV charging, tooth brush, stovetops	Portable devices, Maglev, trains, RFID	Large scale routing, smartcards, implants

Table 3. The most important parameters of WPT types part 2 [8, 9]

Technology	Magneto-dynamic coupling	Microwaves	Light waves
Range	Short	Long	Long
Directivity	N.A.	High	High
Freq.	Hz	GHz	≥THz
Antenna	Rotating magnets	Parabolic dishes, phased arrays	Lasers, photocells
Current and possible applications	EV charging, buses, implants	Solar powered satellite, powering drone, charging devices	Charging devices, powering space elevator climbers

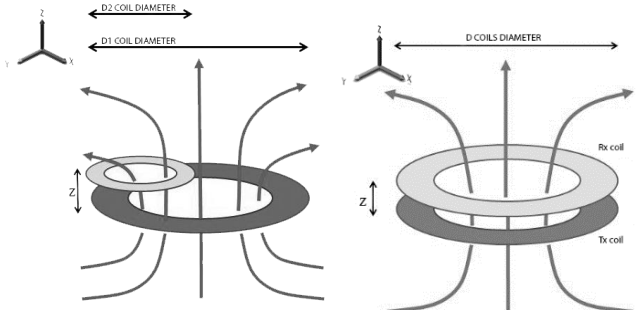

Fig. 4. Bad – not centralized coils in Cartesian coordinates, and on the right side correctly designed coil system

3. Overview of existing commercial wireless charging station for electrical vehicle

In this chapter there are shown chosen wireless charging stations which are currently under development or have been recently introduced to the market.

3.1. Qualcomm Halo

First one of wireless charging solutions which is described in this paper is project Halo WEVC (Wireless Electric Vehicle Charging) from Qualcomm. This American company is one of the largest CPU producers (Central Processing Unit) for handheld electronics like navigation units, smartphones, tablets and many other devices.

Qualcomm Halo assumes wide availability of parking places equipped with wireless charging station, if they plan was done, users will be able to charge their cars almost anywhere, near work, shop, church, school etc. A long awaited premiere of wireless charging car solution from BMW based on Qualcomm technology took place on 28th May 2018. It`s first vehicle with factory fitted (optional of course) inductive charging. Whole system consists of "GroundPad" – this element is nothing else than Tx coil with security electronics in sealed case which could be used indoor and also outdoor, Rx coil fitted to car chassis to receive energy and set of sensors to navigate driver to park directly above GroundPad [16] as is shown in Figure 6. Producer claims system charging power at 3.2 kW level with efficiency rate near 85%. For now

GroundPad can be only leased. The other cars with Qualcomm Halo charging solutions include Rolls Royce 102EX and Renault ZOE, but Qualcomm is an active member of standards development organizations as ISO, IEC and SAE. It should be added that the Qualcomm Halo technology allows to charge up to 22 kW from 3-phase grid. Qualcomm Halo is aimed to OEM producers and right now it is futile to look for it on free market.

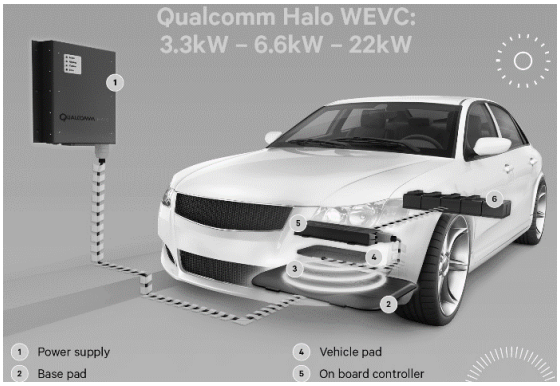

Fig. 6. Qualcomm Halo WEVC system diagram [16]

3.2. Plugless Power

Another solution is "Plugless Power". It`s a proposal from Plugless company which is founded by Evatran in 2009 year, after TED conference (Technology, Entertainment and Design). Similarly to Qualcomm, we have system built from two coils, one Tx in charging pad, second Rx in car chassis and wall control panel as is shown on draft in Figure 7.

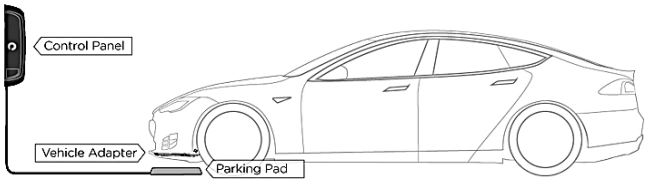

Fig. 7. Draft of the Plugless Power charging system [15]

Plugless Power charging system is tested and compatible with Tesla S, BMW i3, Chevrolet Volt, Nissan Leaf. For this car, Plugless offers on free market ready plug&play systems with two charging power configurations which are described in Table 3 [15]. This kind of company policy supports popularization of electrical vehicles and their wireless charging among non-commercial customers. Unfortunately right now company doesn`t have European version of charging devices.

Table 3. Plugless Power technical parameters

Parameter	Charging power	
Charging power	3.2 kW continuous	7.2 kW continuous
Input voltage	120 V (US type)	240 V (US type 2 phase)
Connection	NEMA 5 – 15	Nema 14 – 50
Required connection current	30 A wall socket	50 A wall socket
Durability of charging pad	680 kg (per wheel)	680 kg (per wheel)
Temperature range	-30°C to 50°C	-30°C to 50°C
Distance between charging coils (Air Gap)	10 cm	10 cm
Ground clearance	17.8 cm	17.8 cm

3.3. OLEV

In conventional contactless chargers solution users must find parking place with wireless charger, park and wait to charge their vehicles. Unfortunately even contactless charging or typical cable charging does not solve problems with range in one battery charge, but OLEV technology approached this issue completely differently.

OLEV (On-Line Electric Vehicle) technology was created in Korea Advanced Institute of Science and Technology (KAIST) where was first time tested [13]. This kind of charging system uses SMFIR (Shaped Magnetic Field in Resonance) technology [16]. Now OLEV is developed by two companies, OLEV Korea and OLEV Boston. OLEV technology is focused on buses and trucks, because it`s weight is around 200 kg per vehicle and is too heavy for passenger cars. This make sense with big transit buses and trucks where length of vehicle combination is greater than for example Nissan Leaf, and 200 kg more doesn`t make a huge difference especially when it could reduce weight of battery without any negative impact to range, that allows to transport heavier loads. Another idea of using OLEV is equipping airports with this technology, every vehicle in closed area of airports could be charging directly from lane, without any air pollutions.

Active charging conception, as is shown in Figure 8 is based on cables or coils under the street surface and appropriate modulation parameters of the voltage flowing through them and adapted, compatible electrical vehicles.

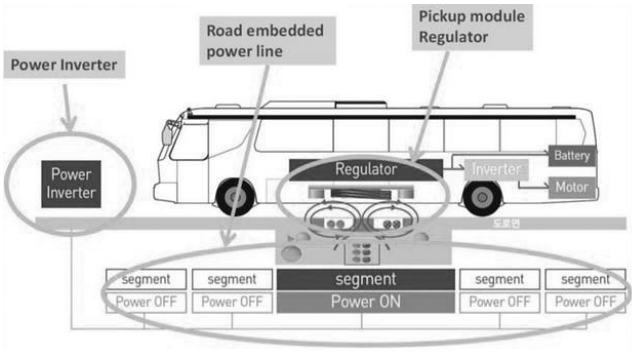

Fig. 8. OLEV active charging system [3]

This mass-scale solution is still the future, but when road and infrastructure managers equips roads with this system, a real revolution may take place. Users will stop worrying about range of their electrical vehicles, because they will be online charging when they drive on specially designated road lanes. This technology could significantly increase EV`s sales.

3.4. Bombardier primove

Another big company that has made a large investments is Bombardier, company known for the production of aircraft. Their product is named primove and it`s really complex, starting from electrical cars, via e-buses, e-trucks and finally to trams. For electrical cars solution is similar to Plugless Power, but for e-buses, e-trucks and trams it introduces an innovative approach.

E-buses, huge percentage of this car type are using in cities to transport citizens between bus stops. In other solutions e-buses were charging only on bus depot or wirelessly from road lane. First type is uncomfortable and the second one is too expensive right now because it requires completely road renovation and road infrastructure. Bombardier solution is cheaper and more realistic, they propose to revitalize bus stops and put charging transmitting coils under stops area. Someone after reading that could say, "ok, but is nothing new" but primove is a smart charger, when e-bus approaches the stop, charging pad under surface is launched and Rx coil on e-bus chassis is lowered directly above Tx coils as was shown on Figure 9. The only obstacle between coils is material of bus stop surface. That solutions can improve speed, power and efficiency of wireless charging, and also is invisible to citizens so what is really important in old town area it doesn`t disturb in urban architecture [12].

Trucks, vehicles are responsible for transporting large objects and loads but also for generating large quantity of greenhouse gases. In last quarter of 2017 Tesla shown their first electrical

truck prototype which name is Tesla Semi, truck with huge range, near 800 km – but it`s a prototype. Bombardier found solution also for trucks, they propose to build trucks wireless fast charging ports not only in gas stations but primarily on most of delivery points. That provides to driver but more to their company and delivery point environment becomes more comfortable, clear and cheap solution than petrol trucks, without any greenhouse gases.

Solution for trams, similarly to e-buses is designed directly for cities, in conventional systems trams riding on rails and are powered from overhead lines, this type of power also interferes with architecture.

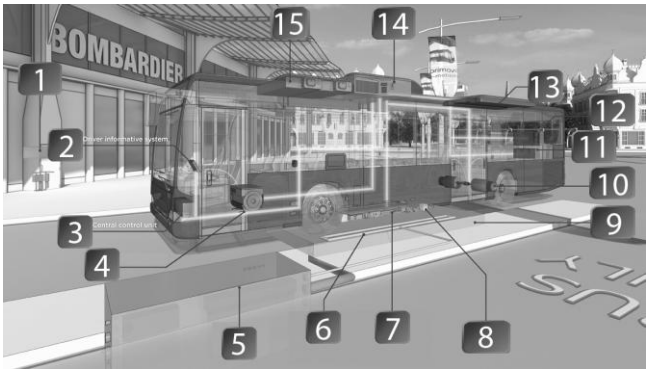

Fig. 9. Bombardier primove, contactless charging system for e-buses [12]: 1 – cooling unit, 2 – driver information system, 3 – central control unit, 4 – steering pump, 5 – wayside electrical installation, 6 – vehicle detection, 7 – pick – up system, 8 – onboard sending device, 9 – charging slab, 10 – traction motor, 11 – 24V battery, 12 – heating, 13 – HVAC, 14 – primove propulsion system, 15 – primove battery system

Primove proposes to connect static contactless charging with active charging similar to OLEV, but static charging should be in designated trams stops and the active charging should be calculated and placed in the critical parts of lines. This solution is less expensive than full OLEV technology and more comfortable than only trams stops, this concept is shown in Figure 10. Another advantages are minimising of architecture pollution, easy way to install equipment in new or existing lines of trams because all elements fit in space between tram rails, also entire system is compatible with e-bus, that means in one investment cities could use infrastructure for trams and e-buses, that is a big benefit also for citizens, because city government will save huge money.

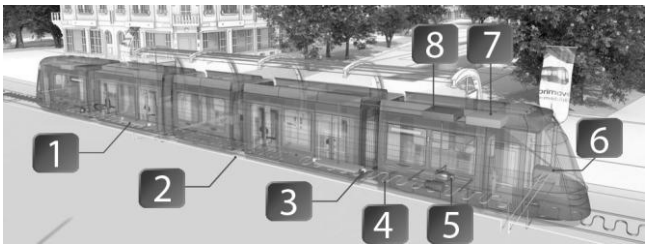

Fig. 10. Bombardier primove, contactless charging system for trams [12]: 1 – pick-up system, 2 – vehicle detection, 3 – onboard sending device, 4 – charging segment, 5 – traction motor, 6 – inverter, 7– primove battery system, 8 – power management

4. Conclusions

The biggest problem with contactless energy transfer (CET) [5] charging is lower efficiency compared to conventional solutions and loses resulting from air gap and dirt accumulating on the coils. However it is possible to reduce losses in components of charger by changing technology of used elements. For example: changing using propylene capacitors can reduce dielectric losses by 2%, or changing IGBT transistors to SiC MOSFET can reduce inverter losses by 4% [2]. Unfortunately it doesn`t solve the problem with losses resulting from air gap, to reduce this value proposal from primove seems to be justified, when we stop on charging point Rx coil or coils are lowered to the ground and lay directly above Tx coils, the only obstacle between them is surface area of the substrate which scientists and engineers should choose or develop in way to minimizes contactless transfer losses. Another concept to reduce losses in inductive power transfer (IPT) circuit is compensation inductance leakage by appropriate connected capacitor to reduce losses on AC side [4]. At this paper was shown few comfortable ways to charge electrical vehicles, this solution can contribute to popularization of EV`s and reduction of greenhouse gases. Also all electrical vehicles can be considered a form of distributed energy storage which can be charge when grid is oversupplied or can transfer energy to the grid when it is necessary [7].

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M.Sc. Damian Dobrzański
e-mail: damian.dobrzanski@pollub.edu.pl

Ph.D. student in Faculty of Electrical Engineering and Computer Science, Lublin University of Technology. Research interests include electrical vehicle- methods and optimization of their charging, contactless charging, synchronous DC/DC converters, EV fast chargers. Applied research techniques include prototyping using the dSpace system and others IT and hardware tools.

otrzymano/received: 4.08.2018 *przyjęto do druku/accepted: 15.09.2018*

DOI: 10.5604/01.3001.0012.5285

ANALYSIS OF THE FLAME PULSATION SIGNALS USING A SHORT-TIME FOURIER TRANSFORM

Żaklin Grądz
Lublin University of Technology, Institute of Electronics and Information Technology

Abstract. *The main aim of the diagnostics of combustion process is ensuring its stability and efficiency. The most important aspect related to the monitoring of the combustion process is a non-invasive acquisition of information from flame and subsequently subjecting it for further processing. Such method of research allows to evaluate the course of the process and determine the characteristic conditions under which the combustion process is stable or not. The article presents the application of short-time Fourier transform for the analysis of flame pulsation signals. The aim of the research was to find an area especially sensitive to the change of combustion process conditions.*

Keywords: combustion process, short-time Fourier transform, flame pulsation

ANALIZA SYGNAŁÓW PULSACJI PŁOMIENIA Z WYKORZYSTANIEM KRÓTKOCZASOWEJ TRANSFORMATY FOURIERA

Streszczenie. *Głównym celem stawianym diagnostyce procesu spalania jest zapewnienie stabilności i efektywności przebiegu procesu. Najważniejszym aspektem monitorowania procesu spalania jest pozyskiwanie w sposób bezinwazyjny informacji z płomienia, a następnie poddanie jej dalszemu przetwarzaniu. Taki sposób badań pozwala na ocenę przebiegu procesu i daje możliwość wyznaczania charakterystycznych stanów, w których proces przebiega stabilnie lub nie. W artykule przedstawiono wykorzystanie krótkoczasowej transformaty Fouriera do analizy sygnałów pulsacji płomienia. Celem badań było znalezienie obszaru szczególnie wrażliwego na zmianę warunków w procesie spalania.*

Słowa kluczowe: proces spalania, krótkoczasowa transformata Fouriera, pulsacja płomienia

Introduction

The recent regulations implemented due to the need for reduction of the emission of harmful gases into the atmosphere, including nitrogen oxides (NOx) led to the popularization of so-called low-emission combustion techniques. In most cases, they involve the application of the combustion technology with air stepping, which is based on the formation of zones in the flame, in which combustion occurs with varying stoichiometry [3, 5, 7, 13]. Zonal combustion is a process in which maintaining the process conditions within specific limits is especially important, in contrast to traditional combustion. Therefore, the application of monitoring systems is necessary. Therefore, monitoring and diagnostics of the combustion process are still a valid and relevant issue of modern energy economics.

Combustion of coal dust under industrial conditions is a complex process, which requires the application of specialized measurement systems for diagnostics. A combustion process is considered efficient when the combustion is stable and emission of resulting pollutants conforms to the valid standards. The generated harmful combustion products include the ones that arise from the burning of elemental coal and hydrocarbons in the case of [5]:

- complete combustion of elemental coal – CO_2,
- incomplete combustion of coal and hydrocarbons – CO, aldehydes, polycyclic aromatic hydrocarbons and soot.

Within the group of combustion by-products, which arise from the presence of fuel additives, one should also distinguish SOx, NOx and ash [3]. In order to mitigate the emission of hazardous compounds, the primary and secondary methods are commonly used. The primary methods are employed directly in the combustion chamber and involve preventing the creation or reducing the undesirable combustion products. Low-emission combustion is an example of a primary method. On the other hand, the secondary methods are applied outside the combustion chamber and their aim is to eliminate the harmful substances using catalytic reduction and absorption methods [5].

The signals acquired from the flame monitoring system are non-periodic. Therefore, short-time Fourier transform can be applied for their analysis and processing.

1. Analysis of the coal pulverized combustion process

Acquisition of the data pertaining to the combustion process which occurs under the industrial conditions requires the application of specialized measurement systems [1, 2, 6, 15]. Flame monitoring system devised in Institute of Electronics and Information Technology of the Lublin University of Technology is an example of such a system [14]. The system, used for obtaining the measurement data from a flame is capable of conducting non-invasive measurements in real-time. Figure 1 presented below shows the scheme of the considered flame monitoring system.

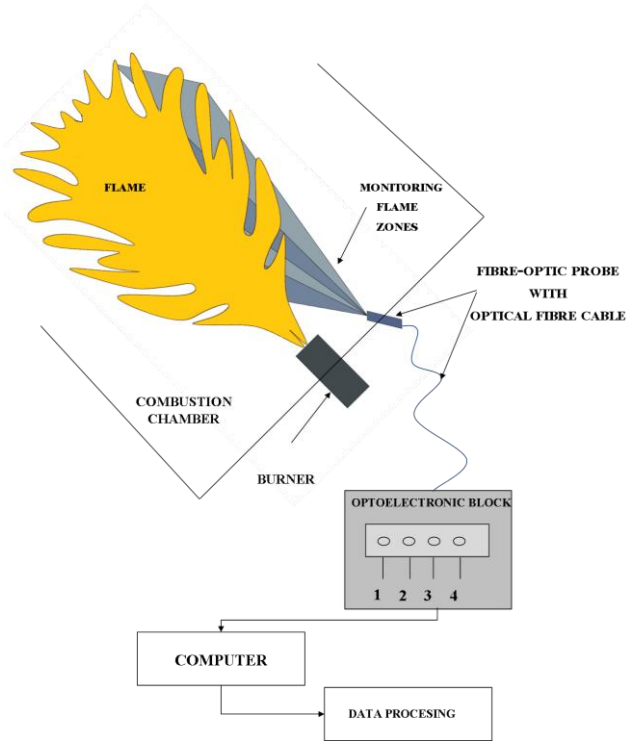

Fig. 1. Flame monitoring system

The flame monitoring system comprises: a measurement probe, photodetectors, and an optoelectronic block. In order to conduct measurements, the head of optical fibre probe is mounted through the hole inside the combustion chamber. The information on the combustion process obtained from the flame is transmitted by means of the measurement head and optical fibre bundles to the optoelectronic block in the form of an optical signal. The optoelectronic block is composed of four identical signal channels. The channels 1–4 enable monitoring of different flame zones, which was presented in Fig. 1.

The design of the probe used for research enables conducting measurements under the conditions characterized by high temperature and dusting. During the measurements, the flame luminosity and pulsation are recorded. Flame luminosity is the parameter that determines the temperature of flame, whereas pulsation is a measure of flame turbulence [12]. In the optoelectronic block, the data are transformed into an electric signal which is subjected to further processing.

2. Frequency analysis of the signal

The analysis of the signals obtained from the combustion process occurring in energy boilers may be conducted in a number of ways. One of them involves the frequency analysis, which may be carried out using the Fourier transform. Discrete Fourier transform is expressed by the formula [10]:

$$X(k) = \sum_{n=0}^{N-1} x(n) W_N^{kn} \tag{1}$$

where $k = 0,1,2, \ldots, N-1$ and $W_N = e^{-j2\pi/N}$.

Processing signals using Fourier transform may be carried out using Matlab software, which is employed for the calculation of the fast Fourier Transform FFT that is realized by the fft function [9]. The correct result of the Fourier analysis of the signal sampled with the frequency f_s is possible only when the distribution of harmonics in the range of positive frequencies does not interfere with the range of negative frequencies [10]. This occurs when the highest frequency in the signal does not exceed the Nyquist frequency [10].

The frequency analysis is conducted while processing the discrete signal x(n), in accordance with the following steps [16]:

- low-pass filtration,
- discretization in time, quatization and coding,
- multiplication of the signal with time window,
- indication of the discrete Fourier transform.

The parameters and equations of several selected discrete windows $w(n)$, which are applied during the frequency analysis, were provided below. Using any function of the window $w(n)$, a fragment of the signal subjected to analysis is cropped. The time windows require multiplication of subsequent signal samples with the samples of time windows. These windows assume non-zero values only for $n = 0,1,2, \ldots, N$-1, where N corresponds to any length of the windows [16] and are determined in the following way [16]:

- Bartlett (triangular) window – width of the main lobe $\Delta ml = 8\pi/N$, relative suppression of the highest side lobe $A_{sl} = 26.5$ dB, definition:

$$1 - \frac{2\left|n - (N-1)/2\right|}{N-1} \tag{2}$$

- Hanning window – width of the main lobe $\Delta ml = 8\pi$/N, relative suppression of the highest side lobe $A_{sl} = 31.5$ dB, definition:

$$\frac{1}{2}\left(1 - \cos\left(\frac{2\pi n}{N-1}\right)\right) \tag{3}$$

- Hamming window – width of the main lobe $\Delta ml = 8\pi$/N, relative suppression of the highest side lobe $A_{sl} = 42.7$ dB, definition:

$$0{,}54 - 0{,}46\cos\left(\frac{2\pi n}{N-1}\right) \tag{4}$$

- Blackman window – width of the main lobe $\Delta ml = 12\pi$/N, relative suppression of the highest side lobe $A_{sl} = 58.1$ dB, definition:

$$0{,}42 - 0{,}50\cos\left(\frac{2\pi n}{N-1}\right) + 0{,}08\cos\left(\frac{4\pi n}{N-1}\right) \tag{5}$$

The definition of window $w(n)$ shows the dependence of $0 \le n \le N-1$.

Matlab software includes numerous defined functions of windows, such as rectangular window, Blackman window, Hamming window, Hanning window, and Bartlett window. The figure presents examples of the window functions [10, 16].

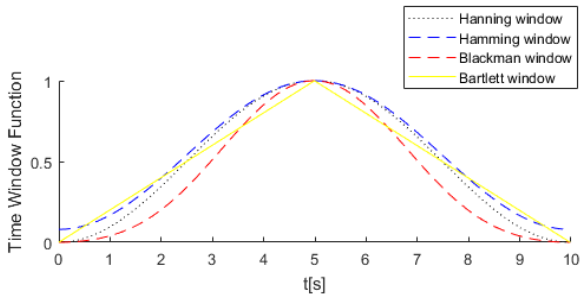

Fig. 2. Shape of the function of Hamming Hanning, Blackman and Bartlett windows

3. Analysis of the measurement data

The measurement data were acquired using the afore-mentioned combustion process monitoring system. One of the parameters recorded in the course of the flame measurements involved its luminosity. Figure 3 presents the first stage of data analysis, which included determining the flame luminosity within the measurement cycle from 4 different channels of the optical fibre probe.

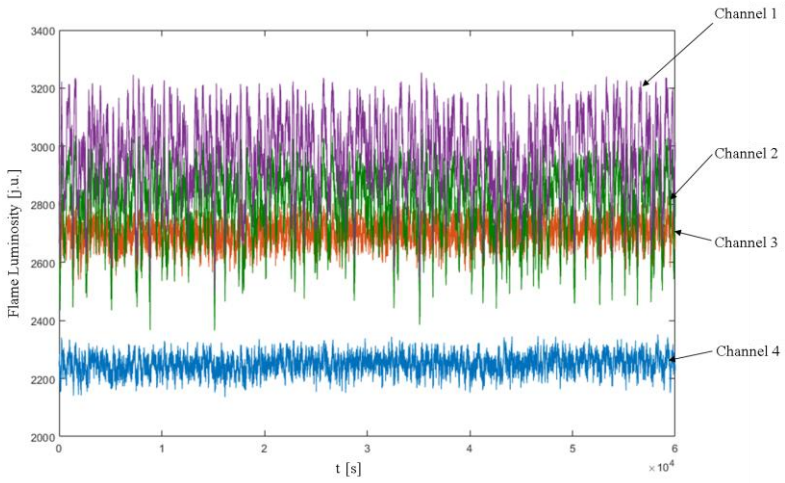

Fig. 4. Measurement of flame luminosity from channel 1–4

Due to the large amount of measurement data, conducting the analysis for an entire signal acquired from a single channel of the optical fibre probe yields little information. Therefore, it is necessary to perform separate analyses for each of the signals. The conditions that influence the flame luminosity or its pulsation include, i.a. changes in the air flow rate, inclusion/exclusion of mazut or changes in fuel supply. The conditions prevailing in the combustion chamber and the composition of the fuel burn have a significant impact on the stability of the combustion process. Separation of particular stable and unstable areas will enable to obtain detailed information on the investigated process.

The next step of result preparation involved processing of selected areas using windowed Fourier transform [4]. The data were subjected to analysis with selected types of time windows, using different lengths.

The figures below present the graphs showing the stable area I for different window lengths: N = 128, N = 1046.

Figures 7, 8 show the graphs for the unstable area I with different window lengths: N = 128, N = 1046.

The diagrams showed above were presented for the unstable area I and II and stable area I, which are especially vulnerable to the changes in the conditions of the combustion process. The graphs show the change in time of the flame pulsation frequency for the areas considered stable and unstable. Increasing the length of the time window is connected with and improvement in the localization of the frequency domain and deterioration in the time domain. On the basis of the analysis results it should be concluded that the stable area I is the most vulnerable.

The graphs showing the unstable area II for different window lengths: N = 128, N = 1046 are presented in the Figures below.

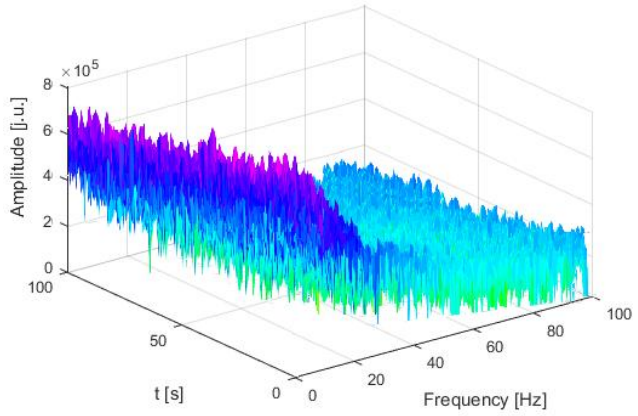

Fig. 5. Fourier Transform graph with Hamming window with the length of N = 128 for the stable area I

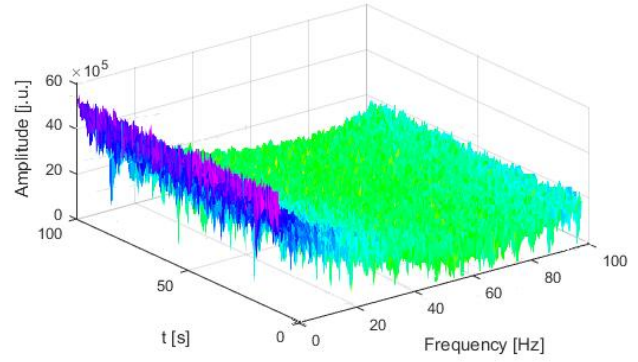

Fig. 6. Fourier Transform graph with Hamming window with the length of N = 1046 for the unstable area I

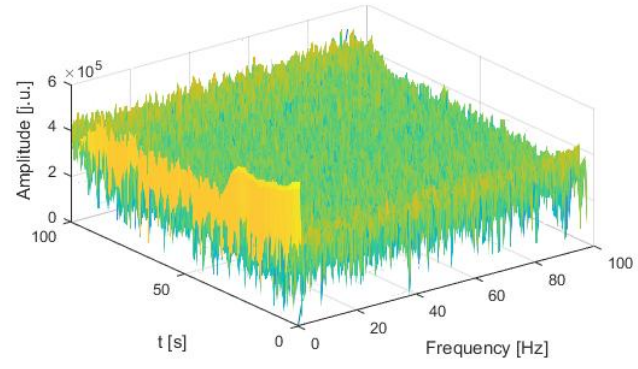

Fig. 7. Fourier Transform graph with Hamming window with the length of N = 128 for the stable area I

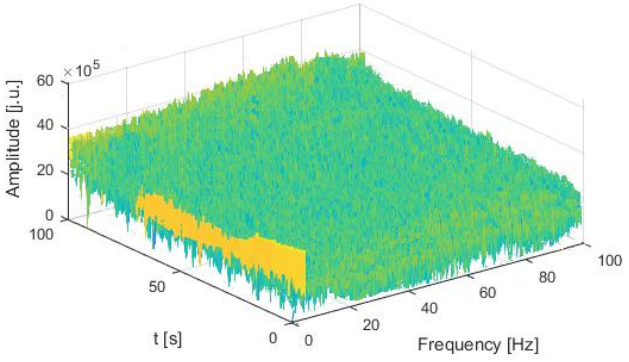

Fig. 8. Fourier Transform graph with Hamming window with the length of N = 1046 for the stable area I

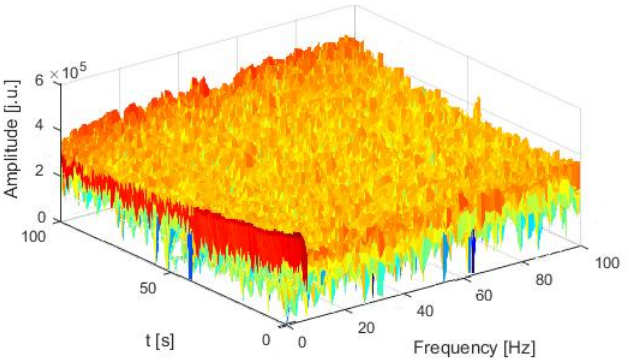

Fig. 9. Fourier Transform graph with Hamming window with the length of N = 128 for the unstable area II

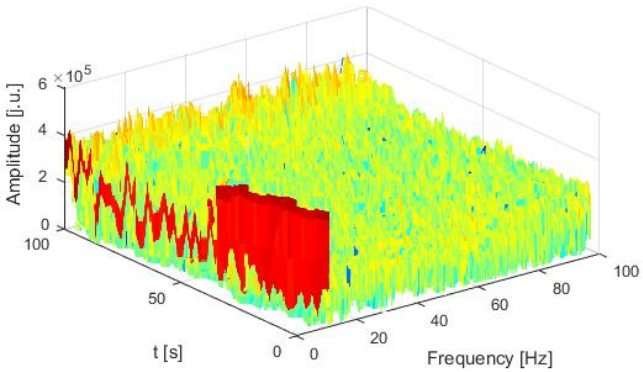

Fig. 10. Fourier Transform graph with Hamming window with the length of N = 1046 for the unstable area II

4. Conclusion

Combustion of coal dust under industrial conditions is a very complex process. Acquisition of data from a flame requires the application of specialized monitoring systems. The systems must be resistant to high temperatures and dusting. Their application yields huge amounts of data pertaining to the combustion process. The information obtained from the flame is transmitted in the optical form to the optoelectronic block, where it is transformed into electronic signal and may be subjected to further processing. The paper presented the analysis of measurement data for 3 different states of the process – unstable (I and II) and stable (I). Due to the fact that changing the type of window does not impact the Fourier transform, the article presents research conducted using the Hamming window. Changing the window size had an influence on indicating the signal frequency. Selecting a narrow window in the time domain causes the window in the frequency domain to become wide and vice-versa. While carrying out the Fourier transform in the time domain is could be seen that the window size has an influence on indicating the frequency of the investigated signal [8, 11].

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M.Sc. Eng. Żaklin Grądz
e-mail: z.gradz@pollub.pl

Assistant in the Institute of Electronics and Information Technology of Lublin University of Technology and Ph.D. student at the Electrical Engineering and Computer Science Faculty. Scientific activity includes the analysis of the combustion process in terms of its monitoring and diagnostics.

otrzymano/received: 20.07.2018 *przyjęto do druku/accepted: 15.09.2018*

DOI: 10.5604/01.3001.0012.5286

DIGITAL TECHNOLOGIES FOR SUPPORTING THE MANAGEMENT PROCESSES OF TEACHER PROFESSIONAL GROWTH WITHIN THE DEPARTMENTS OF MANAGEMENT IN THE UNIVERSITIES OF THE REPUBLIC OF POLAND

Victor Oliynyk, Iryna M. Androshchuk
State Higher Educational Institution "University of Educational Management" of the NAES of Ukraine

Abstract. *The article examines the possible forms of self-management of the teacher professional growth of the management departments in the universities of the Republic of Poland. The following forms of enhancement of the teacher professional level are analyzed as courses, studies, trainings and portfolio. Distance and open education are characterized as alternative forms of self-management of the teacher professional growth in Polish universities. It was established that teachers of management departments use information systems LMS, LCMS; digital platforms Moodle, ELIAS and USOS in the system of higher education of the Republic of Poland.*

The types of e-learning are described, its possibilities and influence on the teacher professional growth are characterized within the management departments in the Polish universities. The questionnaires and interviews data are analysed for teachers of management departments in the universities of the Republic of Poland, in which the ways and forms are indicated for self-management of professional growth preferred by the teachers of the management departments of Polish universities. The role of digital technologies is analysed as an integral part in self-management of teacher professional growth in the modern conditions of globalization and European integration of Polish society.

Keywords: open education, distance learning, e-learning, professional growth, self-education, self-development, management, digital educational platforms, digital technology

TECHNOLOGIE CYFROWE WSPARCIA PROCESÓW ZARZĄDZANIA ROZWOJEM ZAWODOWYM NAUCZYCIELI AKADEMICKICH KATEDR ZARZĄDZANIA UNIWERSYTETÓW POLSKI

Streszczenie. *W artykule rozważono możliwe formy samorozwoju nauczycieli katedr zarządzania uniwersytetów Polski. Przeanalizowano następujące formy podwyższenia kwalifikacji nauczycieli akademickich z wykorzystaniem technologii cyfrowych: kursy, szkolenia, seminaria, treningi, kształcenie podyplomowe. Została scharakteryzowana edukacja na odległość i edukacja otwarta jako alternatywne formy wsparcia procesu samozarządzania rozwojem zawodowym nauczycieli akademickich uczelni polskich. Ustalono, że w systemie szkolnictwa wyższego w Rzeczypospolitej Polskiej nauczyciele katedr zarządzania najczęściej korzystają z systemów informatycznych LMS, LCMS; platform cyfrowych Moodle, ELIAS i USOS.*

Scharakteryzowano rodzaje e-learningu, opisano jego możliwości i wpływ na rozwój zawodowy nauczycieli katedr zarządzania uczelni polskich. Przeanalizowano dane kwestionariuszy i wywiadów wspomnianych nauczycieli akademickich, podano wskazane przez osoby ankietowane sposoby i formy samorozwoju zawodowego, preferowane przez nich. Przeanalizowano rolę technologii cyfrowych jako integralnej części samodoskonalenia się nauczycieli w nowoczesnych warunkach globalizacji i integracji europejskiej polskiego społeczeństwa.

Słowa kluczowe: edukacja otwarta, nauczanie na odległość, e-learning, rozwój zawodowy, samokształcenie, samorozwój, zarządzanie, cyfrowe platformy edukacyjne, technologia cyfrowa

Introduction

Changes occur in consciousness, approaches to professionalism, determination of its level, forms and ways of its self-development in the times of rapid changes in world society, economy, science and technology. Actual Polish commonwealth of scientists frequently brings up the issue of creating conditions for continuing education for teachers. Polish universities increasingly afford access to educational, didactic, scientific materials and sources within the framework of open and distance education. Courses, trainings, conferences, seminars are offered both for lecturers and students through online mode. The e-learning has become very popular offered by universities, state and non-state educational institutions, which organize qualification upgrading courses, trainings, courses, etc.

Target setting

The need for teacher self-development is beyond doubt in the Polish academic community, since everyone who works at a Polish (both state and private) university carries out self-assessments at the end of the academic year; his professional activity is also evaluated by students, heads of structural units of the university as departments, faculties, institutes, which makes the teacher constantly improve oneself and raise the professional level. Both the senior managers of Polish universities and the teachers themselves are aware that no one can plan teacher professional development management better than make it oneself. As far as this planning involves the assessment of real resources, the determination of the strategic goal, the pace setting and a time for its achievement.

Actual scientific researches and issues analysis

The problem of using digital technology is the subject of interest as an effective form of self-development support for many scholars. The place and role of digital technologies in the teacher professional development are explored among Ukrainian researchers by Y. Bykov, A. Gurzhii, L. Liahotska, S. Kasian, T. Mahyna, V. Oliynyk; the use of digital and cloud technologies in management is analyzed by V. Kamyshyn, N. Klokar, V. Oliynyk, Z. Ryabova, T. Sorochan; the problem of digital technologies is the subject of research among the Polish scientists by I. Garnik, V. Wojcik, A. Zapasa, L. Koziol, M. Koziol, J. Kolodziej, P. Komada, P. Kopcial, K. Redlarski; questions of personal and professional development are of interest to D. Becker-Pestka, J. Kolodziej, C. Pujer. However there is currently no comprehensive study analyzing the role of digital technologies in the process of supporting the teacher professional self-development within the departments of management in the universities of the Republic of Poland. That accounts for the urgency of this article.

The objective

The objective of the scientific intelligence is to characterize the most common forms of self-development of the teacher professional competence within the departments of management in Polish universities and to outline the significance of digital technologies in this process.

1. Theoretical and methodological framework of the research

The analysis of the legal framework, scientific sources, university development strategies, questionnaires and interviews of teachers of the management departments in the state universities of the Republic of Poland provide grounds for arguing that the teacher professional growth takes place due to the planned processes of management and self-management in Polish universities. The professional growth of teachers and other employees is indicated for strategic purposes in the development strategies of Polish universities since the quality level of education offered to students depends on the teacher level of professionalism. We analyze the teacher self-development powered by digital technologies within management departments in the universities of the Republic of Poland in the framework of given intelligence rapidly developing and occupying a prominent place among all other innovative educational and managerial technologies.

We will represent the interpretation of the concepts of "profession" and "teacher" by Polish scientists in order to reveal the theoretical aspects of the above problem. According to T. Nowacki considered the creator of the pedagogical work in the Republic of Poland, "the profession means the implementation of a number of socially useful measures separated as a result of the division of labour requiring for the appropriate knowledge and skills from the employee as well as psychophysical features that determine the work of a professional, are systematically repeated and a source of funding for the worker and his family" [15, p. 287].

In the normative-legal framework of higher education of the Republic of Poland, the concept of "teacher" is defined as "nauczyciel akademicki – academic teacher (translated by author)". This person works in the higher education system as a didactic, scientific and didactic or just scientific worker. An academic teacher should be distinguished from a teacher working in school. According to the dictionary of occupational titles, which is current on the territory of the Republic of Poland, "academic teacher" is placed under the cipher 2311, and then specialties are listed for various fields. Teachers of the management departments belong to humanistic sciences – 231106 [14].

The analysis of theory and practice has confirmed the assumption that each teacher working in the management departments is a participant of the professional growth process. Teachers of the management departments in the universities of the Republic of Poland analyze and fix the following in order to plan their own professional growth: 1) the existing level of professionalism; 2) the expected level of professionalism in the close-up and distant perspective; 3) measures necessary to achieve the expected level of professionalism; 4) analyze required resources (human and material) for this purpose; 5) monitor their own professional activities.

Continuing education reflected in the Law on Higher Education in Poland plays a significant role in the self-development process of the teaching staff of the management departments. It concerns the renewal and deepening of general knowledge, skills and professional qualifications of both employees and employers [18]. Courses, seminars, trainings, internships constitute forms of continuing education for teachers in the Polish universities. It can be organized both at the place of work and away from it. Polish scholars unite forms of the education organization into two groups [11, p. 468–473]: away from the place of work including lecture, discussion and at the place of work including instruction, coaching, mentoring.

The purpose of courses and trainings is largely to expand the competencies of the employee in a particular industry. Training is characterized by systematic and planned nature. Trainings and courses allow the teacher to acquire the knowledge required to complete the tasks of the department and the university. It also creates opportunities for the satisfaction of the needs of the higher educational institution in the field of its staffing policy [11, p. 7]. Planned courses and trainings proceed on the basis of SWOT-analysis in Polish universities, aim at forming new competencies or developing existing ones at the level indicated for the near future by the teacher filling out the questionnaire. Scientists distinguish these definitions and emphasize that the course is a broader concept than training in the system of continuing education of the Republic of Poland [6, p. 61].

It is worth noting that postgraduate studies are one of the important forms of the teacher professional growth within the management departments. According to the Law on Higher Education of the Republic of Poland, postgraduate education is a mode of study that can be used by those who have the first degree (bachelor) [18]. This studies differ from the one described above with a specific structure and correspondence to the National Qualifications Framework. According to Polish law, the duration of studies is not less than two semesters and the result of training is the postgraduate thesis defence and obtaining a diploma complying with a certain qualification degree. 33% of respondents indicated that they had postgraduate education (second higher education, postgraduate studies, etc.) and 67% of teachers do not have such kind of education while questioning teachers of the management departments in the universities of the Republic of Poland. At the same time 89% of them obtained postgraduate education using distance or intramural and distance form of study.

There is a large number of hours for self-study namely self-education in the postgraduate studies programs. The concept of self-education is meant self-acquisition of knowledge in Polish scientific community. We agree with D. Jankowski, who notes that "self-education is a process, that is a number of logically interrelated, precisely organized actions of the person being trained who is aimed at an independent, rudderless obtaining the necessary information, intellectual and manual features as well as the development of such cognitive abilities as observation, attention, imagination, memory and critical thinking" [7, p. 120–121].

The teacher professional growth within the management departments and their qualification enhancement are associated with rapidly changing labour markets in Poland and the world. Technological and informational development of the world society has led to the fact that Internet and accordingly digital technologies affect the nature and content of continuing adult education in each industry.

Poland's Development Strategy until 2020 grounds the development of the digital society of the country on strengthening of three areas: infrastructure, content and services development as well as demand. First and foremost the latter requires the maturity of the digital competencies of individuals who do not use the Internet at all and development of the competences of individuals who are closely related to Internet and digital technologies and use it [13].

The report "Information Society in the Figures by the Ministry of Administration and Digitalization" (2014) states that "digital competences are a group of *information competencies* covering the ability to search for information, its understanding, assessment of its probability and suitability, *informatics competencies*, which are the ability to use a computer and other electronic learning tools, the Internet as well as various digital applications, programs, and create a digital content, as well as *functional competencies*, which are the ability to apply the above-mentioned competencies in practice" (translated by author) [17]. The digital competencies mean the knowledge, skills, high level of self-motivation and self-awareness in this case which allow effectively using of existing digital technologies in professional activity for teachers of the management departments in the universities of the Republic of Poland.

As a result of the intelligence analysis exploring the application of digital technologies we note that digital technology as we know it is an innovative technology using digital technique and information systems; the activity of technical, economic and organizational nature with an eye toward introducing digital devices and digital systems into the development of various

sectors of the country. Dramatic changes have taken place in the system of higher education in the Republic of Poland during the last decade in the implementation of digital technologies in university education. Therefore, a problem appeared in the studies of teachers and university staff in order to form the competencies necessary for the use of digital technologies both in the educational process and in self-development support.

The introduction of open educational platforms is a topical issue in the university practice In the Republic of Poland: Polish specialists are working to create a platform for all teachers, which will give equal access to interactive educational materials from various subjects and will also offer an electronic journal of the same form for all universities. This platform should have educational digital content. It will include publications of educational content, information about vacancies for teachers, the possibility of raising the level of professionalism (planned courses, seminars, trainings, etc.).

It should be emphasized that a digital policy is carried into execution in the Polish society based on the digital education of the individual; this is a change in the attitude towards the digital world. Much attention is paid to the application of the cloud as a model for managing digital educational tools and learning environment. There is a comprehension of the need for simultaneous enhancement of the level of didactic and digital competencies among the participants in the educational process in the Republic of Poland; the concept of cyber-didactic competencies has been formed for this purpose. The goals of cyber-didactics include activating a "student" (a person who studies), providing interaction between a "student" (a person who studies) and a "teacher" (a person who teaches) and individualization of training (an individual training program in accordance with the "student's" requests).

The introduction of digital learning technologies has led to the emergence of a new system called e-learning and provides the opportunity to conduct training, courses, seminars and implement postgraduate learning through digital technologies. The use of the aforementioned system undoubtedly contributes to the effectiveness of self-education and planning of support for the teacher self-development.

The concept e-learning has several synonymous terms in the Polish language as "distance learning" and "online education". As scientists point out the great positive of such training is that the person while studying can raise his professional level at a convenient time and in a convenient place [10, p. 48]. E-learning is understood to be somewhat broader in scientific sources. It concerns learning supported by such tools as computer programs, platforms, electronic sites, pages, educational portals and services, teaching and didactic materials on electronic media [5]. E-learning requires high motivation for training. Those who study must develop their own will power, motivate themselves to work out the material, accomplish tasks, and acquire the digital learning technologies independently [3].

According to questionnaires, teachers of management departments often choose distance courses and training usually carried out using the e-learning platform. The reason for this is the material resources (savings on accommodation, travel), the combination of work and study (non-working time education), time management and the opportunity to study in a convenient place and at an appropriate pace. Teachers note that e-learning courses and training allow them to work with materials at a convenient time often checking the level of the acquired information, controlling their achievements in education, staying in touch with the authors of educational materials, moderators, tutors, having the opportunity to ask questions and promptly receive answers to it.

Teachers mostly use such components of the teaching materials on the platform as text; simple graphical and multimedia elements as photographs, drawings and animations; movies and audio files containing educational information; tests and tasks; various types of advancement questions and tasks, lexicons, auxiliary files, hyperlinks [19, p. 16].

Unfortunately, not all Polish universities fully use digital learning technology. The reason for this is largely the inadequacy of technical capabilities to the requirements; the attachment of senior managers of university and structural units to standard forms of education, the stereotype prevalence of the of middle and senior age teachers, who consider that the intramural form of education during courses, training and postgraduate education forms a higher level of professional competences. In this context 85% of the interviewed teachers aged 60 and older argue that self-education is effective working out books and articles in printed form in reading rooms of academic libraries or at home; while 90% of teachers under the age of 60 prefer internet resources, electronic books and electronic articles, visit electronic libraries belonging not only to universities of the Republic of Poland but also to other countries of the world, although do not reject the processing of printed sources. They also note frequently usage of such digital learning media as computers (laptops), tablets, multimedia whiteboards, projectors, and digital programs for creating educational projects.

The analysis of the university sites of the Republic of Poland confirms the fact that the number of educational digital platforms is increasing every year at state universities. Distance learning centers are established forming courses, trainings, seminars based on customer requests, their requirements and wishes; the drawback noted by the teachers is that such forms of e-learning offered by distance learning centres are paid. However teachers of the management departments note in questioning and interviewing that combination of traditional and innovative forms of training among which digital technologies are more and more popular embodies the future of both the Polish and world university education.

The combination of traditional forms of learning and e-learning is called blended learning or b-learning [19, p. 64–65]. As the analysis shows e-learning can completely duplicate the traditional form of learning in practical use taking into account the peculiarities of e-learning or supplement the traditional form of learning with the relation that the teacher who studies will determine for himself. Teachers of the management departments mentioned in the interview that they typically use b-learning.

The development of e-learning has led to the emergence of its two directions in Polish universities: corporate and academic [19]. Corporate e-learning is first of all directed to achieving the goal of increasing the competitiveness of the firm (in our case it is the University of the Republic of Poland) through the development of human resources (in this case it is the teaching staff of the management departments). "A characteristic feature of corporate e-learning is the fact that it can be performed apart from the educational institution" [9, p. 64]. As for academic e-learning it is "characterized by much wider goals than the improvement of the educational process and its economic processes" [9, p. 65]. This is due to the fact that academic e-learning has to fulfil practically all university functions and transfer the learning process to the network. The aforementioned areas of e-learning develop independently of each other and differ not only by objectives but also by methods and means serving its implementation.

The dominant types of information systems supporting e-learning in Polish universities are following [2, p. 29]:

- LMS (Learning Management System) is a system that allows to report, administer and monitor your academic achievements, manage your teaching materials and rights and also register for course participants;
- LCMS (Learning Content Management System) is a system that enables the creation, edition, access and management of didactic content; it ensures an opportunity to control the process, to create didactic content, as well as to archive it beyond the functions available under the LMS.

Moodle is the most common among the educational digital platforms used by universities in the Republic of Poland, since it has a free license and this significantly saves the budget of universities. 1500 connections to this platform are fixed in Poland

[2, p. 30]. Digital platform ELIAS is also presented on the Polish market of higher education. Like Moodle, it has a modular structure but offers wider opportunities for individual user needs and also has the ability to integrate with other digital systems operating in the university and serving deans, academic communities and scholarship commissions that contain solemn information on didactic materials, announcements, vacancies or additional classes [2, p. 34].

Before long the USOS system (Uniwersytecki System Obsługi Studiów) is gaining in popularity, it was installed at the University of Warsaw at the Faculty of Mathematics, Computer Science and Mechanics in 2000 as the first version. The MUCI Consortium (Międzynarodowe Centrum Informatyzacji – International Informatization Center) was specially created to this end, which task was to develop and implement a management system of educational and organizational processes at the universities in the Republic of Poland. Such a system operates to the full extent in 17 state Polish universities. Many universities have implemented some of its capabilities as electronic student registration, electronic deans, electronic libraries, etc.

On-line services in the USOS system are carried out with the assistance of three-level architecture and associated with such free information and communication technologies as PHP, Smarty I Python.

Teachers of the management departments are quite **active** in the USOS system. It holds their workload, curriculum, schedule of classes and consultations, an individual support for students (tasks, decisions, tests, review works, assessments, scientific guidance on writing course papers and thesis). Many universities also have a public interface for integrating the USOS system with other electronic systems functioning in a higher educational institution – USOS API. USOS can also collaborate with the local systems of a specific university: an e-mail server, a central authorization server, e-learning on the Moodle platform, library systems.

Analysis of the digital platforms usage suggests by teachers of management departments in the universities of the Republic of Poland that they frequently use the USOS local system – 85.7% of respondents; 42.9% of teachers use the Moodle system; other platforms are used by 57.1% (respondents could choose several answers) [1].

A new culture has been formed in the digital environment in higher education of the XXI century: open digital educational means – e-means for formal education; e-textbooks, textbooks on the Internet (scattered, hypertext, multimedia). Polish students tend to have no formal textbooks, but digital analogues to printed textbooks. Inference should be drawn that the teacher of the Polish university must be the author of digital content. For this purpose Polish universities and institutions of non-formal education organize and conduct courses in order teachers to receive information and media education that is the ability to find information, analyze it, distinguish it from the false one, to process and create digital content based on standard documents. Moreover, the digital humanities should be adhered meaning to be able to combine humanistic and digital practices.

Despite the constant development of digital technologies in higher education in the Republic of Poland, there are many unresolved issues:

- dissonance between the student activity in the digital world (online life) and constraints dominated in Polish universities as well as the teacher perceptions of the Internet role in the life of students;
- presence of non-motivated teachers regarding the use of digital technologies in teaching activities and in professional self-development support;
- functioning university documents related to the digital world (password-protected Wi-Fi daily requiring for manually update IP-addresses, complications in access to digital means);
- absence of real (registered in normative documents) incentives and motives for introducing digital technologies into the educational process by teachers;
- misconception of senior managers of universities in the Republic of Poland and its structural subdivisions (institutes, faculties, departments) that acquisition of digital means and provision university staff with digital programs is the sufficient condition to support their professional growth and improve the quality of education.

2. Research results

In the context of the above, it was established that digital technologies play a significant role in supporting self-management of the teacher professional growth within the management departments in the universities of the Republic of Poland. Teachers note that the development of their professional competence takes place during seminars – 66.7%; courses – 33.3%; internship – 33.3%; trainings – 6.7%. Concerning the availability of postgraduate education 33% of the questioned teachers reported the answer "yes", 67% answered "no". At the same time 89% of them underlined that, all of the above-mentioned forms of training were received through e-learning. All respondents acknowledged that they prefer e-learning, distance learning and open education while 57.1% of the questioned teachers of management departments used this form in their teaching activities in the universities of the Republic of Poland; 42.9% used as students.

3. Conclusions and perspectives for further studies

Taking into account the foregoing we can assert digital technology of support is dominant in the management of self-development of professional competence of teachers within the management departments of Polish universities. Continuing education in shape of courses, seminars, trainings, postgraduate education plays a crucial role in the process of the self-management of teacher professional growth in Polish universities at the present stage of world society development. All of these forms of obtaining new competences or improving existing ones are increasingly being offered to teachers in the universities of the Republic of Poland in the form of e-learning both in distance and open education using digital technologies.

As noted, most of the teachers of management departments use digital technologies as a source of new information and an opportunity to improve their professional level in their professional activities in Polish universities. Within the framework of self-education teachers are attenders and participants of educational and scientific portals, sites, have their own electronic professional blogs, use the services of electronic libraries and bookshops, express their thoughts on online forums, collect information about conferences, seminars, courses, trainings, postgraduate education and are its active members, post their own e-portfolios and create websites reflecting personal and professional growth.

According to the analysis of sources, questionnaires and interviews of teachers of the management departments, they prefer digital technologies in the process of supporting self-development management. Such digital platforms as Moodle, ELIAS and local USOS platform facilitate it. At the same time, LMS (Learning Management System) and LCMS (Learning Content Management System) are the dominant types of information systems used by the universities of the Republic of Poland. Teachers save time and money as digital systems, platforms and digital technologies offer a variety of forms and ways for developing existing and new competencies and enable to study without discontinuing from basic teaching activities and meet the requirements of students on placing materials for their usage.

Despite the urgency and great achievements in the application of digital technologies in the supporting process of the teacher self-development in universities of the Republic of Poland, there are a range of problems demanding to be addressed both by teachers and the senior managers of universities and its structural units (institutes, faculties, departments): to use digital technologies

for the purpose of creation open access for participants of educational process to educational university content; to promote the motivation of teacher self-development; to create a system of mechanisms for stimulating teachers for the active use of digital technologies; to facilitate the creation of conditions for exercises, courses, trainings with the use of digital technologies at the university where the teacher works.

Perspectives for further studies in this area are the study and description of the conditions for the teacher professional growth of the management departments in the university of the Republic of Poland.

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Prof. Victor Oliynyk
e-mail: vikt.oliynyk@gmail.com

Doctor of pedagogical sciences, professor, active member of National Academy of Educational Sciences of Ukraine, Honored Worker of Education of Ukraine, Advisor to Rector of the State Higher Educational Institution "University of Educational Management" of the National Academy of Educational Sciences of Ukraine. Kyiv.
ORCID ID: 0000-0002-2576-0722

Ph.D. Iryna M. Androshchuk
e-mail: irenandro@gmail.com

Ph.D. in Education, Professor of the Department of Pedagogy, Management and Administration of the Education and Scientific Institute of Management and Psychology of the State Higher Educational Institution "University of Educational Management" National Academy of Educational Sciences of Ukraine, doctoral student at the State Higher Educational Institution "University of Educational Management" of the National Academy of Educational Sciences of Ukraine, Kyiv.
ORCID ID: 0000-0002-3557-793X

otrzymano/received: 22.08.2018 *przyjęto do druku/accepted: 15.09.2018*

DOI: 10.5604/01.3001.0012.5289

SPOTKANIE PRZESZŁOŚCI Z PRZYSZŁOŚCIĄ, CZYLI MUZEUM JAKO BUDYNEK TYPU SMART

Mirosław Dechnik
Politechnika Krakowska im. Tadeusza Kościuszki, Małopolskie Laboratorium Budownictwa Energooszczędnego

Streszczenie. *W artykule przedstawiono charakterystykę technologii Smart Building w kontekście zastosowania w budynku muzeum. Zaprezentowano rolę zintegrowanego systemu sterowania i automatyzacji w inteligentnym budynku muzealnym, jego funkcje, a także problematykę maksymalizacji efektywność energetycznej, przy jednoczesnym zapewnieniu optymalnych warunków konserwacji zabytków oraz przebywania ludzi.*

Słowa kluczowe: muzeum, automatyka budynku, efektywność energetyczna, inteligentny budynek, Smart Building

THE PAST MEETS THE FUTURE – A MUSEUM AS A SMART BUILDING

Abstract. *This article presents the characteristics of Smart Building technology in the context of their implementation in a museum building. The role of integrated building automation and a control system in an intelligent museum building, its functions, and the issue of maximizing energy efficiency, while ensuring the optimal conditions for preservation of relics, as well as people comfort were presented.*

Keywords: museum, building automation, energy efficiency, intelligent building, Smart Building

Wstęp

Dynamiczny rozwój techniki cyfrowej spowodował, że w wielu dziedzinach życia wykorzystuje się technologię informatyczną, systemy komunikacji oraz automatyki. Znalazły one zastosowanie także w budynkach, tworzących nasze bezpośrednie otoczenie, w których współczesny człowiek spędza większość czasu. Zjawisko to, doprowadziło do rozwoju idei „inteligentnego budynku". Określenie to wywodzi się z anglojęzycznego Smart Building [4].

Nowoczesna idea Smart Building, wkracza także do obszarów dotychczas utożsamianych z przeszłością – budynków muzealnych. Muzea rozumiane jako instytucje towarzyszą ludzkości od ponad 200 lat, natomiast świadome gromadzenie kolekcji ma już przeszło 2000-letnią historię. Rolą muzeów jest ochrona zabytków stanowiących dziedzictwo ludzkości oraz ich udostępnianie publiczności w formie wystaw. Mimo postępującej cyfryzacji zbiorów i trwającemu już od dziesięcioleci procesowi zastępowania rzeczywistości fizykalnej rzeczywistością reprodukcji, ludzie wciąż chętnie odwiedzają muzea [11, 13].

Początki idei inteligentnego budynku sięgają lat 70-tych XX wieku. Rozwój technologii, a także zmieniające się potrzeby ludzi, wywierały wpływ na pojęcie „inteligentny budynek", powodując, że jego znaczenie nieustannie ewoluowało. W różnych regionach świata wypracowano liczne interpretacje tego określenia, które do dziś nie zostały ujednolicone. Jako „budynek inteligentny", można obecnie określić obiekt, który w sposób zintegrowany, efektywnie zarządza zasobami, usługami i ich wzajemnymi powiązaniami w celu zaspokajania zmieniających się potrzeb jego użytkowników, przy jednoczesnej minimalizacji kosztów i ciągłym poszanowaniu środowiska naturalnego [4, 20].

Za „inteligencję" budynku odpowiada zintegrowany system sterowania i automatyzacji, czyli system BACS (ang. Building Automation and Control System) umożliwiający pełną współpracę z urządzeniami/systemami automatyzacji budynku. Jest on także nazywany systemem zarządzania budynkiem BMS (ang. Building Management System) lub systemem zarządzania i sterownia budynkiem BMCS (ang. Building Management and Control System). Za obsługę poszczególnych funkcji budynku inteligentnego są odpowiedzialne inteligentne (typu Smart) instalacje elektryczne, będące wyspecjalizowanymi systemami automatycznego sterowania, określanymi również jako systemy automatyki budynkowej. „Inteligencja" budynku wynika z możliwości efektywnego współwykorzystania dostępnych urządzeń technicznych, dzięki zintegrowanemu zarządzaniu systemami automatycznego sterowania. Natomiast jej stopień zależy od zastosowanych systemów, ich wzajemnych powiązań oraz oprogramowania i zaimplementowanych algorytmów. Odróżnia to budynki inteligentne, od „zwykłych" budynków wyposażonych w niezależne systemy sterowania [4, 14].

Koncepcja Smart Building jest jeszcze stosunkowo młoda, zwłaszcza w zastosowaniu krajowym. Dopiero nowe obiekty – głównie użyteczności publicznej – wyposaża się w „inteligentne" rozwiązania, natomiast zdecydowana większość istniejących budynków wciąż bazuje na tradycyjnych instalacjach elektrycznych [4].

Współcześnie jednym z największych wyzwań stojących przed muzeami jest redukcja zapotrzebowania na energię. Organizacja muzeum jako budynku typu Smart otwiera nowe możliwości minimalizacji zużycia energii, niedostępne dotychczas dla tradycyjnych rozwiązań, umożliwiając jednoczesne zachowanie warunków mikroklimatycznych sprzyjających konserwacji zabytków, komfortu przebywania ludzi oraz bezpieczeństwa użytkowania budynku. Osiągnięcie kompromisu jest jednak w tym przypadku bardzo trudne. W celu odpowiedniej konserwacji zabytków konieczne jest zapewnienie określonych oraz stabilnych warunków mikroklimatu wnętrza w zakresie temperatury i wilgotności, a także możliwie niskiego poziomu oświetlenia. Z drugiej strony odwiedzający i obsługa wymagają doskonałych warunków termicznych i oświetleniowych, a także wysokiej jakości powietrza. Ponadto w muzeach często w jednym pomieszczeniu sąsiadują ze sobą eksponaty wykonane z różnych materiałów, o zróżnicowanej wrażliwości na czynniki środowiskowe. Ważne są również kryteria ekonomiczne zastosowanych rozwiązań. Ta wielokryterialna specyfika współczesnego muzeum, czyni proces projektowania budynku muzealnego niezwykle złożonym zadaniem [4, 7, 8, 14, 15, 19].

Możliwości uzyskania wysokiej efektywności energetycznej budynku muzeum, nie zależą wyłącznie od funkcjonalności samego systemu automatyki, ale wymagają także odpowiedniej konstrukcji instalacji technologicznych z nim współpracujących. Instalacje te powinny być wzajemnie dopasowane do zakładanego stopnia wpływu systemu automatyki na efektywność energetyczną budynku. Konieczna jest więc integracja procesu projektowania i udział projektanta automatyki budynkowej już na etapie tworzenia założeń funkcjonalnych dla budynku oraz jego ścisła współpraca z projektantami innych branż [4, 7].

1. Znaczenie właściwych warunków mikroklimatycznych w muzeum

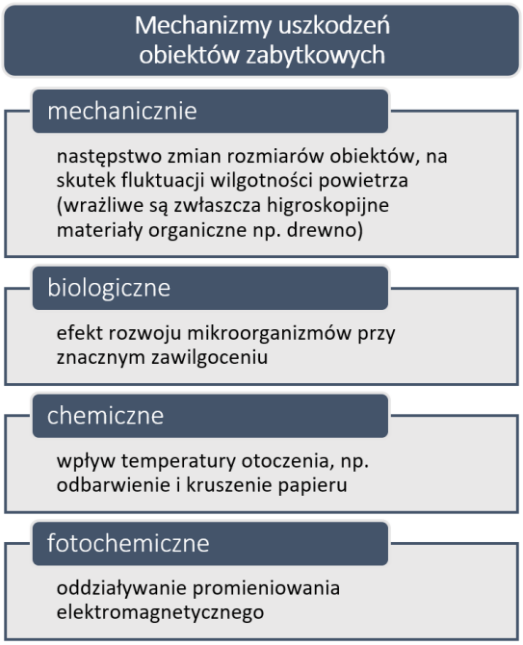
W Holandii jeszcze w latach 80-tych XX wieku, zwracano niewielką uwagę na znaczenie warunków mikroklimatycznych panujących w muzeum w kontekście zagadnienia ochrony eksponatów. Dopiero w latach 90-tych XX wieku zainicjowano działania mające na celu wyposażanie budynków muzealnych w rozwiązania, umożliwiające wytworzenie warunków bezpiecznych dla obiektów zabytkowych, opóźniających zachodzące w nich procesy starzeniowe [13].

Obecnie znane są różne rodzaje mechanizmów uszkodzeń obiektów zabytkowych, na skutek oddziaływania warunków mikroklimatycznych wnętrza (rys. 1). Mechanizmy te prowadzą do przyspieszenia procesów starzeniowych obiektów zabytkowych. Na ich podstawie można sklasyfikować czynniki zagrażające trwałości zabytków [10]:

- warunki temperaturowo-wilgotnościowe wnętrza,
- jakość powietrza, tj. zawartość pyłów, związków chemicznych i czynników biologicznych,
- oświetlenie naturalne (dzienne) i sztuczne.

Stopień niszczącego działania tych czynników jest zależny od rodzaju materiału, z którego są wykonane obiekty zabytkowe oraz czasu ekspozycji na czynnik niebezpieczny.

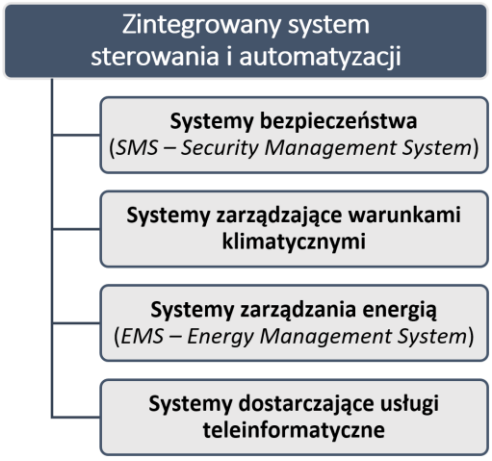
Na świecie, zwłaszcza w krajach posiadających stosunkowo dużo zabytków, utworzono stosowne normy i regulacje prawne, określające bezpieczne warunki środowiskowe dla przechowywania lub ekspozycji tego typu obiektów, również w zależności od typu kolekcji. W Polsce funkcjonują nieformalne tzw. normy konserwatorskie oraz zalecenia normy PN-EN 15757. W różnych opracowaniach naukowych i normach optymalne warunki mikroklimatyczne dla zabytków są jednak zróżnicowane [2, 8, 9, 10, 23].



Rys. 1. Mechanizmy uszkodzeń obiektów zabytkowych w muzeum [2, 3, 19]

2. Budynek muzeum typu Smart – integracja systemów i możliwości

Klasyczne systemy sterowania i automatyzacji budynku działają niezależnie, dlatego ogólna ich struktura w budynku jest rozbudowana (każdy z systemów posiada własne czujniki i okablowanie), a przy tym ograniczona funkcjonalnie. Dzięki integracji systemów w budynku typu Smart możliwe jest wzajemne współwykorzystanie dostępnych zasobów technicznych. Zintegrowany system sterowania i automatyzacji zarządza wszystkimi procesami zachodzącymi w budynku. Indywidualne systemy i instalacje techniczne inteligentnego budynku, można podzielić na obszary funkcjonalne, które działając w ramach nadrzędnego zintegrowanego systemu, wzajemnie się komunikują i współdziałają (rys. 2). Wśród nich można wyróżnić podsystemy funkcjonalne odpowiedzialne za obsługę poszczególnych funkcji. Należy jednak podkreślić, że granica między nimi jest często trudna do określenia, ze względu na podobną technologię oraz postępującą integrację [4, 12].



Rys. 2. Obszary funkcjonalne zintegrowanego systemu sterowania i automatyzacji

2.1. Systemy bezpieczeństwa

W obszarze systemów bezpieczeństwa realizowane są zadania zapewniające ochronę ludzi i mienia. Ze względu na przechowywane w muzeach cenne zbiory, obszar ten pełni niezwykle ważna rolę.

System kontroli dostępu umożliwia wejście do stref chronionych (np. budynku, pomieszczenia, terenu zewnętrznego) jedynie upoważnionym użytkownikom, natomiast system kontroli wjazdu otwiera bramę lub szlaban jedynie upoważnionym pojazdom. W celu identyfikacji uprawnionego personelu, systemy te mogą wykorzystywać klawiatury kodowe, czytniki kart dostępowych, rozpoznawanie odcisku palca lub tablic rejestracyjnych w przypadku pojazdów. System sygnalizacji włamania i napadu nadzoruje strefy chronione wykorzystując różnorodne czujniki, m.in. ruchu, stłuczenia szyby, otwarcia okna lub drzwi. System sygnalizacji pożarowej prowadzi nieustanny monitoring przestrzeni budynku przy pomocy detektorów np. dymu, ciepła lub płomienia, umożliwiając wykrycie pożaru już w początkowej fazie. System kontroli jakości powierza wykrywa obecność niebezpiecznych substancji lotnych, natomiast system ochrony przed zalaniem pojawienie się wody na posadzce.

W sytuacji wykrycia zagrożenia, budynek podejmuje najbardziej adekwatne dla jego typu działania. W przypadku detekcji nieuprawnionego wejścia do strefy chronionej włącza alarm, powiadamia służby ochrony oraz użytkownika. Kiedy wybuchnie pożar alarmuje użytkowników i powiadamia służby ratownicze oraz realizuje przewidziany scenariusz działań, sterując np. nagłośnieniem ewakuacyjnym, systemem oddymiania ciągów komunikacyjnych oraz prowadzącym oświetleniem awaryjnym w celu umożliwienia bezpiecznej ewakuacji ludzi. W celu ochrony mienia może także uruchomić system automatycznego gaszenia. Telewizja dozorowa oraz monitoring wizyjny i dźwiękowy umożliwiają obsłudze bieżącą weryfikację zagrożeń oraz dostęp do historycznych zapisów.

Po opuszczeniu budynku przez użytkowników, zintegrowany system sterowania zabezpiecza obiekt, uzbrajając system alarmowy oraz zamykając zewnętrzne przesłony okien.

System zasilania gwarantowanego poprawia pewność dostarczania energii elektrycznej do newralgicznych odbiorów lub całego obiektu.

W budynku muzeum niezwykle ważne jest zagwarantowanie wysokiej niezawodności systemu zarządzania budynkiem, zwłaszcza w zakresie funkcji bezpieczeństwa. W tym celu możliwe jest zastosowanie redundantnych urządzeń (serwerów danych, sterowników sieciowy), które przejmą funkcje tych uszkodzonych [4].

2.2. Systemy zarządzające warunkami klimatycznymi

Systemy zarządzające warunkami klimatycznymi oddziałują na instalacje i urządzenia odbiorcze odpowiedzialne za zapewnienie warunków mikroklimatycznych użytkowania pomieszczeń. Systemy te powinny przede wszystkim realizować cele sterowania dla zapewnienia warunków, które:

- są przyjazne dla personelu oraz odwiedzających,
- sprzyjają właściwej konserwacji zabytkowych zbiorów, zarówno przechowywanych w specjalnych pomieszczeniach jak i udostępnianych publiczności w formie wystaw.

O ile warunki sprzyjające konserwacji większości rodzajów obiektów zabytkowych, tj. stabilna temperatura w zakresie 18–24°C i wilgotność względna 50–60% są na ogół akceptowalne przez zwiedzających (w dostosowanej odzieży), to utrzymywanie możliwie niskiego poziomu oświetlenia oraz niedostatecznej dla ludzi wentylacji są nie do zaakceptowania [2, 10, 15, 19].

Dostosowanie temperatury w pomieszczeniu może być realizowane poprzez sterowanie ogrzewaniem i chłodzeniem, a odpowiednia wilgotność przez nawilżanie lub osuszanie. Świeże powietrze o odpowiednich parametrach może być dystrybuowane przez system wentylacji lub być przygotowane już w pomieszczeniach dzięki lokalnym urządzeniom grzewczym i/lub chłodniczym, takim jak grzejniki, klimakonwektory lub systemy płaszczyznowe (podłogowe, sufitowe, ścienne). Na warunki termiczne w pomieszczeniu może mieć wpływ także wykorzystanie kurtyn powietrznych lub regulowanie dostępu światła słonecznego. Zapewnienie wymaganej jakości powietrza w zakresie poziomu wilgotności lub stężenia dwutlenku węgla, następuje poprzez sterowanie wentylacją, klimatyzacją i otwieraniem okien. Jeżeli podczas naturalnego przewietrzania wystąpią opady lub zbyt silny wiatr, okna są automatycznie zamykane [4].

Szczególnie niebezpieczne dla obiektów zabytkowych są szybkie i znaczące zmiany temperatury i wilgotności we wnętrzach [10]. Tego typu niekontrolowane fluktuacje parametrów temperaturowo-wilgotnościowych pomieszczeń muzealnych, wynikające głównie ze zmienności zewnętrznych warunków atmosferycznych oraz zysków ciepła od oświetlenia oraz ciepła i wilgoci od ludzi [9], powinny być eliminowane przez adekwatne sterowanie.

Muzea charakteryzują się najbardziej wymagającymi kryteriami oświetleniowymi spośród wszystkich budynków [1]. Oświetlenie w muzeum odpowiada za właściwą prezentację wystawianych eksponatów, skupia uwagę na przedmiotach, prowadzi odwiedzających przez wystawę, a także podkreśla architekturę wnętrza. Wytworzone przyjazne otoczenie świetlne wpływa na nastrój i emocje zwiedzających, a także sprzyja właściwemu odbiorowi wystawy, skłaniając do estetycznych przeżyć. Z drugiej strony promieniowanie świetlne uszkadza eksponaty przyspieszając zachodzące procesy starzeniowe. Konieczne jest więc zachowanie kompromisu między wrażeniem wzrokowym odbiorcy (możliwość dokładnego objerzenia obiektów), a wymaganiami konserwacji eksponatów. W celu jego osiągnięcia, system zarządzania warunkami klimatycznymi, w zakresie oświetlenia powinien realizować cele sterowania [1, 2, 3, 21, 24]:

- priorytetowe wykorzystywanie światła naturalnego,
- wytworzenie możliwie ergonomicznych warunków oświetleniowych, przy uwzględnieniu limitów natężenia oświetlenia (dla najbardziej wrażliwych eksponatów dopuszczalne jest jedynie natężenie oświetlenia rzędu 50÷150 lx),
- ograniczenie czasu ekspozycji zabytków na światło.

Dla wypracowania odpowiednich warunków oświetleniowych, zintegrowany system sterowania może dynamicznie regulować ilości światła dziennego penetrującego do pomieszczenia, za pomocą ruchomych przesłon zacieniających, w zależności od warunków zewnętrznych. Natomiast oświetlenie sztuczne (elektryczne) powinno dostosować się do jego zmienności, uzupełniając niedobory. Oświetlenie elektryczne oraz dzienne może być także sterowane w zależności od obecności użytkowników, poprzez odpowiednio: włączanie/wyłączanie, ściemnianie oraz otwarcie/zamknięcie przesłon. Możliwe jest także udostępnienie sterowania światłem zwiedzającym, umożliwiając np. oświetlenie tylko wybranych eksponatów. W przypadku nieobecności zwiedzających w danej strefie, eksponaty powinny pozostać nieoświetlone [3, 4, 5].

2.3. Systemy zarządzania energią

W zakresie usług zarządzania energią, sterowana może być praca wszystkich instalacji odbiorczych w budynku, natomiast realizowane sterowania powinny respektować ograniczenia wynikające z dbałości o stan zabytków oraz komfort użytkowników.

System monitoringu zużycia energii i mediów dostarcza obsłudze muzeum informacje o bieżącym, historycznym oraz prognozowanym zużyciu energii, w przystępnej postaci. Dzięki temu stanowi wsparcie w zakresie gospodarowania nośnikami energii, a także pełni dzięki temu funkcję edukacyjną, kształtując świadomość personelu oraz zwiedzających.

System zarządzania i optymalizacji zużycia energii i mediów nadzoruje pracę źródeł ciepła i chłodu (np. kotłów gazowych, agregatów chłodniczych, pomp ciepła, układów kogeneracyjnych). Energia jest następnie indywidualne – w zależności od zapotrzebowania – rozprowadzana do poszczególnych pomieszczeń (stref) budynku w celu realizacji funkcji ogrzewania i chłodzenia, z wykorzystaniem sprzężenia zwrotnego od temperatury pomieszczenia. Odmiennie niż w rozwiązaniach klasycznych, taki sposób sterowania umożliwia ograniczenie zużycia energii poprzez wykorzystywanie jej tylko w czasie i miejscu gdzie istnieje na nią zapotrzebowanie. Uniemożliwiane jest także jednoczesne ogrzewanie i chłodzenie strefy przez lokalne urządzenia, również poprzez adekwatne dostosowanie temperatury dostarczanego powietrza.

Dystrybucja świeżego powietrza do pomieszczeń przez układ wentylacji jest regulowana według zapotrzebowania, w zależności liczby użytkowników w poszczególnych pomieszczeniach (detekcja z wykorzystaniem czujników ruchu lub na podstawie parametrów jakości powietrza) lub stopnia wykorzystywania oświetlenia sztucznego. W przypadku nieobecności użytkowników krotność wymian powietrza jest ograniczana do minimum. Możliwe jest także wykorzystanie zużytego powietrza poprzez odzysk ciepła zimą i chłodu latem za pośrednictwem odpowiednio sterowanego wymiennika lub częściowa jego recyrkulacja na podstawie informacji o stężeniu CO_2 w pomieszczeniach. W okresie letnim, konieczność wykorzystania aktywnych źródeł chłodu w ciągu dnia może być ograniczona, dzięki akumulacja chłodu w konstrukcji budynku poprzez wietrzenie nocne [4, 10, 13, 17].

Pozytywne efekty energetyczne możliwe są do osiągnięcia także poprzez sterowanie płaszczyznowymi systemami grzewczo-chłodniczymi z wykorzystaniem pojemności cieplnej budynku. Możliwe jest również wykorzystanie energii geotermalnej dla celów grzewczych lub chłodniczych we współpracy z pompą ciepła, poprzez chłodzenie tzw. pasywne lub za pośrednictwem poziomych gruntowych wymienników ciepła (wstępne dostosowanie temperatury powietrza dla systemu wentylacji). Optymalne zintegrowane sterowanie pozwala na maksymalizację efektywności energetycznej tych rozwiązań [15, 17, 18].

Kluczowe znaczenie dla efektywności energetycznej budynku muzeum ma też właściwy dobór nastaw, w szczególności temperatury i wilgotności zadanej w pomieszczeniach oraz ich dopuszczalnych tolerancji (im węższy zakres, tym wyższe zużycie energii). Wartości te mogą być statyczne lub dobierane dynamicznie m.in. w zależności od pory roku lub warunków zewnętrznych. Dawniej, w muzeach wyposażonych w klimatyzację, preferowano bardzo restrykcyjne utrzymywanie ściśle określonych warunków temperaturowo-wilgotnościowych. W ostatnich latach odchodzi się jednak od tej metody, ze względu na energochłonność procesu, na rzecz dopuszczenia

kontrolowanych fluktuacji, w celu zachowania równowagi między preferencjami ludzi, wymogami konserwacji obiektów zabytkowych oraz zapotrzebowania na energię [13, 14].

W zakresie funkcji oświetlenia wewnętrznego i zewnętrznego, może być regulowane jego natężenie, w zależności od obecności użytkowników oraz dostępności światła naturalnego. Pozycjonowanie ruchomych przesłon zacieniających (rolet, żaluzji) umożliwia także ograniczenie nagrzewania pomieszczeń w lecie oraz wspomaga ogrzewanie pomieszczeń w zimie [3, 4].

System zarządzania poborem mocy i energii elektrycznej ogranicza pobór mocy, wyłączając odbiory o najniższym priorytecie, w celu ochrony odbiorcy przed dodatkowymi opłatami ze strony dostawcy energii elektrycznej oraz zwiększa pewność zasilania dzięki utrzymywaniu obciążenia poniżej progu wyzwalania zabezpieczeń. System ten może także sterować odbiorami, których praca może zostać odłożona w czasie, w celu wykorzystania czasu maksymalnej generacji źródeł odnawialnych lub obniżenia opłat za energię elektryczną, a także dobowej stabilizacji poboru mocy z sieci. System zarządzania produkcją i magazynowaniem energii pozyskanej ze źródeł alternatywnych, może wykorzystywać predykcję okresów i wielkości generacji mocy dla zapewnienia optymalnego wykorzystania ich potencjału. Współdziałając z systemem zasilania gwarantowanego, może uniezależnić budynek muzeum od dostaw energii elektrycznej z sieci.

W przyszłości systemy zarządzania energią budynków inteligentnych mają być zintegrowane z infrastrukturą inteligentnej sieci elektroenergetycznej Smart Grid [4].

2.4. Systemy dostarczające usługi teleinformatyczne

Dziedzina systemów dostarczających usługi teleinformatyczne obejmuje obszary: okablowania strukturalnego, lokalnych sieci komputerowych oraz połączenia z sieciami zewnętrznymi, bezpieczeństwa informatycznego, systemów transmisji danych, obrazu i dźwięku (np. oprawa wizualna i dźwiękowa wystawy) oraz systemów automatyzacji miejsc pracy (np. rejestracja odwiedzających, rejestracja czasu pracy, usługi informacyjne) [4].

2.5. Pozostałe funkcje

Zintegrowany system sterowania i automatyzacji muzeum dla realizacji celów sterowania takich jak zarządzanie źródłami energii, zamykanie okien lub bezpieczne pozycjonowanie żaluzji, wykorzystuje informacje o zewnętrznych warunkach atmosferycznych. Dane te, dotyczące m.in. temperatury, opadów, prędkości wiatru i nasłonecznienia, pochodzą z lokalnej stacji pogodowej. Inteligentny budynek muzeum może także integrować takie funkcje jak:

- obsługa urządzeń audio–video,
- systemy komunikacji poziomej i pionowej,
- podgrzewanie podjazdów, rynien, gzymsów,
- zdalne zarządzanie budynkiem,
- nawadnianie roślin,
- ładowanie pojazdów o napędzie elektrycznym,
- integracja z innymi budynkami w ramach inteligentnego osiedla lub miasta (Smart City).

Obsługa może komunikować się z systemem za pomocą naściennych zadajników, pilotów, telefonu komórkowego lub komputera. Nastawy mogą być zadawane w obrębie pomieszczeń muzeum lub spoza budynku poprzez sieć Internet – w tym przypadku należy zwrócić jednak szczególną uwagę na kwestie bezpieczeństwa komunikacji.

W przeciwieństwie do muzeów wyposażonych w klasyczne niezależne systemy sterowania, w przypadku muzeum typu Smart jakakolwiek modyfikacja zadań systemów lub rozszerzenie funkcjonalności, np. w przypadku zmian w aranżacji i przeznaczeniu pomieszczeń lub potrzeb, jest niezwykle łatwa i często ogranicza się do wykonania czynności konfiguracyjnych za pośrednictwem stacji operatorskiej.

Z organizacją muzeum jako budynku typu *Smart*, związane są także szerokie możliwości aranżacji atrakcyjnej wystawy, wykorzystującej multimedialne formy przekazu. Aktywne sterowanie światłem, dźwiękiem, projektorami i ekranami (inicjowane wejściem zwiedzającego do wyznaczonej strefy) przekształca statyczną wystawę w multimedialny spektakl, który dzięki wykorzystaniu różnych zmysłów człowieka, może wzmocnić interakcję i emocjonalne zaangażowanie zwiedzającego. Ciekawe możliwości stwarza także wykorzystanie smartfonów w interakcji z wystawą np. odczyt kodów QR [4, 5, 16].

3. Rozwiązania typu Smart w polskich muzeach

W Polsce coraz więcej muzeów jest wyposażonych w zaawansowane systemy sterowania. Muzeum Miasta Gdyni oddane do użytku w 2007 r. wyposażone jest m.in. w:

- systemy kontroli dostępu, sygnalizacji włamania i napadu, sygnalizacji pożaru,
- sterowanie indywidualnymi oprawami oświetleniowymi w przestrzeni ekspozycyjnej, sterowanie oświetleniem pomieszczeń biurowych w zależności od obecności użytkowników, sterowanie oświetleniem zewnętrznym w zależności od natężenia oświetlenia dziennego,
- sterowanie ogrzewaniem i chłodzeniem w zależności od warunków atmosferycznych, wraz z funkcją nocnego ograniczenia wykorzystania urządzeń grzewczo-chłodniczych.

Innym przykładem jest Brama Poznania, gdzie w budynku starych fortów (stanowiących wejście oraz lobby muzeum), przeszklonym tunelu nad rzeką i nowoczesnej części muzealnej zastosowano m.in. sterowanie oświetleniem oraz systemy bezpieczeństwa wykorzystujące czujniki obecności, systemy sterowania ogrzewaniem i chłodzeniem (belki chłodzące), sterowanie roletami w salach konferencyjnych, a także wideodomofony. Zużycie energii elektrycznej jest monitorowane w ramach systemu zarządzania energią. Wyzwaniem dla projektantów była historyczna część muzeum znajdująca się pod opieką konserwatora zabytków. Zastosowanie nowoczesnych rozwiązań było możliwe pod warunkiem, że sensory i urządzenia wykonawcze nie zmienią estetyki zabytkowych wnętrz, co osiągnięto dzięki odpowiedniemu dostosowaniu ich koloru. Kolejnym przykładem jest Muzeum Narodowe – Centrum Dialogu Przełomy. We wnętrzach tego budynku (w części podziemnych) zaimplementowano m.in. funkcje sterowania oświetleniem w zależności od obecności, ogrzewania i chłodzenia (wykorzystujące ogrzewanie podłogowego i klimakonwektory), a także sterowania wystawą wykorzystującą multimedialne formy przekazu [6, 22].

4. Podsumowanie

Istotą „inteligencji" budynku typu Smart jest zintegrowane zarządzanie jego funkcjami, realizowane przez system sterowania i automatyzacji, bazujący na strukturze inteligentnej instalacji elektrycznej. Integracja systemów jest cechą, która odróżnia budynki typu Smart od budynków wyposażonych w klasyczne, niezależne systemy sterowania i automatyzacji.

Idea Smart Building nieustannie się rozwija otwierając nowe obszary zastosowań. Pomimo że jest jeszcze stosunkowo młoda, to budynki inteligentne już dziś oferują imponujące możliwości funkcjonalne. Budynki muzealne typu Smart mogą być bardzo efektywne energetycznie, pomimo restrykcyjnych wymagań dotyczących komfortu użytkowania i ochrony zabytków. Najwyższy stopień energooszczędności może być osiągnięty poprzez sterowanie z uwzględnieniem bezwładności termicznej budynku, harmonogramu funkcjonowania muzeum oraz wykorzystania metod predykcyjnych. Niewątpliwymi zaletami są też łatwość dopasowania zadań systemu do zmian w aranżacji oraz możliwość integracji scenariusza wystawy.

W nowoczesnym budynku muzealnym, zastosowanie rozwiązań Smart nie nastręcza trudności technicznych, choć wciąż wiąże się wyższymi nakładami inwestycyjnymi w porównaniu do rozwiązań tradycyjnych. Dużym wyzwaniem technicznym może być natomiast implementacja rozwiązań Smart w budynku historycznym, adaptowanym na potrzeby muzeum, z uwagi na ograniczenia techniczne i prawne. O ile zintegrowany system sterowania może bazować nawet na infrastrukturze bezprzewodowej, to dla realizacji celów sterowania wymaga ona odpowiedniej, adekwatnej infrastruktury instalacji technicznych budynku.

Dzięki złożoności zachodzących procesów i konieczności znalezienia kompromisu między współczesnymi wymaganiami, budynek muzeum jest doskonałym obszarem zastosowania nowoczesnych rozwiązań z zakresu Smart Building.

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Mgr inż. Mirosław Dechnik
e-mail: mdechnik@pk.edu.pl

Absolwent AGH w Krakowie (2013 r.), mgr inż. elektrotechniki w specjalności energoelektronika i napęd elektryczny. Obecnie pracownik Małopolskiego Laboratorium Budownictwa Energooszczędnego Politechniki Krakowskiej oraz doktorant AGH w Krakowie na Wydziale Elektrotechniki, Automatyki, Informatyki i Inżynierii Biomedycznej. Jego główne zainteresowania naukowe dotyczą zagadnień sterowania oświetleniem oraz zintegrowanego sterowania procesami w budynkach.

otrzymano/received: 13.02.2018 *przyjęto do druku/accepted: 15.09.2018*

DOI: 10.5604/01.3001.0012.5290

WPŁYW WYBRANYCH PARAMETRÓW TECHNICZNYCH SYSTEMU NA ODBIÓR FAL RADIOWYCH

Jacek Łukasz Wilk-Jakubowski
Politechnika Świętokrzyska, Katedra Systemów Informatycznych, Zakład Informatyki

Streszczenie. *Artykuł omawia wpływ wybranych parametrów systemu na odbiór fal radiowych, co ma zastosowanie w optymalizacji systemów łączności. Cel ten realizuje się poprzez dobór parametrów technicznych urządzeń np. współczynnika sprawności anteny odbiorczej. Zwiększenie współczynnika dostępności dla danego systemu wiąże się z minimalizacją wpływu wielu niepożądanych czynników na transmisję fal radiowych (w tym tłumienia podstawowego oraz influencji klimatyczno-atmosferycznej). W rezultacie możliwe staje się zoptymalizowanie istniejących już systemów teletransmisyjnych oraz projektowanie nowych systemów, pozwalających na znaczną poprawę jakości i wiarygodności przekazywanych informacji (zaprezentowane wyniki ograniczą się do częstotliwości z zakresu pasma Ku – powszechnie wykorzystywanego w łączności satelitarnej).*

Słowa kluczowe: parametry techniczne, modelowanie obliczeniowe, tłumienie sygnału, propagacja fal radiowych

THE INFLUENCE OF SELECTED TECHNICAL PARAMETERS ON THE RECEPTION OF RADIO WAVES

Abstract. *This article presents the influence of selected parameters on the reception of radio waves to optimize communication systems. That goal is achieved by selection of technical parameters of system, eg. antenna efficiency. The result is to minimize the negative effects of free space propagation and induction of climate and Earth's atmosphere in order to increase the G/T figure. In practice, changes in the climatic and atmospheric conditions are significant factors affecting the quality of satellite signal. These results can be used by satellite systems engineers to calculate the link budget analyses of current and future systems through scientifically solid evaluation and assessment. So, these estimates may be useful to improve the design and performance of telematic networks, or to minimize the interruption or lack of communication between the terminal and the satellite in Ku band.*

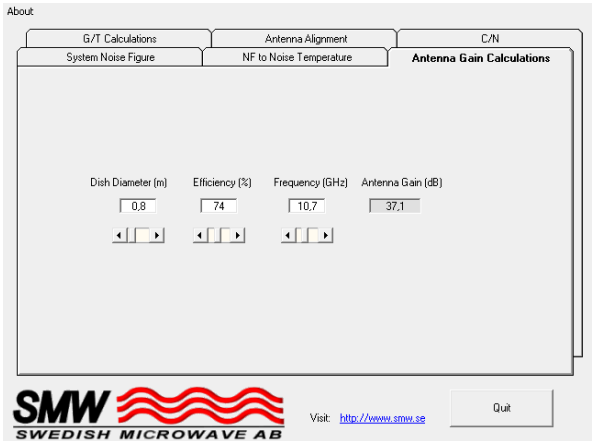
Keywords: technical parameters, computational modeling, signal attenuation, radio waves propagation

Wstęp

W praktyce istnieje wiele czynników przekładających się na odbiór fal radiowych. Jednym z nich jest tłumienie w wolnej przestrzeni propagacyjnej (ang. free space propagation), zwane również tłumieniem swobodnej przestrzeni oraz tłumieniem podstawowym. Oprócz tego na rozchodzenie się fal radiowych wpływają różne od wyidealizowanego przypadku propagacji w wolnej przestrzeni warunki rozchodzenia się fal radiowych. W tym kontekście należy wskazać wpływ: (1) atmosfery ziemskiej (w tym czynników klimatyczno-atmosferycznych w niej zachodzących) [3, 5, 22, 25, 28, 41, 42]; (2) naturalnych źródeł szumów o podłożu ziemskim, jak i pozaziemskim [4, 7, 23, 27, 28, 31, 32, 35, 36, 39, 42, 46, 47]; (3) strat wynikających z braku precyzji ustawienia anteny oraz (4) zastosowania rzeczywistych, stratnych elementów systemu odbiorczego (m.in. straty cyfrowej modulacji, całkowite straty w łączu, szumy fazowe konwertera LNB, nieliniowe charakterystyki filtrów w demodulatorze i stopnia mocy w satelicie, działanie dekoderów itp.) [2, 24, 37, 43]. W tym artykule przeanalizowano wpływ wybranych parametrów technicznych systemu odbiorczego, ze szczególnym uwzględnieniem współczynnika sprawności anteny, na odbiór fal radiowych, przy założeniu pozostałych parametrów jako niezmienne w czasie (ich standardowe wartości zostały podane w dalszej części artykułu). Wykorzystano model szacowania tłumienia sygnału spowodowanego wystąpieniem opadów deszczu zgodny z zaleceniami ITU-R [26, 40].

1. Prowadzone badania

W ostatnich latach stopień relewancji influencji meteorologiczno-środowiskowej – w związku z nasilającymi się anomaliami klimatycznymi oraz wyraźnie zauważalną niestabilnością meteorologiczną – uległ znaczącemu wzrostowi. Teledetekcja umożliwia modelowanie deszczu z wykorzystaniem technik GIS. Monitorowanie procesów kształtujących pogodę i klimat na Ziemi, analiza składu atmosfery ziemskiej oraz pomiary propagacyjne fal radiowych odgrywają zatem istotną rolę w kierunku dokładnego poznania wpływu rozmaitych mechanizmów i zjawisk na rozchodzenie się fal radiowych [8–10]. W tym kontekście działania te nabierają szczególnie ważnego znaczenia. Spośród wielu czynników klimatycznych uwydatnia się oddziaływanie deszczu – jako jednego z najważniejszych hydrometeorów [11–17]. Dla określonego natężenia opadów (zmierzonego zawartością wody) najważniejszy wpływ na tłumienie fali radiowej, jak również jego depolaryzację ma deszcz (wpływ innych hydrometeorów jest zwykle pomijany). Dla kątów elewacji większych niż 10º deszcz może być przyczyną kilkudziesięcio dB tłumienia. Istotnym czynnikiem degradacji dla fal o częstotliwości rzędu kilkunastu GHz jest także absorpcja molekularna w gazach atmosferycznych stanowiących składniki powietrza. Może ona wnosić tłumienie o wartości kilkunastu dB dla małych kątów elewacji [47]. W celu oszacowania wartości tłumienia można posłużyć się modelem regresji, który pozwoli określić przewidywaną degradację sygnału [33]. Zaproponowane przez autora krzywe propagacyjne bez konieczności znajomości Regulaminu Telekomunikacyjnego oraz rekomendacji ITU-R pozwalają oszacować np. wartość tłumienia sygnału satelitarnego w obszarze Kielc, która odzwierciedla rzeczone tłumienie w obszarze Polski. W praktyce gęstość strumienia mocy na powierzchni Ziemi uzależniona jest od zysku anteny.



Rys. 1. Szacowanie zysku rzeczywistej anteny z wykorzystaniem oprogramowania SMW Link

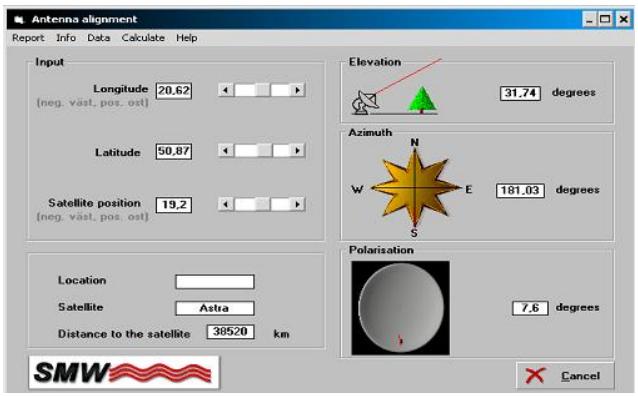
Warto zaznaczyć, że natężenie opadów w obszarze Kielc jest reprezentatywne dla obszaru całej Polski (34,4 mm/h) [45–47]. W Kielcach zrealizowano wiele badań również w ramach Europejskiego Projektu Badawczego ICT COST Action IC0802 "Propagation tools and data for integrated Telecommunication, Navigation and Earth Observation systems", w którym uczestniczyła Politechnika Świętokrzyska w Kielcach [19, 20, m.in. 31].

2. Lokalizacja stanowiska pomiarowego oraz parametry odbioru

Do celów analizy wykorzystano model matematyczny systemu satelitarnego czwartej klasy dostępności, który pozwala na uzyskanie średniej dostępności w ciągu roku na poziomie 99,99% oraz w najgorszym miesiącu na poziomie 99,948%, co odpowiada przestojowi równemu 0,877 godz. w skali roku oraz 0,379 godz. w skali najgorszego miesiąca. Wykorzystanie systemu satelitarnego pozwoliło uwzględnić nie tylko wpływ troposfery ziemskiej (istotny szczególnie dla naziemnych systemów łączności), ale również innych warstw atmosfery (propagacja transjonosferyczna) i zakłóceń od pozostałych systemów łączności (w modelu uwzględniono oddziaływanie sąsiednich systemów o parametrach EIRP = 51 dBW (pasmo 26 i 33 MHz), w konsekwencji czego pojawiły się nieodzowne dla transmisji satelitarnej zakłócenia interferencyjne). Ponieważ zakłócenia pomiędzy wiązkami anten stanowią bardzo ważne źródło szumów w wielowiązkowych systemach łączności satelitarnej (powodują zwiększenie szumów termicznych), pominięcie ww. zakłóceń byłoby błędem. Gdy znana jest gęstość szumów, możliwe jest oszacowanie mocy szumów dla danej szerokości pasma (w odniesieniu do 1 Hz). Ich wartość (wyrażającą stosunek całkowitej mocy sąsiednich sygnałów interferujących z danym kanałem w stosunku do mocy fali nośnej kanału oraz stosunek sumarycznej mocy sygnałów spolaryzowanych krzyżowo nakładających się na dany kanał do mocy fali nośnej kanału) przyjęto na poziomie 100 dBHz (typowe wartości zawierają się w przedziale od 100 do 115 dBHz). Można korzystać w tym celu z wielu narzędzi, jak np. oprogramowanie licencyjne SatMaster firmy Arrowe.

Parametry miejsca odbioru (miasto Kielce) są następujące: 50,87N, 20,62E, wysokość 300 m n.p.m., kąt polaryzacji do odbioru sygnałów z satelity Astra 1KR: 7,6° (19,2E).

W celu określenia prawidłowego położenia anteny można wykorzystać mapy topograficzne, nadajnik GPS lub użyć dedykowanego oprogramowania, jak np. SMW Link (rys. 2).



Rys. 2. Określenie kąta polaryzacji z wykorzystaniem oprogramowania SMW Link

W Polsce zaleca się do odbioru sygnałów z satelity Astra 1 KR anteny o średnicy minimum 60 cm (do analiz wykorzystano antenę o średnicy 80 cm) [1]. W tym celu posłużono się sygnałem spolaryzowanym poziomo (horyzontalnie) o częstotliwości 10,7 GHz (dane satelity: EIRP = 51 dBW, pasmo 26 MHz). Wybór polaryzacji był nieprzypadkowy (w praktyce fale o polaryzacji poziomej są znacznie bardziej tłumione od fal o polaryzacji pionowej). W przypadku propagacji fal radiowych o polaryzacji horyzontalnej atmosfera ziemska nie wykazuje istotnego tłumienia w zakresie o częstotliwości 0,1–6 GHz, zaś dla fal o polaryzacji pionowej okno rozszerza się aż do 50 GHz. Istota znajomości wyników odzwierciedlających tłumienie, wzrost szumów systemowych, degradacja czy depolaryzacja fali radiowej jest ważna na potrzeby projektowania optymalnych łączy telekomunikacyjnych.

Podobnie, istotne są parametry techniczne zastosowanych urządzeń na potrzeby modelowania komputerowego. Całkowite straty w łączu, straty wynikające z błędu wizowania anteny oraz współczynnik szumów konwertera LNB założono na poziomie 0,3 dB.

Szumy nieba istotnie wpływają na stosunek mocy nośnej sygnału do mocy szumów CNR (ang. Carrier-to-Noise Ratio), co przekłada się na spadek poziomu nośnej oraz dobroci G/T (ang. antenna gain-to-noise-temperature figure), wyrażającej stosunek zysku energetycznego anteny do zastępczej temperatury szumów systemowych. Zwiększenie współczynnika dostępności (gotowości) G/T pozwala zredukować moc i vice versa. Zmniejszenie temperatury szumowej nieba oddziałuje na spadek temperatury szumowej systemu. Hydrometeory stanowią zatem swego rodzaju tłumik, będący źródłem szumów cieplnych, które dodają się jako wielkość addytywna do całkowitej degradacji sygnału. Znamienne jest to, że wielkość szumów termicznych przewyższa tłumienie fali radiowej dla częstotliwości mniejszej niż 10 GHz.

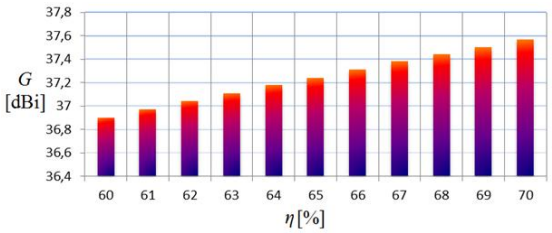
3. Wyniki badań

Poniżej zamieszczono tabelaryczne zestawienia ilustrujące wpływ współczynnika sprawności anteny w zakresie od 60% do 70% na zysk anteny, temperaturę szumową systemu oraz moc fali nośnej na wyjściu konwertera LNB (zwanego dalej wyjściem LNB) dla czystego nieba (pogoda bezdeszczowa).

Tabela 1. Wyniki modelowania obliczeniowego podczas pogody bezdeszczowej (brak opadów opadów)

Sprawność anteny [%]	Zysk anteny [dBi]	Temperatura szumów systemowych [K]	Moc fali nośnej na wyjściu LNB [dBW]
60	36,9	82,43	-57,71
61	36,97	81,59	-57,64
62	37,04	80,75	-57,57
63	37,11	79,91	-57,5
64	37,18	79,07	-57,43
65	37,24	78,23	-57,37
66	37,31	77,39	-57,3
67	37,38	76,55	-57,23
68	37,44	75,71	-57,17
69	37,5	74,87	-57,11
70	37,57	74,03	-57,04

Wzrost współczynnika sprawności w zakresie 60–70% przekłada się na zwiększenie zysku anteny (rys. 3). Anteny o dużym zysku energetycznym pozwalają częściowo skompensować wpływ niepożądanych czynników na odbiór fal radiowych (zysk anteny oprócz częstotliwości fali radiowej zależy również od średnicy anteny oraz od jej sprawności – rys. 1).



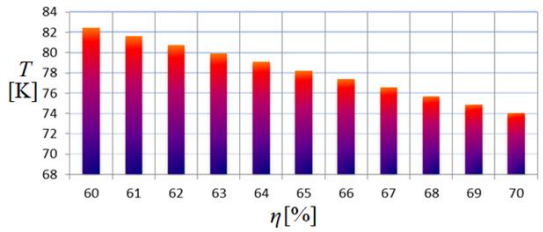
Rys. 3. Wpływ współczynnika sprawności anteny η [%] na zysk anteny G [dBi]

Zwiększenie współczynnika sprawności anteny przekłada się na zmniejszenie niepożądanego wpływu temperatury szumowej systemu (rys. 4). Na jakość odbioru sygnałów oddziałują także szumy cieplne wewnątrz układów fizycznych (ang. thermal noise), które występują w każdym rezystorze oraz naturalne ziemskie i pozaziemskie źródła szumów [48]. Dla anteny naziemnej w odbiorniku źródło szumów stanowi promieniowanie nieba określone przez jego temperaturę luminancyjną (energia szumów cieplnych wzrasta wraz ze zwiększeniem temperatury). Z kolei dla anteny umieszczonej na satelicie źródło szumów o określonej temperaturze termodynamicznej stanowi Ziemia.

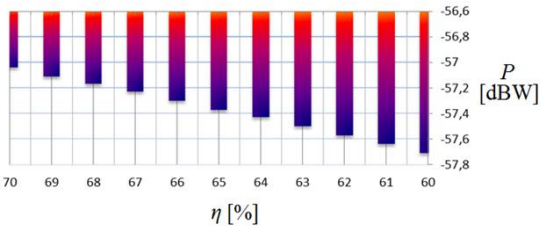
Współczynnik sprawności anteny oddziałuje również na moc fali nośnej na wyjściu LNB (rys. 5). Na jej wartość wpływają ponadto czynniki niezwiązane z parametrami technicznymi systemu odbiorczego, jak np.: współrzędne geograficzne miejsca odbioru, ukształtowanie terenu, częstotliwość, tłumienie podstawowe (w atmosferze).

W tabeli 2 przedstawiono analogiczne wyniki uzyskane podczas opadów deszczu.

Wystąpienie opadów deszczu nie wpływa na zwiększenie zysku anteny, dlatego też niezależnie od sytuacji meteorologicznej uzyskane wyniki są takie same (rys. 6). Dla współczynnika sprawności anteny w zakresie 60–70% (z krokiem równym 1%) zysk anteny wynosi odpowiednio: 36,90; 36,97; 37,04; 37,11; 37,18; 37,24; 37,31; 37,38; 37,44; 37,50; 37,57.



Rys. 4. Wpływ współczynnika sprawności anteny η [%] na temperaturę szumów systemowych T [K]

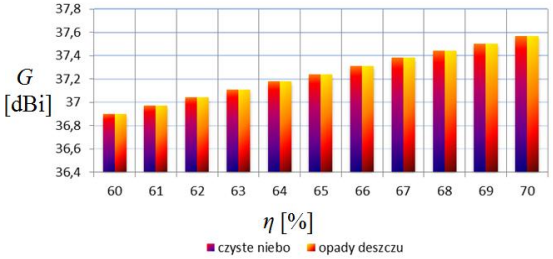


Rys. 5. Wpływ współczynnika sprawności anteny η [%] na moc fali nośnej P na wyjściu LNB [dBW]

Tabela 2. Wyniki modelowania obliczeniowego podczas pogody deszczowej (opady deszczu)

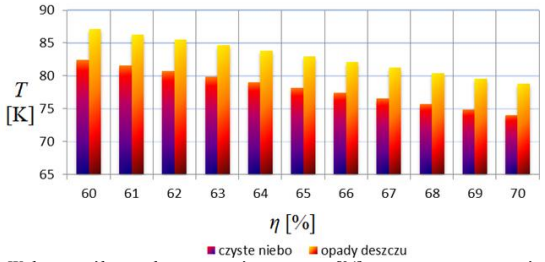
Sprawność anteny [%]	Zysk anteny [dBi]	Temperatura szumów systemowych [K]	Moc fali nośnej na wyjściu LNB [dBW]
60	36,9	87,17	-57,8
61	36,97	86,33	-57,73
62	37,04	85,49	-57,66
63	37,11	84,65	-57,59
64	37,18	83,81	-57,52
65	37,24	82,97	-57,45
66	37,31	82,13	-57,38
67	37,38	81,29	-57,32
68	37,44	80,45	-57,25
69	37,5	79,61	-57,19
70	37,57	78,77	-57,13

W przypadku wystąpienia opadów deszczu zauważalny jest wzrost temperatury szumów systemowych w stosunku do pogody bezdeszczowej (opady deszczu skutkują podwyższeniem temperatury szumów systemowych poprzez zwiększenie temperatury szumowej nieba). Opady deszczu stanowią zatem dodatkowe źródło szumów termicznych, powodując wzrost temperatury szumów systemowych o 4,74 dB – w rozpatrywanym zakresie współczynnika sprawności anteny 60–70% – w stosunku do pogody bezdeszczowej (rys. 7).

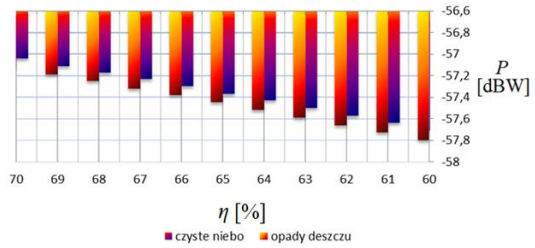


Rys. 6. Wpływ współczynnika sprawności anteny η [%] na zysk anteny G [dBi] w zależności od sytuacji meteorologicznej (pogoda deszczowa lub bezdeszczowa)

Zwiększenie sprawności anteny powoduje wzrost mocy fali nośnej na wyjściu konwertera LNB. Podczas opadów deszczu notuje się różnicę mocy fali nośnej na wyjściu LNB w stosunku do pogody bezdeszczowej o około 0.1 dBW. Podczas opadów deszczu dla współczynnika sprawności anteny od 60% do 70% odnotowano różnicę mocy fali nośnej na wyjściu LNB w stosunku do pogody bezdeszczowej na poziomie 0,008–0,09 dBW (rys. 8).



Rys. 7. Wpływ współczynnika sprawności anteny η [%] na temperaturę szumów systemowych T [K] w zależności od sytuacji meteorologicznej (pogoda deszczowa lub bezdeszczowa)



Rys. 8. Wpływ współczynnika sprawności anteny η [%] na moc fali nośnej P na wyjściu LNB [dBW] w zależności od sytuacji meteorologicznej (pogoda deszczowa lub bezdeszczowa)

4. Podsumowanie

Obecnie przedmiotem współpracy wielu placówek akademickich, instytucji naukowych oraz jednostek rządowych państw Europy i całego świata jest tworzenie możliwie najbardziej skutecznych, niezawodnych technologiczno-organizacyjnych mechanizmów teletransmisyjnych, które będą zdatne do prawidłowego funkcjonowania niezależnie od zagrożeń integralności powszechnych systemów radiokomunikacji i transmisji danych. W ramach potencjalnych niebezpieczeństw można wyodrębnić zarówno zagrożenia antropogeniczne, jak i wynikające z oddziaływania wielu czynników klimatyczno-atmosferycznych wymienionych w artykule. Odpowiedzią na powyższe wyzwania jest zapewnienie łączności, relatywnie odpornej na opisane wyżej czynniki ryzyka, mogącej – w sytuacjach krytycznych – nieprzerwanie funkcjonować z zadeklarowaną niezawodnością. Ponadto systemy takie – z wykorzystaniem satelitów – mogą w przypadku zagrożenia (akty terrorystyczne, sabotaż, konflikty zbrojne) z powodzeniem substytuować infrastrukturę naziemną. Jednym z takich projektów jest Europejski Projekt Badawczy ICT COST Action IC0802 "Propagation tools and data for integrated Telecommunication, Navigation and Earth Observation systems" [19, 20], którego celem było m.in. testowanie modeli deterministycznych w odniesieniu do statystycznych obliczeń [4, 7]. Tego typu badania przeprowadzono również w Polsce, w reprezentatywnym ze względu na warunki klimatyczno-atmosferyczne obszarze Kielc. Ponieważ zmiana parametrów technicznych łącza odbiorczego przekłada się na zmianę jakości odbioru sygnałów radiowych, pożądane wydaje się być dalsze prowadzenie tego typu analiz pod kątem optymalizacji istniejących już systemów teletransmisyjnych oraz projektowania nowych systemów, pozwalających na znaczną poprawę jakości i wiarygodności odbieranych sygnałów. W oparciu o przeprowadzone badania możliwe staje się oszacowanie „zapasu sygnałowego", a tym samym zminimalizowanie ryzyka utraty łączności satelitarnej wskutek wystąpienia niepożądanych zjawisk, co globalnie przekłada się na rozwój technologii TIK, w tym również sieci satelitarnych [18, 21, 29, 30, 34, 38, 44].

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Dr inż. Jacek Łukasz Wilk-Jakubowski
e-mail: j.wilk@tu.kielce.pl

Na Politechnice Świętokrzyskiej ukończył zarówno studia magisterskie w 2009 r. (na kierunku Elektrotechnika), jak i studia doktoranckie w 2013 r. (w dyscyplinie Elektrotechnika). Autor wielu publikacji naukowych (w tym: monografii, rozdziałów, artykułów), w których podejmuje tematykę ICT dotyczącą optymalizacji systemów zarządzania kryzysowego i transmisji danych w przypadku wystąpienia niekorzystnych zjawisk, w tym klęsk żywiołowych. Uczestnik wielu konferencji krajowych i zagranicznych.

otrzymano/received: 11.06.2018 *przyjęto do druku/accepted: 15.09.2018*

DOI: 10.5604/01.3001.0012.5293

DWA RÓWNOLEGŁE POMIARY WIETRZNOŚCI JAKO DOKŁADNA OCENA LOKALNYCH ZASOBÓW ENERGII WIATRU

Piotr Gnyp
Politechnika Śląska, Wydział Inżynierii Środowiska i Energetyki

Streszczenie. *Pomiary wietrzności przeprowadzono przy użyciu dwóch masztów pomiarowych oddalonych od siebie o 17,6 km. Wyznaczono dwa numeryczne modele terenu – numeryczny model wysokościowy terenu oraz numeryczny model szorstkości terenu. Podczas analizy danych pomiarowych zauważono znaczące różnice w zmierzonej prędkości wiatru pomiędzy masztami pomiarowymi. Dodatkowy pomiar wietrzności może okazać się niezbędny dla uzyskania pełnej informacji o charakterze wietrzności dla danej lokalizacji.*

Słowa kluczowe: pomiar wietrzności, numeryczny model wysokościowy terenu, numeryczny model szorstkości terenu, systemy informacji geograficznej

TWO PARALLEL WIND MEASUREMENTS AS AN ACCURATE ASSESSMENT OF LOCAL WIND ENERGY RESOURCES

Abstract. *The wind measurements were made using two measuring masts spaced 17.6 km apart. Two numerical terrain models were identified - the numerical terrain model and the numerical roughness model. During measurement data analysis significant differences in measured wind speed between measuring masts were noted. Additional wind measurements may be necessary to obtain complete wind quality information for the location.*

Keywords: wind measurement, digital elevation model, surface roughness, geographic information systems

Wstęp

Obecnie, aby przeprowadzić proces inwestycyjny mający na celu wybudowanie farmy wiatrowej, niezbędne jest przeprowadzenie lokalnych pomiarów wietrzności. Pomiar wietrzności powinien trwać minimum rok, aby uchwycić jego sezonową zmienność. W miesiącach letnich występują niższe wartości prędkości wiatru ze względu na okres wegetacyjny roślin. Na niższe prędkości wiatru ma wpływ zwiększona szorstkość terenu spowodowana rozwojem roślinności. Na zmianę prędkości wiatru poza rozwojem roślinności mają wpływ ukształtowanie i pokrycie terenu [5, 9].

Aby poznać rzeczywiste warunki wiatrowe, należy sprawdzić nie tylko ich sezonową zmienność ale zróżnicowanie rozkładu wiatru spowodowane charakterystyką terenu. W celu dokładnej oceny warunków wietrzności, jeden maszt pomiarowy może stać się niewystraczający i należy przeprowadzić dodatkowy, jednoczesny pomiar wietrzności. Takie podejście pozwoli poznać zmiany w prędkości i kierunku wiatru spowodowane zmianami orografii i szorstkości terenu [2].

Analizowana lokalizacja i miejsce przeprowadzenia badań znajdowało się w pasie nadmorskim (okolice Słupska). W tych rejonach odnotowuje się najwyższe średnioroczne prędkości wiatru. Analiza danych pomiarowych została wykonana w oprogramowaniu dla energetyki wiatrowej WindPRO, natomiast analiza ukształtowania i pokrycia terenu w oprogramowaniu GIS – Global Mapper [3, 7].

1. Aparatura pomiarowa

Pomiar wietrzności został przeprowadzony przy użyciu dwóch masztów pomiarowych zlokalizowanych w województwie pomorskim (okolice Słupska). Każdy z masztów miał wysokość 100 m i zbierał dane w okresie:

- Maszt pomiarowy M1 – (15.03.2011 – 30.06.2014),
- Maszt pomiarowy M2 – (15.03.2011 – 30.06.2014).

Dane pomiarowe zostały rejestrowane przy użyciu aparatury pomiarowej na którą składały się anemometry, wiatrowskazy oraz urządzenie rejestrujące wyposażone w moduł GSM do transmisji danych. W tabeli 1 zestawiono dane dotyczące lokalizacji masztów pomiarowych M1 i M2, natomiast w tabeli 2 ich konfigurację. Rysunek 1 ilustruje położenie masztów pomiarowych M1 i M2 na tle województwa pomorskiego. Rysunki 2 i 3 przedstawiają szczegółowe położenie masztów pomiarowych na tle map lotniczych [16].

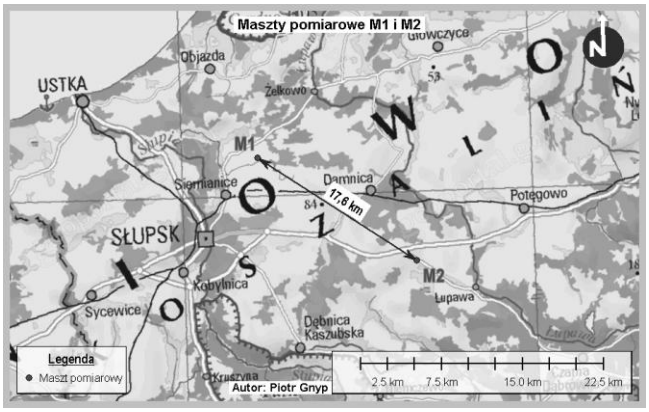
Konfiguracja masztów pomiarowych została dobrana zgodnie z zaleceniami organizacji Measnet. Wszystkie czujniki rejestrujące cechowały się wysoką dokładnością, zostały poddane kalibracji przed i po zakończonym okresie pomiarowym. Do rejestrowania prędkości wiatru wybrano wysokiej klasy anemometry Thies First Class Advanced, zgodne z normą PN-EN 61400-12-1. Zakres pomiaru anemometrów Thies First Class Advanced to przedział 0,3–75 m/s przy linowości pomiaru wynoszącym r = 0,999 (w przedziale 4–20 m/s) [10, 11, 14].

Tabela 1. Dane dotyczące lokalizacji masztów pomiarowych M1 i M2

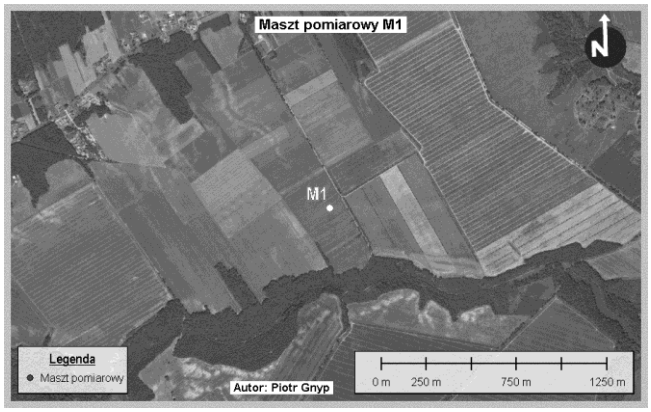
Maszt pomiarowy	M1	M2
Województwo	pomorskie	
Powiat	Słupsk	
Gmina	Słupsk	
Współrzędne lokalizacji	17° 06' 27,20" E 54° 31' 56,00" N	17° 19' 50,60" E 54° 26' 34,40" N
Wysokość lokalizacji	68 m n. p. m.	76 m n. p. m.

Tabela 2. Dane dotyczące konfiguracji masztów pomiarowych M1 i M2

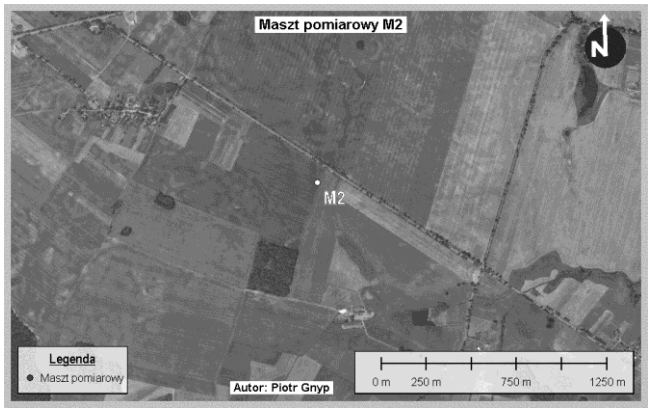
Maszt pomiarowy	M1	M2
Województwo	Wysokość instalacji [m]	
Anemometr 1	100,0	100,0
Anemometr 2	98,5	98,5
Anemometr 3	74,0	74,0
Anemometr 4	40,0	40,0
Wiatrowskaz 1	98,5	98,5
Wiatrowskaz 2	40,0	40,0



Rys. 1. Położenie masztów pomiarowych M1 i M2 na tle województwa pomorskiego



Rys. 2. Szczegółowe położenie masztu pomiarowego M1



Rys. 3. Szczegółowe położenie masztu pomiarowego M2

Do pomiaru kierunku wiatru zastosowano potencjometryczny wiatrowskaz Thies Compact o zakresie pomiaru 0–360°. Rozdzielczość pomiaru wynosi 0,5° przy dokładności 2°[12].

Do rejestrowania danych pomiarowych wybrano urządzenie rejestrujące Ammonit Meteo-32, charakteryzujące się możliwością podłączenia do 10 czujników pomiarowych. Rejestrator Ammonit Meteo-32 posiada możliwość rejestrowania danych na karcie pamięci oraz możliwość podłączenia modułu GSM do transmisji danych [13].

Rysunki 4 i 5 ilustrują zastosowane czujniki pomiarowe a rysunek 6 – urządzenie rejestrujące Ammonit Meteo-32.

Rys. 4. Anemometr Thies First Class Advanced [11]

Rys. 5. Wiatrowskaz Thies Compact [12]

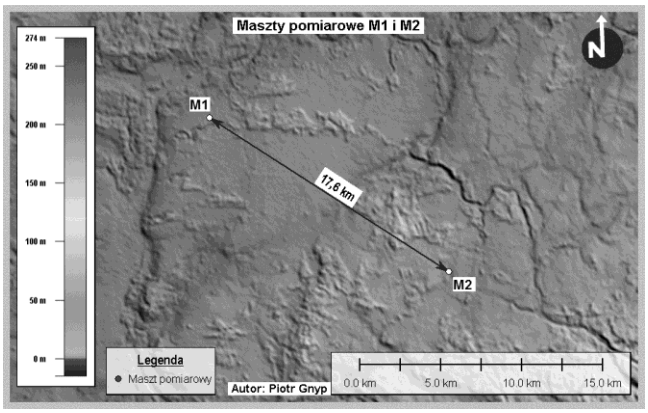
Rys. 6. Urządzenie rejestrujące Ammonit Meteo-32 [13]

2. Charakterystyka terenu

Teren wokół masztów pomiarowych można zakwalifikować jako równinny, w większości uprawiany rolniczo z dużymi zwartymi kompleksami leśnymi. Brak jest wysokich obiektów, które można by zakwalifikować jako przeszkody terenowe zaburzające w sposób istotny przepływającą masę powietrza. Dla analizowanego obszaru określono dwa numeryczne modele terenu – numeryczny model wysokościowy terenu oraz numeryczny model szorstkości terenu. Modele zostały wykonane w oprogramowaniu GIS – Global Mapper.

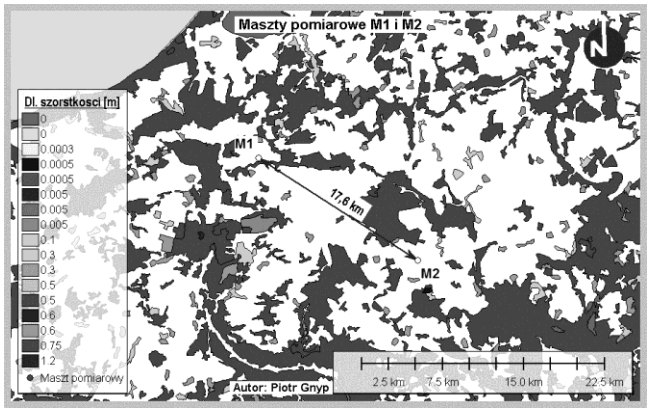
Numeryczny model wysokościowy terenu został wykonany na podstawie danych SRTM-3 (Shuttle Radar Topography Mission). Dane Shuttle Radar Topography Mission pochodzą z misji przeprowadzonej przez Narodową Agencję Aeronautyki i Przestrzeni Kosmicznej Stanów Zjednoczonych (NASA), której celem było zebranie danych do opracowania globalnego numerycznego modelu terenu. Dane zostały zebrane metodą interferometrii radarowej z poziomu promu kosmicznego Endeavour. Dla obszaru odpowiadającego położeniu Polski, dane SRTM-3 cechują się rozdzielczością wynoszącą 60 m × 90 m [4].

Surowe dane SRTM-3 pozyskane z serwerów NASA zostały poddane analizie w oprogramowaniu GIS – Global Mapper. Zasięg użytego modelu obejmował swoim zasięgiem obszar 625 km^2. Rysunek 7 przedstawia próbkę numerycznego modelu wysokościowego terenu [4, 17].



Rys. 7. Próbka numerycznego modelu wysokościowego terenu

Numeryczny model szorstkości terenu opracowano na podstawie danych dotyczących pokrycia terenu pozyskanych z serwerów Europejskiej Agencji Ochrony Środowiska (EEA). Europejska Agencja Ochrony Środowiska publikuje dane dotyczące pokrycia terenu pod nazwą Corine Land Cover. Dane Corine Land Cover dotyczą zmian w pokryciu terenu w latach 2006–2012. Do wygenerowania numerycznego modelu szorstkości terenu wykorzystano dane z 2012 roku. Analiza szorstkości terenu została wykonana w oprogramowaniu GIS – Global Mapper. Odpowiednim obszarom zostały przyporządkowane wartości odpowiadające długości szorstkości. Rozdzielczość modelu to 100 m × 100 m. Całkowity zasięg numerycznego model szorstkości terenu obejmował swoim zasięgiem obszar 3025 km^2. Rysunek 8 przedstawia próbkę numerycznego modelu szorstkości terenu [1, 18].



Rys. 8. Próbka numerycznego modelu szorstkości terenu

3. Metodologia obliczeń

Do poznania parametrów charakteryzujących wiatr, niezbędne jest zastosowanie metod statystycznych. Do statystycznej metody opisu wiatru stosuje się rozkład Weibulla, który przedstawia prawdopodobieństwo wystąpienia danej prędkości wiatru. Rozkład Weibulla jest funkcją, którą cechują dwa parametry, parametr kształtu (k) oraz parametr skali (A). Rozkład Weibulla zapisuje się przy pomocy równania [2, 8]:

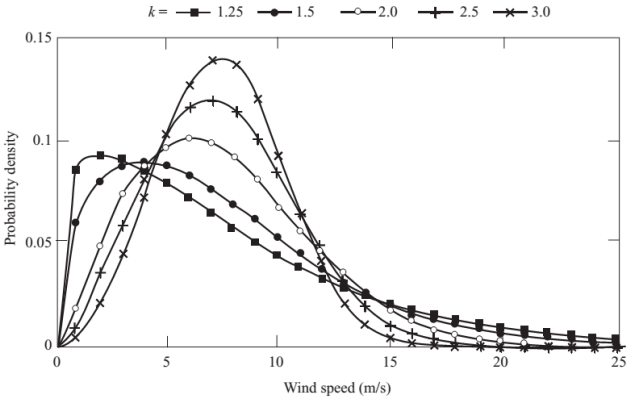
$$f(v) = \frac{k}{A}\left(\frac{v}{A}\right)^{k-1} \cdot \exp\left(-\left(\frac{v}{A}\right)^{k}\right) \tag{1}$$

gdzie: f(v) – gęstość prawdopodobieństwa wystąpienia wiatru o wartości prędkości v, k – parametr kształtu, A – parametr skali.

Parametr k określa kształt rozkładu Weibulla. Niskie wartości parametru k charakteryzują miejsca o dużej zmienności warunków wiatrowych (przeważnie są wartości mieszczące się w przedziale 1,0–1,5). Wyższe wartości parametru k wskazują na lokalizacje cechujące się stabilnością warunków wiatrowych. Wysokie wartości parametru k (2,5–3,0) określają lokalizacje o najlepszych walorach do lokalizowania siłowni wiatrowych [2, 8]. Na rysunku 9 przedstawiono przykłady rozkładu Weibulla dla różnych wartości parametru k. Skumulowany rozkład Weibulla wyraża się poprzez poniższy wzór [2]:

$$F(v) = \exp\left(-\left(\frac{v}{A}\right)^{k}\right) \tag{2}$$

gdzie: F(v) – prawdopodobieństwo wystąpienia prędkości wiatru o wartości v, k – parametr kształtu, A – parametr skali.



Rys. 9. Przykłady rozkładu Weibulla dla różnych wartości parametru k [8]

Bardzo ważnym parametrem charakteryzującym wiatr jest jego profil obrazujący zmiany prędkości wraz ze zmianą wysokości. Dzięki zastosowaniu anemometrów zainstalowanych na różnych wysokościach masztu pomiarowego można wyznaczyć jego oczekiwany przebieg. Przebieg profilu wiatru jest silnie determinowany przez ukształtowanie i pokrycie terenu. Wysokie wartości szorstkości terenu powodują szybsze wyhamowywanie i spiętrzenie napływającej masy powietrza.

Profil wiatru można wyznaczyć przy użyciu równania [6]:

$$\frac{v_1(z_1)}{v_2(z_2)} = \left(\frac{\ln z_1 - \ln z_0}{\ln z_2 - \ln z_0}\right) \tag{3}$$

gdzie: v_1 – zmierzona prędkość wiatru, v_2 – prędkość wiatru w osi siłowni wiatrowej, z_1 – wysokość wykonania pomiaru, z_2 – wysokość do osi siłowni wiatrowej, z_0 – parametr określający szorstkość terenu.

4. Wyniki badań

Podczas analizy danych o wietrzności pochodzących z masztów pomiarowych M1 i M2 wyznaczono główne parametry rozkładu wiatru. Wyznaczono średnioroczne i średniomiesięczne prędkości wiatru oraz średnią prędkość wiatru z całego okresu pomiarowego. Wyznaczono parametry rozkładu Weibulla (parametr k oraz A) oraz profile wiatru. Rysunek 10 przedstawia próbkę danych z masztów pomiarowych M1 i M2. W tabelach 3 i 4 zestawiono rozkłady prędkości wiatru dla masztów pomiarowych M1 i M2 dla wysokości 100 m. Rozkład parametrów Weibulla dla masztów pomiarowych M1 i M2 przedstawiono w tabelach 5 i 6. Rysunek 11 ilustruje obliczone profile wiatru dla masztów pomiarowych M1 i M2.

Rys. 10. Próbki danych z masztów pomiarowych M1 i M2

Tabela 3. Rozkład prędkości wiatru dla masztu pomiarowego M1 dla wys. 100 m

Miesiąc	Maszt pomiarowy M1			
	2011	2012	2013	2014
	Prędkość wiatru v [m/s]			
Styczeń	-	8,54	6,92	8,65
Luty	-	7,73	5,82	8,24
Marzec	7,58	7,52	6,76	7,36
Kwiecień	7,57	6,72	6,88	6,53
Maj	6,70	6,84	5,91	6,61
Czerwiec	6,46	6,38	5,64	5,76
Lipiec	5,67	5,89	5,82	-
Sierpień	7,13	5,90	5,97	-
Wrzesień	7,50	7,44	6,29	-
Październik	7,73	7,17	7,37	-
Listopad	7,38	7,47	7,33	-
Grudzień	9,35	7,41	8,91	-
$v_{śr/rok}$	7,31	7,08	6,64	7,19
$v_{śr/cały\ okres}$	7,05			

Tabela 4. Rozkład prędkości wiatru dla masztu pomiarowego M2 dla wys. 100 m

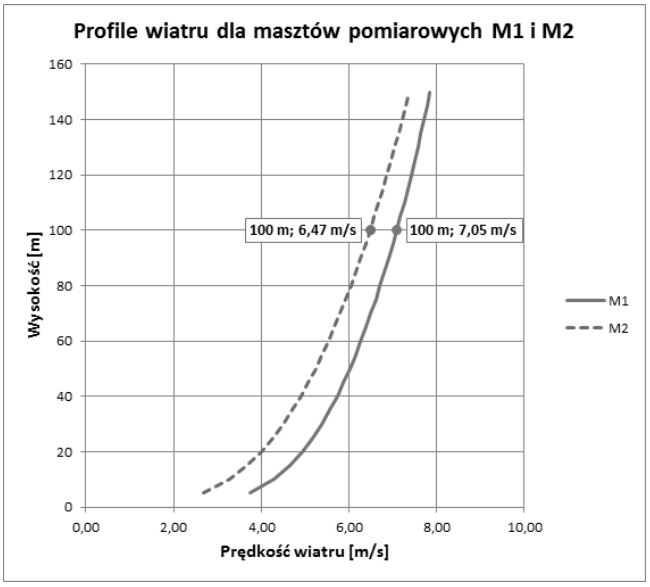
Miesiąc	Maszt pomiarowy M2			
	2011	2012	2013	2014
	Prędkość wiatru v [m/s]			
Styczeń	-	7,48	6,49	7,59
Luty	-	7,18	5,50	7,07
Marzec	7,26	7,16	6,50	6,87
Kwiecień	7,02	6,29	6,35	5,92
Maj	6,13	6,32	5,47	6,25
Czerwiec	6,06	5,91	5,33	5,41
Lipiec	5,39	5,42	5,54	-
Sierpień	6,39	5,45	5,46	-
Wrzesień	6,72	6,74	5,75	-
Październik	6,96	6,49	6,63	-
Listopad	6,35	6,63	6,79	-
Grudzień	8,72	7,02	8,11	-
$v_{śr/rok}$	6,70	6,51	6,16	6,52
$v_{śr/cały\ okres}$	6,47			

Tabela 5. Parametry rozkładu wiatru dla masztu pomiarowego M1 na wys. 100 m

Kierunek	Parametr A [-]	Parametr k [-]	Śr. prędkość wiatru [m/s]	Częstotliwość występowania [%]
N	5,93	2,033	5,25	5,1
NNE	6,28	2,774	5,59	5,6
ENE	6,76	2,716	6,01	6,0
E	7,25	3,052	6,48	5,3
ESE	8,26	3,334	7,41	6,3
SSE	8,58	3,980	7,78	9,4
S	8,28	3,848	7,49	9,3
SSW	8,18	3,743	7,38	10,4
WSW	8,64	3,250	7,75	14,9
W	9,13	2,281	8,09	15,8
WNW	7,04	1,819	6,26	7,1
NNW	6,12	2,006	5,43	4,8
Średnia	7,98	2,620	7,09	100,0

Tabela 6. Parametry rozkładu wiatru dla masztu pomiarowego M2 na wys. 100 m

Kierunek	Parametr A [-]	Parametr k [-]	Śr. prędkość wiatru [m/s]	Częstotliwość występowania [%]
N	6,13	2,539	5,44	5,2
NNE	6,19	2,616	5,50	5,5
ENE	6,39	2,950	5,70	6,4
E	6,45	2,884	5,75	4,9
ESE	6,64	3,052	5,94	5,7
SSE	6,90	3,348	6,19	9,1
S	7,24	3,209	6,49	10,9
SSW	7,60	3,372	6,82	10,7
WSW	7,98	2,947	7,12	15,0
W	8,54	2,176	7,56	15,4
WNW	7,06	1,925	6,26	7,0
NNW	6,41	2,436	5,69	4,6
Średnia	7,30	2,548	6,48	100,0



Rys. 11. Obliczone profile wiatru dla masztów pomiarowych M1 i M2

5. Podsumowanie

W wyniku przeprowadzonej analizy zauważono, że mimo małej odległości pomiędzy masztami pomiarowymi M1 i M2, wynoszącej 17,6 km, prędkości wiatru były zauważalnie różne. Różnica w zmierzonej prędkości wiatru, z całego okresu pomiarowego, na wysokości 100 m wyniosła 0,58 m/s.

Odnosząc tą wartość do przebiegu krzywej mocy siłowni wiatrowej, prognozowana produktywność energetyczna może znacząco się różnić. Zakładając, że przy średniorocznej prędkości wiatru na poziomie 7,05 m/s (warunki dla masztu pomiarowego M1) i gęstości powietrza 1,225 kg/m^3 siłownia wiatrowa Vestas V100 o mocy nominalnej generatora 1,8 MW jest w stanie wygenerować 6563 MWh rocznie, natomiast dla średniorocznej prędkości wiatru wynoszącej 6,47 m/s (warunki dla masztu pomiarowego M2) siłownia ta wygeneruje 4891 MWh rocznie.

Różnica w prędkości wiatru o 0,58 m/s oznaczać będzie zmianę w wytwarzaniu energii elektrycznej na poziomie 1582 MWh/rok (24,1%) [15].

Średni kierunek wiatru był porównywalny, nie odnotowano znaczących odchyleń. Dla masztu pomiarowego M1 średni kierunek wiatru z całego okresu pomiarowego wynosił 228,1°, dla masztu M2 wyniósł 226,1°. Różnica w zmierzonym kierunku wiatru na wysokości 100 m pomiędzy masztami M1 i M2 wyniosła 2°.

Eksperyment mający na celu wykazanie różnic w charakterze wietrzności dla dwóch bliskich lokalizacji pokazał, że ukształtowanie i pokrycie terenu mają wpływ na przepływająca masę powietrza. Niewielkie różnice w zmierzonej prędkości wiatru mogą mieć istotny wpływ na planowaną produktywność energetyczną projektowanej farmy wiatrowej.

Przed podjęciem decyzji o wykonaniu pomiarów wietrzności dla danej lokalizacji należy przeanalizować ukształtowanie i pokrycie terenu. Dla zróżnicowanych obszarów okazać się może, że dodatkowy pomiar wietrzności będzie niezbędny dla wykonania prawidłowej prognozy, gwarantującej efektywniejsze wykorzystanie zasobów wiatru.

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Mgr inż. Piotr Gnyp
e-mail: piotr.gnyp@hotmail.com

Doktorant na Wydziale Inżynierii Środowiska i Energetyki Politechniki Śląskiej. Absolwent Wydziału Inżynierii Procesowej i Ochrony Środowiska Politechnika Łódzkiej.
Od 2009 roku związany zawodowo z branżą energetyczną, w szczególności przy projektowaniu, zarządzaniu i rozliczaniu inwestycji w obszarze odnawialnych źródeł energii.
Zrealizowane projekty w obszarze energetyki wiatrowej na łączną moc zainstalowaną wynoszącą około 200 MW.

otrzymano/received: 20.10.2017 *przyjęto do druku/accepted: 15.09.2018*