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AUGMENTED INTELLIGENCE FOR TEACHING ROBOTS BY IMITATION

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Abstract: The process of augmenting intelligence in Human Robot Interaction has a complex character and can’t be pre-programmed explicitly. Nowadays, teaching robots is a well-established concept ranging from demonstration by variants of teleoperation to imitation by external observations. We illustrate an innovative approach for learning intelligence and gestures by imitations of robots by brain augmentation captured by Emotiv brain-listening headset and human poses tracked by Microsoft Kinect motion-sensing device. Thus, robots learn continuously by observations from human brain activities and motions and really become personal. By innovative algorithms, robot operations that satisfy the current physical, cognitive, emotional and social intelligence over time are calculated and transmitted to robot sensors, modules and controllers. The concept of added brain intelligence will also evolve into technology to increase brain capacity and will shape our experience and skills in the future. Summarizing, the paper proposes a new concept for human-robot personal communication by augmenting bio intelligence to robot and vice versa - machine intelligence to human.

Keywords: TEACHING ROBOTS BY IMITATION, HUMANOID ROBOT NAO, KINECT-ENABLED APPLICATIONS, EMOTIV-ENABLED APPLICATIONS, AUGMENTED BIO INTELLIGENCE, TEACHERS FOR ROBOTS

1. Introduction

Recently, teaching robots has been popular as “programming by demonstration”; used when kinematics or dynamic models are difficult to be described and programmed in advanced. The robot behaves like a 'puppet' that operator move and manipulate in real time or record its posture in a timeline-based program in offline mode. We propose another type of teaching - by augmenting brain and gesture intelligence. Robots of the future will coexist and cooperate with humans, therefore they have to achieve physical, cognitive, emotional and social intelligence. The Fourth Revolution began with the rapid development of ICT and AI in particular, allowing a new paradigm for communication: by augmenting bio intelligence to robot and vice versa - machine intelligence to human. An innovative approach for Human-robot interaction (HRI) by brain or motion augmentation that help to personalize the communication with humans are proposed and to some extent illustrated in this paper.

Training robots in complex tasks require humanistic intelligence or human-like movements, impossible to be preprogrammed and calibrated in advance since it is personally specific, difficult to obtain due to the dynamic environment in HRI and continuous need of new repertoire. That imposes human intelligence to be integrated into the digital devices and robots that surround us everywhere. But not digitally by pushing a button, clicking, dragging or speaking, but biologically and continuously through emotions, thoughts or intentions [1]. Thus, digital devices will connect to our physical, emotional and mental state and will be able to meet our needs and at the same time learn from us and really become personal [1]. Thus, we can add intelligence through continuous interaction and feedback between the person and the robot, which will be permanently linked to each other, and the intelligence of the robot will begin to coincide with our own. A symbiosis that puts individual human values at the center of future interfaces to digital devices obeying to the ethical and philosophical considerations. If the robot is connected to human biological essence (the part of us that is most related to our individuality is our brain) on the basis of signals from the brain activity the relevant information can be found about current cognitive and emotional states that play an important role in decision-making, adequate behavior and a healthy lifestyle. Nowadays, teaching robots (the learners) in movements is a well-established concept ranging from demonstration by variants of teleoperation, hand guiding and shadowing to imitation by sensors on a Human (the teacher) or by external observations [2]. Sensors used to record the movements are external to the teacher and may or may not be located on the robot learner. Teaching robots by brain augmentation is a new concept with remarkable development since a decade or two ago recording and decoding brain activity by portable devices was science fiction. Sensors used to record the brain activity are located on the teacher. The brain keeps our cognitive and emotional intelligence, it is a rich source of information and our experience, extremely adaptable and manages our actions [1]. However, what happens in our brains and how to measure it is a great challenge. The brain is hidden and protected, and if invasive approaches and expensive equipment have been used so far, portable, non-invasive and affordable EEG devices (based on encephalography) have emerged with a high-quality output signal. They measure the change in brain pulse voltage by means of sensors on the scalp. "EMOTIV" [3] and "NeuroSky"[4] are pioneers in the field, and the signals received are comparable to those of expensive medical EEGs.

Teaching robots by motion augmentation requires the use of human motion capturing systems for extracting the observed poses. Motion sensing devices and technologies like Microsoft Kinect [5] and Leap Motion [6] allow developers to create innovative applications and solutions that allow users to interact naturally with digital technologies. Leap Motion, the world’s most powerful hand tracking, builds a more human reality, really immersive, where Virtual Reality might start with your or robot hands.

The concept of added brain intelligence will also evolve into technology to increase brain capacity and will change our experience and skills in the future by increasing our memory or even communicating with each other by thoughts faster and smarter. Machines learn from information while we learn from experience, so if the information is processed from the robot, we will overcome the massive masses of data avoiding to be overwhelmed by information. Robots will process data and give us the essential and “experience” and this will inevitably affect the health of future generations. Moreover, for people who have suffered from an accident or illness - such brain-machine interfaces will replace lost functionality using emotions, facial expression, and thoughts.

How to teach social or mechanical robots? According to Wikipedia - a social robot is an autonomous robot that interacts and communicates with humans by following social behaviors and rules attached to its role. So, a new profession should be established into near future – teachers to teach robots. Those teachers should be aware with social skills and roles. From technical point of view the
teachers should be aware with system architecture and system-level view, with the SDK for the technology, how to set up configuration options for the services and how to program the motion-sensing or brain-listening controllers, etc. From developing point of view they should be aware with software algorithms how to process the signals from the brain over time together with machine learning algorithms in order to find relevant information about current emotions, thoughts or intentions that have to be translated into commands for the robots sensors and teletype printing or speech generators. Software algorithms that analyze the Kinect skeleton stream data and identify the 3D positions of body limbs over time with inverse kinematics is an attempt a kinematic model of the robot to be recovered and to be an input for the kinematic modules of the robot.

Thus, we propose a new concept for human–robot personal communication by augmenting bio intelligence to robot and vice versa - machine intelligence to human. The proposed innovative approach for learning intelligence and gestures by imitations of robots by brain augmentation captured by Emotiv brain-listening headset and human poses tracked by Microsoft Kinect motion-sensing device are illustrated and partially implemented in projects METEMSS [7] and Robo-academy [8].

The proposed EMOTIV-NAO framework, combining the BCI with the APIs of the NAO robot, is enough general and could be used for different cognitive tasks or other EEG-based controlled systems that can bypass conventional channels of communication (i.e., muscles) to provide direct communication and control between the human brain and physical devices by translating different patterns of brain activity into commands in real time [10]. With these commands a mobile robot can be controlled or can serve as an assistant of child or a therapist in a joyful skills-learning environment by imitation. Proposed, developed and tested by experiments is an innovative model for development of brain-robot game for learning skills by imitation to help the child to become more emotionally engaged with the social world. The brain activity under consideration is the blinking rate in time that provides a way to monitor the attention and social engagement by measuring blinking on NAO’s eyes because children with autism avoid eye contact. The authors in [11] reviews the deployment of EEG based control in assistive robots, especially for those who in need and neurologically disabled. They describe the methods used for (i) EEG data acquisition and signal preprocessing, (ii) feature extraction and (iii) signal classification methods.

In the proposed system we use EMOTIV Insight Brain Activity Tracker with 5 electrodes and 2 referenced to record EEG signal. It is a 5 channel, wireless headset that records and translates human brainwaves into meaningful data you can understand. In the current project we use 1 of them on the forehead to construct a Brain-Computer Interface (BCI) to control the NAO eyes led sensors through wireless interface. First, EEG signals were filtered in order to extract the different brain rhythms (δ, θ, α, β), so that the different frequency bands were individually analyzed, as well as combined together. The existing EEG based biometric systems are classified to the employed acquisition protocols in terms of cognitive task, the number of electrodes and their spatial configuration, the feature extraction algorithms, the classification algorithms and their effectiveness in clustering the observations [11]. For example, Fig. 2, shows an examples of Delta, Theta, Alpha, Beta, and Gamma waves acquired through the channel O2 using a “rest state with closed eyes” protocol.

We considered different channel configurations to obtain the most reliable acquisition protocol using the AF4channel. Then, we extract the features for eye-blinking from EEG signals as the ratio between the power of Theta and Alpha rhythms. We map the changing of this peak to parameters of eye-LEDs that mimic NAO blinking in order to control NAO’s eye-LEDs in ALLeds module on the robot side.

Fig. 1 Assistive technologies in METEMSS [7]

Fig. 2. Taken from [11] - Delta, Theta, Alpha, Beta, and Gamma waves acquired through the channel O2 using a “rest state with closed eyes” protocol

The proposed EMOTIV-NAO framework, combining the BCI with the APIs of the NAO robot, is enough general and could be used for different cognitive tasks or other EEG-based controlled mobile robots.

2.2. Training robots in human-like movements

Human-robot interaction by gestures personalizes the communication with humans in various contexts, from daily life to special educational needs. Human-like movements in gestures can’t be pre-programmed explicitly since the localization and motion planning of humanoid robots relies on dynamic/kinematic models, which are not always available or difficult to obtain due to the dynamic environment in HRI. Since, the marker based motion captured systems for extracting 3D poses over time are expensive
and require careful calibration, a lot of work has been studied for imitation by external observations for extracting 3D poses from an image sequence. Sensors used to record the movements are external to the robot and may or may not be located on the robot learner. We propose in [12, 13, 14] different innovative approaches for teaching robots to imitate gestures. In [12] we integrate Kinect motion-sensing device and controller with direct feedback from an originally developed angular displacement sensors mounted in an artificial anthropomorphic robot hand. The robot learns by external observations of the 3D teacher poses captured by Kinect. We analyze the Kinect skeleton stream data and identify the 3D positions of upper body limbs over time. Inverse kinematics algorithm for calculating the corresponding joint angles for each pose and decomposition into a per-frame algorithm and a method for optimal control of joint motors by position in a lack of a dynamic model is found. More details for the proposed, developed and tested by experiments models for teaching robots to imitate gestures can be found in [12] and [13], where two different prototype of artificial hands were designed and tested. Processing Kinect body data to solve Inverse Kinematics task for teleoperation of humanoid robot NAO is presented in more details in [14]. We Kinnect body data to solve Inverse Kinematics task for teleoperation of humanoid robot NAO is presented in more details in [14].

3. Training robots by body parts guiding and shadowing labelled and tailored to bio signals

This section illustrates how to teach by animation programmable robots in complex movements by body part guiding and recording in timeline mode. The illustration of steps are for NAO robot with Choregraphe [15] - a multi-platform desktop application, allowing teachers to create animations, behaviors and dialogs, test them on a simulated robot, or directly on a real one, monitor and control NAO and enrich Choregraphe behaviors with own Python code.

In Choregraphe you can use an ‘Animation Mode’ for Training robots by body parts guiding and shadowing. In the ‘Animation Mode’ you create movements easily, in conjunction with the Timeline Editor. In this mode, the robot behaves like a puppet that you can manipulate, letting you record its posture in a Timeline. In this mode, tactile commands help you manipulate the robot. You can use tactile commands to manage the stiffness. A visual feedback let you know which limb is currently stiffened or not. Yellow means that the Stiffness is ‘On’. Green means that the Stiffness is ‘Off’. Use Stiffness-control tactile commands to manipulate its limbs one by one in order to make the robot take the posture you want to store. When you change the real NAO position, you can see that the virtual 3D NAO changes position too. To move joints of a simulated robot, using the Limb properties that allow you to check and modify the joint values (and then move the limbs) using the Limb properties. This panel enables you to modify the joint values of each limb and allows you to adjust the joint value. You can move it, as well as enter a value in the associated text box. The robot tries to reach the command value with its joint as soon as possible. At each steps you have to save the defined values in the currently opened Timeline box [15].

We propose during the animation to decompose the desired movement in order to use switch case over the single motions. For instance, you teach your robot in complex movements, however you would like to use script to switch them depending on daytime, accessibility, task to do, obstacles at home/office, brain activity, emotions and intensions. Thus, you need to run a Python script to access a Timeline object. In Python load and unload events methods automatically are called when the box is loaded or unloaded. Resource list used in the Choregraphe Timeline box (as shown in Fig.4) in Python method “onResource” is called when the resources of the box are set to Callback on demand and the resources are asked by another box. You need to define resource functions for it to be called.

The choreographies tailored to songs in the project METEMSS [7] are an example how to adapt to the style of dance that fits the target groups.

4. Training teachers to teach robots

The proposed from us new paradigm for augmenting bio intelligence to robot and machine intelligence to human requires a change in the way how robots to be trained. This imposes a new profession “teachers for robots” to be appeared in a near future. It is most natural for our community programmers to be assigns to do this by going through additional training. What additional skills are required and how to teach social or mechanical robots? Robot communicates with humans obeying to rules attached to its role. So, teachers should be aware with skills and roles. Since the robots will work at the same workplace and coexist with people and other robots, they need to socialize. Robots must comply with ethical and legal norms. Asimov’s three laws for the behavior of robots are a good basis for the development of a modern legal normative base. They have to be “implemented” in the teaching process but not only. The perception of “good and bad” for people and robots is different. Additional training of teachers for generic guidelines for robot behavior is imposed by the greater ubiquity of robots.

Another point of view could be seen in [16], where authors make a concrete, operational proposal as to how the information-theoretic concept of empowerment can be used as a generic heuristic to quantify concepts, such as self-preservation, protection of the human partner, and responding to human actions. They focus less on how a robot can technically achieve a predefined goal and more on what a robot should do in the first place. They are interested how a heuristic should look like, which motivates the robot’s behavior in interaction with humans. They present proof-of-principle scenarios demonstrating how empowerment interpreted in light of these perspectives allows one to specify core concepts with a similar aim as Asimov’s Three Laws of Robotics in an operational way. Significantly, this way does not depend on having to establish...
an explicit verbalized understanding of human language and conventions in the robots [16].

Robot teachers must have sufficient knowledge of the technical specifications and robot services. They need to apply appropriate syllabus and teaching through appropriate programming tools. Robot training methods today are at an early stage of development. One is the teaching by imitation, which is specifically and partly offered in the present work. It is illustrated in terms of imitation of some human movements that are reproduced by a particular robot. This approach will continue with respect to all movements and imitation of human behavior in different conditions.

Where the training should take place? Probably in specialized services and / or in "robot schools". The future development of robotics will impose not only new rules and legislations to be created but also engineering knowledge, practical manuals and training syllabuses.

5. Conclusions

The main contribution in the proposed paper is the innovative model how to augment to robots physical, cognitive, emotional and social intelligence and vice versa experience and memory to humans. We describe and demonstrate the potential of the EMOTIV-ROBOT and KINECT-ROBOT frameworks for providing a natural interface to teach robots by imitation to perform mechanical and social tasks that are impossible to be preprogramed and calibrated in advance. At the same time, the proposed from us new paradigm for augmenting bio intelligence to robot and machine intelligence to human requires transformations in the way how robots to be trained. The learning of people how to teach robots and appearance of new profession "teachers for robots" is inevitable. These teachers should take additional training in knowledge and heuristics concerning how to motivate the robot’s social behavior in interaction with humans and updating the Asimov’s Three Laws of Robotics.

Acknowledgments

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Fig. 3. EMOTIV-NAO wireless framework for developing an EEG based brain-robot interface
KEY COMPONENTS OF THE ARCHITECTURE OF CYBER-PHYSICAL MANUFACTURING SYSTEMS

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Abstract: The future of industry contains many challenges. Necessity is to increase the degree of digitization and achieve a new level of productivity. The rise emergence of modern production lines operating in accordance with the concept of Industry 4.0 foresees the creation and implementation of new technologies and the emergence of autonomous production units capable of independent existence within the manufacturing process. They must closely communicate with other elements and cooperate with all the elements in the production process. In this article we describe architecture of theoretical cyber-physical system and give components and technologies necessary to implement a modern enterprise designed according to Industry 4.0 standards.

Keywords: INDUSTRY 4.0, PROCESS, MANUFACTURE, STANDARDS, ARCHITECTURE

1. Introduction

The result of implementing new technologies and new ways of communicating between industrial facilities is the fact that the boundaries between the real environment and the virtual world are being wiped out. New technologies in industry are well known as Industry 4.0 concept or Cyber-physical production systems. The main target of successful application of the concept of Industry 4.0 into practice is the realization of intelligent, interconnected production systems that can dynamically respond to changing conditions during production and are able to vary their physical and logical structure during the work cycle.

Cyber-physical systems are represented by a set of electronic and mechanical components linked to each other by means of sensors and networks that provide intelligent platform for flow and analysis of data (6).

The complexity of these production systems is significant and essential part of modern equipment in addition to physical facilities and operations are software tools to enable research in integration of information and management systems and solving problems in the field of acquiring knowledge (data mining), simulation of production and service processes and logistics systems with the possibility of their optimization, planning and management of production (ERP systems) and business intelligence tools (BI).

Using these technologies, it is possible to create a combination of virtualized production environments to physical - Digital Twins (DT).

2. Architecture of Cyber-Physical systems

Due to the complexity of the industries, design of the structure of intelligent factory must meet a number of criteria and consider the applicability in different sectors and different types of manufacturing processes. There are a number of works dealing with issues of structure and standardization in the area of cyber-physical production systems. The work of the authors (12) describes a method of realization through a five-level architecture, referred to as 5C. The proposed model is based on a standardized model that extends with new features. The core of work of authors in article (6) describe the implementation of intelligent manufacturing systems in the Industry 4.0, and define the modern elements necessary for the existence of such production units. Several different approaches to managing and defining the structure of the CPS is described in article (10), while there are analyzed possibilities of centralized and decentralized management of production processes. In the author's work (1), a categorial and hierarchical framework is proposed in which the Industry 4.0 concept is described as achievable by the continuous and incremental development process, the main parameters of which are automation and intelligence: the intelligent manufacturing system is highly automated at the manufacturing company level and is self-repairing, self-optimizing and self-configuring.

It is clear that the autonomous intelligent manufacturing subsystems and the relationships between them are too complicated to manage human operators in real time. The solution is to control production process using an intelligent software with artificial intelligence using neural networks technology.

Decisions relevant to management in modern factories will be obtained through a real-time simulation that includes all the states, processes and components of the real world. The technology of digital twins (DT), virtualization and simulation of processes in a virtual environment is an important aspect in the management of production systems. By using DT, it is possible to predict the machine settings and parameters in a simulation environment in the virtual world, whereby switching to a different product (any change in the production process) allows the devices to be set up to configuration based on simulations in the virtual world. This approach significantly reduces machine setup times, improves quality and prevents malfunctions and outages (11).

In the pyramid model (Fig. 2) is assumed architecture of the manufacturing enterprises realized in accordance with the Industry 4.0 concept represented by layers, where the lower level consists of intelligent sensors and regulators interconnected by IoT technology (12). The process of obtaining accurate and reliable data from devices and their components is the first step in the implementation of cyber-physical system. Data can be directly measured by sensors in the production process or obtained from management or enterprise production systems (ERP, MES).
Because these are data representing a number of variables of different kinds (time dependent / independent), it is important to choose a suitable method of interpreting the measured data and to select the appropriate form of recording. As a result of the ever increasing use of sensors and machines in the network, it results in the continuous generation of a large data volume (Big Data) (3). For processing of such amount of data are used special techniques and technologies and proper processing and evaluation of these data is very important for softness and quality simulation model twin digital production process.

3. Technology platforms in Cyber-Physical systems

Based on the above information, we can summarize the components and technologies necessary for the implementation of a modern enterprise conceived in accordance with Industry 4.0 and exploiting the potential offered by the proposed technology (6). The future of flexible production and Cyber-physical manufacturing is the use of all modern approaches, communication between all components and the autonomy and intelligence of all elements in production.

- Advanced (autonomous) robotized production lines maximize efficiency, modern technology, accuracy and speed of production are an essential element in the implementation of CPS
- Autonomous supervisory/service mobile units (drones with camera system or handlers to carry light objects)
- drones are easy to use as independent mobile supervisory units (equipped with a camera) or as highly mobile transport units with the appropriate equipment for the transfer of objects
- Industrial 3D printing
- technology of 3-dimensional printing (additive manufacturing) is able to provide a high degree of efficiency and variability in the production of a wide range of products. By creating 3D objects based on data from materials such as plastic or metal, it is possible to create complex, easily customizable products whose design is impossible to carry out with classic production techniques.
- Autonomous traffic units (autonomous carts and manipulators)
- ground handlers and vehicles for transporting heavy loads are forming a connection between the individual modules of CPS
- Intelligent management and control system
- central management and control of all production processes and units must be implemented in such a way as to eliminate the possible errors in the management of complex and time-dependent production processes. This presupposes the exclusion of classical control centers with human service. Manufacturing and manufacturing processes should be managed by an appropriate intelligence management system with an ERP and CRM connection management interface.
- Distributed communication systems – sensor networks + IoT
- all objects in the production process have to communicate with the control system wirelessly. Together with the sensor system they create an information data network. Based on these data, the central management system is able to analyze production procedures and processes and optimize them to achieve even greater production efficiency.
- Intelligent final inspection - 3D scanner
- an intelligent control system that accurately identifies the parameters of complex elements and products through a set of cameras camera and 3D scanner.
- Augmented operator
- in the case of excessively complicated manufacturing processes, the physical capabilities of human staff need to be improved using an additional technical solutions
- Energy-efficient production
- a modern manufacturing enterprise must use renewable energy sources such as solar panels, energy passive buildings, recycling of raw materials and the like.
4. Conclusion

Modern manufacturing facilities of future are represented by highly automated production lines including sophisticated management and control computing systems. However, the manufacturing process is still dependent on the operators. The future lies in a combination of increasing device autonomy, applying new technologies and improving operators’ capabilities, plus increasing the interoperability of all elements.

Fig. 4 New technology in future factories

In addition, it is necessary to improve interaction in the man-machine context, not only by enhancing and introducing smart technology on the machine side but also by the human abilities, possibly using other electronic specialized circuits implemented directly at the operator. Together with virtualization technologies (predictive simulation), the aforementioned possibilities offer interesting perspectives on the management of production processes in the upcoming period.

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PARTICIPATORY SYSTEMS – A PARADIGM SHIFT TO ANSWER THE CHALLENGES OF AN INTEGRATED WORLD

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Abstract: The increasing integration of technology and everyday life creates a new set of challenges in multiple fields. The fully connected world, in which virtual and physical layers interact seamlessly is a goal envisioned and pursued by many, yet there are some major obstacles in the way of achieving it. One of the fundamental differences between previous systems and the envisioned solution, from information technology point of view, is the diffusion of the roles of service providers and consumers. Traditional solutions, with fixed roles and abstracted physical layers can be too rigid to address the arising challenges. In order for these systems to work, they have to be vastly more scalable and account the physical layer too in the system architecture. In this paper, we investigate and show some examples and notable works on a possible solution to these problems, the field of participatory systems. In a participatory system, the roles of client and service providers are diffused, clients are working together as an integral part of the system, pooling their resources and providing services among themselves.

Keywords: PARTICIPATORY SYSTEMS, VOLUNTEER COMPUTING, SOFTWARE SYSTEM ARCHITECTURE, IoT

1. Introduction

The concept of participatory systems has a long history in computing. The considerable amount of unused computational resources, residing in the hardware of the client has inspired many to search for ways to utilize it. One of the natural consequences of this idea led to the emergence of volunteer computing systems, like BOINC [1]. These systems used the computational resources of their clients, like ordinary desktop PCs to pursue specific goals, primarily scientific ones. Uses of these systems included tasks like protein folding, radio signal analysis and the search for Mersenne primes. These systems are usually unique, dedicated to a single problem and have a limited lifetime, bound to the solving of that specific task. Although they serve different purposes, they often have a common technological basis, for example the aforementioned BOINC platform provides the technological background for several different projects.

Another approach to utilize the resources of clients is to use participatory methods to augment the capabilities of a ‘live’ system. This approach could be taken even further, clients could become the sole providers of a service, which would offer significant advantages. Even with the limited approach, the inclusion of clients actively participating in the system would achieve a certain amount of self-scaling. The more clients joining and participating, the greater the capabilities of the system becomes. An architecture designed according to these principles would solve many of the greatest technological challenges in a fully connected world, for example the sheer scale of these systems.

The goal of this paper is twofold, in the first part we provide an overview about the state of the field of participatory systems by showing a possible classification method based on our previous work [2], providing examples for each class. Then, in the second part, we focus on open problems in the world of IoT and integrated solutions, where participatory methods could prove to be advantageous. Finally, we outline some research directions for participatory systems, worth pursuing to achieve these goals.

The structure of this paper is dictated by these two goals, after this introductory section, we delve into the overview and classifications of participatory systems in the second section. Here we show the classification methods and examples for each class. In the third section, we discuss the open problems and use-cases where participatory methods could be of use. Finally, we wrap the discussion in the last part, where we reiterate the topics covered and outline some future directions.

2. Classification and examples of participatory systems

Definition: A Participatory System is a system which provides services to its clients with active participation on their part. In a system like this, clients are working as an integral part of the whole providing services themselves, among themselves.

Strictly to the definition a great deal of typical information systems could be classified as participatory, in essence one could say that the quality of the activity requirement from clients is the determining factor. In order to narrow the number of possible candidates we establish some classification parameters. For each of these parameters, we show some examples to demonstrate how different solutions behave.

The first consideration for classification is from the perspective of clients, the second we investigate is from the direction of the goals followed by the system. Finally, we will look at the systems from a technological a technical standpoint.

2.1 Clients

When looking at the classification problem from the perspective of clients, we intend to determine the effects of the characteristics of participating client on the system. We could ask questions like; Are participating clients a mandatory part for the operation of the system or they just enhance the system capabilities? Are there multiple roles of clients, or every client can be considered the same? When referring to client participation, do we mean the client machine or the actual person sitting behind the desk? In the following, these questions are investigated.

2.1.1 Client Driven and Client Enhanced systems

A participatory system can be either client driven or client enhanced. A client driven system requires the active participation of its clients to provide service, a client enhanced system can serve non-participating clients in itself, while adding new clients improves the system’s capabilities.

A good example for a client driven system would be a completely distributed peer-to-peer file sharing system. As a concrete example one could look at the tracker-less version of the BitTorrent protocol. In this example, every client is equal in the system, their goals are the same and without their participation the system would be purposeless.

For a client enhanced system, we could take the example of a peer-to-peer streaming solution, where clients share the data among themselves [3]. In these systems, usually there is a primary source of content (e.g. a centralized server) and clients who want to access this data. By having the clients share the data they receive, the load on the centralized server can be reduced significantly. This approach has already been adopted by the industry in the form of peer assisted content delivery networks, for example Peermesh [4], Peer5 [5] or Swarmify [6].
2.1.2 Homogenous and Heterogeneous client roles

Another classification point would be the characteristics of client roles, there are homogenous and heterogeneous systems when looking at these roles.

In the first case, clients are a homogenous group from the perspective of their roles filled in the system. Each client interacts with the system the same way, consumes its services and actively participates in providing them to others.

In case of a heterogeneous system, there are more than one group of clients. E.g. one group may participate in service provision, while others could only consume the said service.

Volunteer computing systems, for example the previously described BOINC bases solutions, like SETI@Home [7] or Folding@Home [8] are heterogeneous systems. In these cases, there are two groups of clients. One of them is the group of participating clients, who willingly dedicate their computational resources to achieve a greater computational capability for the system. The other group is the group of end users, who provide the tasks for clients to solve and use the results for their own purposes.

For a homogeneous system example, we could look at the previously described file sharing system. In a system like that, every client has similar purpose and each of them participates to achieve it.

2.1.3 Interactive and Non-interactive systems

An important consideration for classification is whether the actual human client must participate or not. This interactivity is usually determined by the main purpose of the system, e.g. if the service is request oriented, it often includes interaction.

When the participation requires active human interaction, we talk about an interactive system. This interaction could mean a simple acknowledgement or could be a more challenging task. Often the purpose of these systems is to solve human intelligence problems, which usually have no known perfect algorithmic solution. Examples usually involves exploiting the pattern recognition strength of the human brain and could include tasks like media categorization and tagging, visual processing of satellite imagery [9] or text digitization.

On the other hand, a non-interactive system does not require the active participation of the human client to work, neither it requires their knowledge or their consent. Usually these systems work in the background to improve the service level of a system, like the previously discussed peer-to-peer content delivery platforms, but there are also some less reputable real-world examples.

Strictly to the definition, one could say that bot-nets and cryptojackers [10] (browser based crypto currency miners hidden from the user) are some real-world examples for non-interactive systems.

2.2 Goals

Another possible point of examination are the goals of the system; they play a key role in determining the characteristics.

The key questions one could ask regarding the goals could be stated as the following: Is the end goal of the system a one-time event, or is it an ongoing purpose, like providing a service? Does the system rely on purposefully participating clients, or just opportunistically uses their resources to further its goals?

2.2.1 One-off and Continuous services

One could also examine the end goal of the system, whether it’s a one-time task that can be completed, or it’s a continuous task, integral to the system.

In the first case, if the goal can be fulfilled, we talk about a one-off system. In this case, participants are solving parts of the task, or different tasks possibly leading to the desired solution. If this solution is reached, the system’s life-cycle ends.

A great example for a one-off solution would be the BOINC based volunteer computing system set to solve the minimum sudoku problem [11]. In this case, the question was the following: what is the smallest number of clues (filled numbers) that a Sudoku puzzle can have? The answer that was proved by the system was 17.

The other option, continuous services are more common, both the previously discussed peer-to-peer content delivery systems and the radio signal analysis done by SETI@Home are ongoing, continuous services, aimed at different clients.

2.2.2 Opportunity driven and Purpose driven systems

From the perspective of initiative, one could distinguish opportunity driven and purpose driven systems, the main difference being the context in which they use their client’s resources.

Opportunity driven systems profit from the participation of its clients whose original goal is the consumption of the provided service. On the other hand, purpose driven systems assume its clients are willingly participating to reach the end goal itself.

Volunteer systems, by their nature are always purpose driven, this behaviour is the more common of the two classes. Examples in this case would include grid computing and CPU cycle scavenging systems, like project Bayanihan [12].

As an opportunity driven system a good example would be the case of reCAPTCHA project [13]. In this system, the clients are consuming a primary service, the security gateway intended to protect a resource from autonomous requests, while in the meantime the participants help with the digitization of written text or images.

It’s also feasible to employ primarily purpose driven use-cases, like the running of massively parallel computations in an opportunity driven fashion, which would improve the proliferation of such systems, as described in our previous work [14].

2.3 Technology

From a technological standpoint, we consider the resources contributed by the clients to the system as the prime point of discussion. Client technological characteristics have a determining effect on both system architecture and capabilities. In essence the question on could ask here would sound like this; what does the client contribute?

2.3.1 Computational systems

In a computational system clients are pooling their resources to create a larger, more potent system in terms of computational power. These systems are best employed when working on embarrassingly parallel problems, e.g. running simulations, solving cryptographic problems, or running certain machine learning algorithms.

It is a proven fact by previous works in the field - some discussed earlier, that the capabilities of these solutions are significant. In 2007, the computational capacity of the Folding@Home project superseded the world’s largest supercomputer's performance [15] at the time, and continued for four years.

In most of these computational systems, the original problem is partitioned to smaller tasks, which are assigned to the clients and executed in parallel. When finished, the client uploads the result to a central server which aggregates them.

For reliable results, this mandates the presence of additional security measures, such as redundant calculations to avoid malicious clients providing false solutions. As a consequence, the central component’s complexity and required capacity could be impacted negatively.
2.3.2 Distribution systems

Distribution systems focus on providing data as a service to all of its clients. In a participatory way, this is usually achieved with direct client to client (peer-to-peer) connections. Usually in this case, each client can request data either from the central server or other clients. In theory, the more clients the system has, the greater the ratio of clients distributing the data among themselves, hence less load on the central component.

An example for a participatory distribution system would be the previously mentioned peer-to-peer streaming solution. In this case the goal of the system is to provide each client with an acceptable level of service (i.e. enough data in a timely manner), while minimizing the impact of growing client traffic on the central component.

A more interesting class of distribution systems are information sharing systems, where the information is bound to the clients themselves. This may either be caused by the information originating from the clients themselves, for example if it’s based on a geographical location. An information distribution system’s aim is to provide the relevant information to the interested parties (i.e. clients interested in a geographical area receive information from other clients located there). Good real-world examples here would include community driven navigation software, such as Waze [16].

2.3.3 Sensing systems

A sensing system is another special kind of participatory system, where clients are building larger sensor networks, usually aimed at collecting data from a geographical area.

The field of participatory sensing [17] or crowdsensing [18] deals with these kinds of systems and they are already being adopted by the industry.

While by strict definition we consider all sensing systems participatory, we should make a distinction between sensory networks made up of relatively intelligent, participating clients, such as smartphones and simple distributed sensor networks.

3. Potential uses of participatory methods

The basic concept of a system and its interaction with the users in integrated world is close to what we described as a participatory system. In this case integration means the closing of the gap between physical and virtual layers, making the system boundaries less clear, involving the clients in the actual process is a goal.

Participatory methods are becoming more important in this environment, as this level of integration provides new challenges. Methodologies used in purely virtual or lightly integrated systems can become insufficient at this scale.

In this section, we identify some key aspects and scenarios, where participatory methods offer potential advantages over previously employed practices.

One of the inspirations for grouping the problems in this section was the work of John A. Stankovic's on "Research Directions for the Internet of Things” [19].

3.1 Scaling

Maybe the largest problem with the concept of a fully interconnected world is its scale. The traditional client-server architectures used currently in most information systems are simply unable to scale beyond a point. An alarming indicator of how insufficient the current infrastructure is, is the 2016 Dyn DDoS attack [20], which was the largest of its kind at the time of writing. The relevant aspect of this attack is that it was performed using a botnet made from mostly IoT devices [21]. Experts predict the use of these devices to rise exponentially in the near future, it’s easy to imagine the strain they would impose on current infrastructure.

Answering to the scalability problem with a general solution is not possible. Each individual use-case and system requirement influences the overall system characteristics, sometimes drastically.

What we can do however is come up with some guidelines and key considerations on how to improve scalability, many of them includes the usage of participatory methods.

As opposed to previous large-scale systems, when thinking world scale, it is not enough to provide the large horizontal scaling capability of a system. It’s also imperative to be able to provide the actual computational capacity. While it’s certainly possible physically to simply build more datacentres, it may be economically more feasible to look for other alternatives as the number of clients drastically increase.

Participatory systems could help a great deal in this regard, by utilizing clients to enhance system capabilities, these systems could become self-scaling. By using the clients as service providers themselves, an increase in their number would also mean a larger capacity in the system for serving the said clients. This approach naturally has some limiting factors regarding where it can be used, but the general characteristics of these systems make them a suitable candidate for such solutions.

Novel approaches would be required for some cases where using traditional methods on a smaller scale would be trivial. This task is not insurmountable however, as it was already demonstrated several times throughout history. As recent example, one could look at is the millennium old concept of currency. Currency was re-imagined and recreated in a distributed, yet secure way with the emergence of cryptocurrencies like BitCoin [22]. The task of account keeping and monetary transaction management is one of the source of the original motivation behind the theory of centralized information systems with proper safeguards for consistency and security. Both of these concepts are usually considered the antithesis of peer-to-peer and distributed systems, yet a novel approach with proper theoretical background and innovative implementation could solve it in a satisfactory way.

3.2 Architecture and environment

Heavily related to the scaling, a key difference between the new integrated systems and their predecessors would be the architecture they employ. Previously architecture could be easily separated to virtual and physical components, and each could be evaluated separately. In an integrated system, the components are much harder to separate by this measure.

A key difference however, where participatory methods also come into play is the emergence of a new separating factor; geography. By integrating the virtual and physical world its largely unavoidable to introduce this new factor to the system. It’s necessary for these systems to account for the geographical locations of their clients, as it became a primary client attribute with the close integration.

The geographical aspect however has some fortunate consequences in solving the problems. Similarly to the concept of light cone in general relativity, one could determine the possible dimensions in space and time which would affect the given client when serving a request. This could be used to break up the larger system into smaller chunks, based on client geo-location.

Combining this with the usage of participatory methods, one could turn a centralized, world scale system into a collection of collaborating geographically close clients. For example, a public transportation navigation system could use information shared directly between clients travelling at different locations, without the need for maintaining a centralized service for providing it.

One of the consequences of this approach is that the system would have to be scaled according to the client density instead of the total client number.
Ultimately the base concept of these systems could be summed up as the following: Instead of collecting information to a central place and serving it, each information source serves itself. Clients in these systems turn to information’s source, what is not a centralized role in this case. As information is usually bound to the geographical location this makes a natural grouping of clients.

4. Overview and future directions

In this section, we outline some possible directions worth pursuing in the field of participatory systems and wrap the conversation with an overview of the paper.

4.1 Research directions

One interesting directions to examine would include the modelling of information flow based on geographical locations and its effect on the system. Its worth investigating how clients could discover each other and get the relevant, geo-bound data from the most relevant source.

Another interesting direction would be the investigation of the effects of different client behaviours and characteristics on different participatory systems and possibly set QoS metrics.

4.2 Overview

In the paper we introduced the term of participatory systems, described the brief history of the field and presented some of the more significant related works. We have shown a classification method for these systems, providing examples and possible use-cases for each examined class. We have identified three main classification factors: roles of the participating clients, characteristics of the goals of the system, and technological archetypes.

After that we have shown two major areas in the concept of the fully integrated world where participatory methods could be advantageous; scaling and geographically aware architectures. We discussed the possibility in employing participatory methods to build unprecedented scale systems and compared it to traditional solutions.

We have also examined the effect of client geographical considerations in case of the system architecture. We determined that when the information source is geography based (e.g. depends on the location of the client) we could use participatory methods for the clients to share this information with each other. This would result in a much more scalable system, where the information flow is decentralized.

Finally, we have proposed research direction worth pursuing in the future.

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References


MOVING TARGET DETECTION BY ACOUSTIC FORWARD SCATTERING RADAR SYSTEM

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Abstract. The paper explores the possibility of detection of moving target on the base of their sound shadow (sound blocking) when the target cross the baseline in the Acoustic Forward Scatter Radar System (AFSRS). Experimental sound shadows have been obtained from moving cars. The algorithm under investigation can be applied to create a network of sound barriers.

KEYWORDS: TARGET DETECTION, FORWARD SCATTERING SYSTEM, SOUND SHADOW

1. Introduction

The paper is based on the theory of distribution of sound waves in the airspace and their interaction with moving targets. The idea of this article is to use the sound shadow to detect moving objects crossing the virtual line between the sound transmitter and the sound receiver. In our study, sound receiver and transmitter form bistatic system because are placed in different location, where the bistatic angle between the directions "receiver-target" and "transmitter-target" should be around 180°. This bistatic system is called Forward scattering radar (FSR) system [1]. When the target moves close to the virtual line between the receiver and the transmitter it creates the diffraction of the transmitted signal. In this configuration, the receiver signal is received as a result of the phenomenon of diffraction of sound signals. The Forward Scattering (FS) effect has been studied by many scientists and it is the basis for the creation of different radio barrier systems. In [2], the authors used GSM signals to detect targets. In [3–8], GPS signals have been applied to detect moving targets using the principles of FSR. In [9], the authors proposed the usage of WiFi to detect moving targets by FS principles. Most of proposed technologies are used the principles of FS configuration or split receiver and transmitter and an object passing between them. In [10] are given the normal mode model for a waveguide to analyze the phenomena of forward scattering created by a target crossing the virtual line “transmitter-receiver”, and its physical significance. The experimental results demonstrated the capability of forward scattering detection for slow moving objects.

The diffraction of the sound signals is a well-studied phenomenon and it is similar to the diffraction of the electromagnetic signals. Despite the difference in the nature of the radio and acoustic signals, the shadow effect is present in both types of signals [11]. Such studies have been conducted by the team of this article but with GPS signals, which demonstrated the great potential in this field [3–8]. The purpose of this article is to apply the accumulated knowledge and skills from the field of radio signals in the field of sound signals and as a result to develop algorithms for detecting mobile targets using the sound shadows created by the targets. In this article, one possible algorithm for moving car shadow detection is studied by using the acoustic forward scattering effect.

The proposed algorithm can be used for in automated tracking and traffic management systems in the future smart cities [12, 13]. This algorithm is inexpensive and usable in real-time systems. The resulting audio shadows have specific characteristics and parameters that can be evaluated and used to classify moving objects. This algorithm can also be used to create border or object security systems. Both artificial and natural sources of sound signals as well as background sounds with constant parameters can be used as the sound source.

2. Acoustic Forward Scatter Radar System

Forward scattering system is a special case of bistatic configuration where the bistatic angle is close to 180 degrees. The bistatic angle is the angle between transmitter, target and receiver, as shown in Fig.1.

Fig. 1: Illustration of acoustic forward scattering configuration.

The FSR is based on the Babinet principle, which says that the shadow radiation in the optical case is completely determined by the size and geometry of the shadow contour [1, 2]. Thus scattering on the target with the rectangular cross-section is equivalent to the radiation by a rectangular aperture antenna. This principle is a theorem concerning diffraction, stating that the diffraction pattern from an opaque body is identical to that from a hole of the same size and shape except for the overall forward beam intensity. Diffraction of wave can be divided into two classes: Fresnel diffraction (when the target is close to the transmitter or the receiver) and Fraunhofer diffraction (when the target is far from the transmitter and the receiver) (Fig. 2).

Fig. 2: Sound diffraction.

In Fresnel diffraction, the size of the target is comparable with the Fresnel zones, which takes place when the target is relatively close to...
the receiver or the transmitter. Here, the diffraction pattern varies from high intensities to low intensities as the targets cross different Fresnel zones. These variations will depend on the coverage percentage of one or more Fresnel zones.

Sound waves are affected by the different targets that they come into contact with. For example, denser materials are better at absorbing sounds than thinner ones. Although materials can absorb sounds, they can also reflect and diffract them. Diffraction of a sound is when the wave gets to an object and propagates around it. The phenomenon of diffraction is the basis of the signal propagation in the forward scattering system (Fig. 2). Our first goal is to confirm the possibility of signal blocking caused by moving target crossing the baseline in the Acoustic Forward Scatter Radar System (AFSRS).

Naturally, to ensure the registration of sound shadows the values of the sound signal in the sound shadow zone must be distinct from the noise of the receiver by a few decibels. That’s why we chose to make the recordings of sound signals on a variety of distances, when target are very close to the receiver and are in the sound shadow area. For the simplicity of the experiment, we chose the moving object to be a car crossing the radio barrier.

3. Signal processing

The paper presents a possible variant of signal processing in passive Acoustic Forward Scatter Radar System [11]. The general block-scheme of a possible algorithm for AFSR shadow detection includes: signal decimation and filtration, signal envelope evaluation and signal detection (Fig. 3).

![Fig. 3: Block-scheme of signal processing.](image)

The obtained target signature can be used for estimation of various target parameters in the time and frequency domains. In this experiment, the sound receiver samples the received signals at the sampling rate of 40 KHz. Therefore, the received signal is firstly decimated and next filtered by the bandpass filter in order to remove undesired signals. The next step is evaluation of the signal envelope. For the convenience of detection, the signal envelope is inverted and further is used for target detection by CFAR detector. The CFAR detector is a very important procedure and very often used especially in real systems, because it results in producing of precise target images separated from the existing interference. It is performed by removing clutter from the receive signals using the adaptive CFAR threshold.

4. Experimental results

During the experiments, the sound generator and the microphone are positioned on the two opposite sides of a street. The experiments include moving cars that cross the virtual baseline between the transmitter and the receiver. The acoustic system transmit signal with frequency 5 KHz (Fig. 6). The sound signal registrate at the sound frequency of 5 KHz when car crossing the baseline between the transmitter and the receiver is shown in Fig. 5.

![Fig. 4: Sound recording system.](image)

In this figure, it can be seen the areas with reduced signal power (signal blocking) of the received acoustic signal as a result of this crossing. The sound signal envelope is shown in Fig. 6, where the sound shadows due to the passage of car is clearly visible.

![Fig. 5: Sound record (5 KHz).](image)

During the experiment, both the useful sound signal and other sounds and disturbances are recorded. The spectrum of the recorded signal is shown in Fig. 7, where it is seen that the recorded signal contains a predominant signal at frequency of 5 KHz, but the lower and higher frequencies are interfering.

Through filtering the sound signal with a filter, whose frequency response is shown in Fig. 8, only the sound signal at frequency of 5 KHz is omitted. The filtered sound signal is shown in Fig. 9. The filtered signal envelope is shown in Fig. 10. From this figure can be seen that the sound shadow due to one passing car is well-shaped. A signal envelope inversion is applied before signal detection. The inverted signal envelope is shown in Fig. 11.
Fig. 6: Envelope of sound signal (5 KHz).

Fig. 7: Spectrum of the recorded sound signal.

Fig. 8: Frequency response of the bandpass filter.

From figure 11 can be seen that the sound shadow due to one passing car is well-shaped. The CFAR detector is used to detect the sound shadow and the output of the detector is shown in Fig. 12.

Fig. 9: Filtered sound signal (5 KHz).

Fig. 10: Filtered signal envelope.

Fig. 11: Inverted signal envelope.
Conclusions:

An algorithm for detecting of moving cars crossing the baseline in the Acoustic Forward Scatter Radar System is proposed in the article.

The use of powerful, self-powered sound sources such as AFSRS will allow us in the future to explore the FS effect in the sound range, which appears when objects cross the virtual line between the receiver and the transmitter at very large distances from the transmitter and from the receiver.

The paper provides the opportunity to explore and use information of the audio shadows from sources of sound or noise (like radio shadows) to develop new applications as monitoring and management of urban road traffic.

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References

Abstract: The paper is focused on using computed tomography in forensic research and the performance of computed microtomograph Skyscan 1272. Computed tomography due to its non-destructive analysis of the internal structure of materials can be applied in many fields. This method also provides information on the distribution of fillers, pores, fibers and defects in the tested sample and their 3D visualization using specialized software. Computed microtomograph Skyscan 1272 can be successfully used in forensic investigation of an attacked seals. For example, during unauthorized consumption of energy and water supply, in the tempering with security seals and a consequent theft, in logistics, in the transport of cargo and money, in the counterfeit goods (trademark protection, seals, stamps) etc. Computed tomography is able to verify and detect unauthorized tempering with the security seal, stamps and envelopes.

Key words: computed tomography (micro-CT), 3D visualization (3D model), forensic research, security components

1 Introduction

Computed tomography is a radiological examination method that allows displaying an internal structure of materials using x-ray radiation. CT can be translated into imaging in cuts, in other words displaying the structure without physical disruption of the whole. This method is currently widely used, for example in medicine, archeology, biology, geophysics and many other fields of science. It is based on a mathematical method known as tomographic reconstruction [1]. The resulting image quality is dependent not only on time the data are processes, but also on other factors. X-rays weaken while penetrating various materials. The degree of their absorption is either smaller or greater depending on the density of the material and depends mostly on the properties of the examined material.

This X-ray diagnostics can be successfully applied in forensic examination of a damaged seal in these situations:

- Unauthorized access of energy and water grid – deliberate attack of measuring instruments (water, electric and gas meters), damage to security seals (led, plastic, self-adhesive) in order to eliminate or limit measuring equipment and to illegally withdraw the medium.
- Forensic science – manipulation with security seals in order to enter into secured premises and subsequent theft.
- Logistics, freight and money transfer – manipulation with security seal in order to enter into secured premises and subsequent theft.
- Hunting – manipulation with security seal for the purpose of stealing the game, poaching (in the Czech Republic and in a number of European countries it is mandatory to mark the killed game by a seal with the number of a hunting association on whose territory the game was hunted down).
- Product forgery – brand protection, seals, stamps.

The aim of this article is to present particular equipment of the computer tomography Skyscan 1272 and demonstrate its utilization in the field of forensic science [2].

2 Methodology and means for solving the problem

Using computer tomography, we can easily and nondestructively visualize structures of the observed objects, such as composite materials, tissue, bones, spacer knitted fabric, non-woven textiles, biological materials etc. [4]

![Diagram of x-ray microtomography function](image)

Fig. 1 The diagram of x-ray microtomography function

Figure 1 presents x-ray microtomograph function [4]. X-ray RTG imaging is achieved by the rotation of the tested sample and x-ray radiation emitted under various angles. CCD detection camera is localized opposite of the x-ray emitter. Thin stream passes through the sample and its intensity is detected and transferred into electrical
signals. X-rays weaken while passing through various materials. The degree of absorption is smaller or greater depending on the density of the material and depends mostly on the properties of the examined material [3]. Absorption represents the ability of various substances to absorb x-ray radiation. In case the emitted energy is constant, the absorption of x-ray radiation depends only on the material they pass through. The output of the tomograph is represented by 2D images (cuts).

This method can be used to check the material, localize defects and faults of the inner material structure, material density, relative content of components in different sections of the cut, pore or object distribution, visualization of the examined structures etc. [2].

2.1 Experimental technique
Desktop microtomograph Skyscan 1272 (fig. 2) contains an x-ray emitter with the output of 10 W max, 16 Mpx detection CCD camera, support to fix the sample and a computer terminal. The resolution of the device is 0.5 µm, maximum size of the tested material is 70 mm in diameter and 70 mm in length.

Method of testing the inner material structures is as follows:
Skyscan 1272 scans the object in the form of 2D images and transforms the object into 3D form using specialized software (reconstruction software NRecon). Obtained dataset and scanning results can be verified using program Dataviewer, allowing for detailed inspection of the inner structures of the tested sample from three axes – transaxial, sagittal and coronary. Part of the tomograph is also a software suite for complete 2D and 3D quantitative analysis, for morphometry (measurement of shapes) and densitometry (for the measurement of optical densities of the computed photographic images), for realistic 3D visualizations of the examined objects (creation of 3D models), etc. [4].

2.2 Used materials and methods of measurement
Security components by the company Euroseal a. s. were used for the evaluation and visualization:
- indicative plastic seals of the PL type with wide range of use, manufactured from high quality plastic material,
- plastic seals of the ES type manufactured from high quality plastic material with the addition of metal collet,
- metal cable seals, with body made of aluminum and a seal sealed by metal cable,
- metal container seal made of high quality steel.

One group of security seals was modified in order for the sample dimension to correspond with the required parameters suitable for microtomograph Skyscan 1272. Samples were inserted into the scanner and fixed with rotational support. Scanning process was initiated after setting respective scanning parameters. After the scanning finalization, an obtained 2D dataset was transferred into 3D dataset using NRecon software. Such transformed data were further processed using Dataviewer and CTVox programs. Second group of the selected security seals was exposed to heat, mechanical or chemical deformation. Those damaged seals were scanned and the obtained data processed by special software. Plastic seals were subjected to temperatures of 185 °C and 120 °C or chemically deformed using technical petrol and polyoxymethylen, metal cable seals were mechanically strained by 1, 2, 3, and 4.4 kN. Several obtained images of the undamaged and damaged security seals are presented in the following chapter 4.2.

3 Results and discussion
3.1 Visualization of the undeformed security components
A. Plastic security seals of the PL type

Fig. 3 Plastic security seal of the PL 91 type
Fig. 4 Plastic security seals of the PL 95 type

Scanning parameters for the PL type security seals:

- X-ray voltage 50 kV, current 200 μA, resolution 20 μm, exposition 464 ms, scanning duration 35 minutes.

B. Plastic security seals of the ES type

Fig. 5 Sample of the plastic security seals of the ES type

Scanning parameters for the ES type seal:

- X-ray voltage 80 kV, current 125 μA, resolution 20 μm, exposition 1129 ms, scanning duration 200 minutes.

C. Metal cable seals

Fig. 6 Visualization of the metal cable seals

Scanning parameters for the metal cable seals:

- X-ray voltage 100 kV, current 100 μA, resolution 20 μm, exposition 2130 ms, scanning duration 70 minutes

D. Metal container seals

This security component cannot be tested by the tomograph because of insufficient output of the X-ray. An image provided by the scanner is available.

3.2 Visualization of the deformed security components

A. Thermal deformation of the security components at 120 °C

Fig. 8 A cut through seal of the PL type deformed by heat (120 °C) and a 3D model of the destroyed seal

B. Thermal deformation of the security components at 185 °C
Fig. 9 Photo of a badly damaged seal of the PL 91 type and a view provided by the tomograph into the structure of the security component damaged by thermal deformation (185 °C)

Fig. 10 Photo of the damaged PL 95 type seal and a view into the structure of the security component after thermal deformation (185 °C)

Fig. 11 Photo of the damaged ES type seal and a view provided by the tomograph onto the structure of the security component after thermal deformation (185 °C)

C. Tensile deformation of the security components

Fig. 12 Visualization of the tensile deformation of the metal security components (strained by 1, 2, 3 and 4.4 kN – from left to right)

D. Chemical deformation of the security components

- deformation by the technical petrol

Fig. 13 Seal visualization marked by thermal print and damaged by technical petrol
- deformation by the Polyoxymethylen

Fig. 14 Visualization of the PL 95 type security seal after chemical damage cause by Polyoxymethylen

4. Conclusion
Three levels of examination are applied while examining potentially attacked security seals in order to find out their actual state. The first level is a visual examination, taking place at the location of an attack and doesn’t usually use any other means. The second level is an inspectional examination, which takes place at the location of an attack or in laboratory conditions. It is possible to use other equipment (such as magnifiers, microscopes and reference sample). This research is conducted by specially trained person. The third level is a forensic research conducted in laboratory conditions with a specially trained researcher using special equipment. Conclusions of forensic research can be used as proof during a lawsuit. A sophisticated computed microtomograph was presented here as one of the ways of non-destructive examination, detection and verification of unlawful tempering with security components.

5. References

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ANALYSIS OF OPERATING MODES AND ENERGY EFFICIENT PRACTICES DURING THE OPERATION OF INDUSTRIAL INDUCTION FURNACES WITH NETWORK AND MIDDLE FREQUENCY

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Abstract: Among the main problems of the induction furnaces are the clearly manifested worsened power factor during operation, the asymmetry, the deflection and the variance of the supply voltage in their power supply. Induction furnaces in all their operating modes are a non-linear load with significant and varying consumption of active and reactive energy. Compensation devices are set for the heaviest mode of operation - metal melting. There remains a question of the limits of the low inherent power factor for individual regimes, the size of the penalties for this on an annual basis, and the potential energy saving measures taking into account the possibilities of waste heat utilization. In this connection, the task of implementation of modern optimal management according to predefined criteria is current.

Keywords: INDUCTION HEATING, INDUCTION FURNACES, NON-LINEAR LOAD, POWER FACTOR, ENERGY EFFICIENCY

1. Introduction

Metal casting in the industry is a highly energy-intensive process characterized by a low inherent power factor and wide range of changes in the consumption of active and reactive energy. Achieving high energy efficiency is associated with technical risks associated with disruption of the production process, the application of inappropriate technology, lack of time and qualified personnel and increased capital costs. Energy savings can be realized in two ways - direct savings through lower energy consumption and indirect savings - through less consumption of material resources. Therefore, the goal is to achieve a certain amount of quality output with less energy and fewer raw materials. In order to do this, energy and material flows in the metal casting process should be explored and understood.

2. Research tasks

The object of the research and analysis is the operation of two induction furnaces (IF), one operating at a network frequency \( f = 50 \text{Hz} \) and the other one with an middle operating frequency \( f = 250 \text{Hz} \). One of the advantages of the crucible furnaces is the short melting times due to the high specific power, with the minimum melting times of the metal depending on the frequency [1].

It is known that the energy emitted by the inductor depends on the frequency of the current, the ratio between the geometric dimensions of the crucible and the inductor, the dimensions and the electrophysical properties of the melting material. There are dependencies between the required thickness of the pipe walls of the inductor \( \Delta_i \) and the size of the pieces of burst material from the operating frequency. Recommended at operating frequency \( f = 50 \text{Hz} \), \( \Delta_i = 13 - 20 \text{mm} \), and the pieces dimensions have to be \( 200 - 350 \text{mm} \). At operating frequency \( f = 250 \text{Hz} \), \( \Delta_i = 2 - 4 \text{mm} \), and smaller pieces sizes - \( 150 - 2000 \text{mm} \) [2, 3].

The dependences of the inductor’s energy on the size of the crucible and the electro-physical properties of the process are of great importance for the operation of the induction furnaces in terms of their power supply and efficient operation. Changing the temperature of the metal pieces in the crucible changes both their geometrical dimensions and the contact area between the individual pieces, as well as their magnetic permeability and their specific electrical resistance. This dependence determines a continuous change in the energy emitted by the inductor and requires a flexible control system that ensures that optimum process parameters are maintained throughout its duration. The electrical parameters through which the metal melt process can be controlled are the magnitude and frequency of the supply voltage. Failure to comply with certain conditions in the construction and operation of the crucibles may result in severe accidents which will remove the furnaces for a long time and create an immediate danger to the service personnel. The principle of inductive energy transfer requires, if possible, the smallest wall thickness of the crucible, since it decreases the electrical efficiency factor along with its increase [4]. This thickness cannot be reduced below certain limits in order not to shorten the life of the crucible and to break through. Every 120-150 melts the crucible is heated up and imbed again according to strict requirements followed by sintering. Induction sintering is a process of switching on and off the furnace at a minimum power to achieve a rate of increase in temperature \( 100^\circ \text{C/h} \) to reach a temperature \( t = 800^\circ \text{C} \). Then, increase the rate of temperature rise to \( 150^\circ \text{C/h} \) until the temperature reaches in the crucible \( t = 1000^\circ \text{C} \). The sintering temperature is then maintained for 1-2 hours at \( 50^\circ \text{C} \) above the working temperature, after which the metal can be spilled.

3. Measurements and results obtained

Data of the induction furnaces with network frequency research

The object of the analysis is the operation of the TDM 3150-20 induction furnace with operating frequency \( f = 50 \text{Hz} \), rated power \( S_N = 2500 \text{kVA} \), 9-degree adjustment of the capacitor battery, capacity of the furnace - 10 t. At the beginning of the melting, when the molten metal is in a smaller quantity and the burden is still solid, all the stages of the capacitor bank are included. As the melting speed increases, some of the capacitors are turned off. The main disadvantage of these furnaces is the low melting speed and the need for symmetry to increase the efficiency of the furnace. Therefore, these furnaces are always allowed to work with a ‘marsh’, that is, leaving molten metal from the previous melt. The most economical mode of operation occurs when 25% - 35% of the molten metal is left. Then the duration of the melting is reduced to 1.5 - 2 h, with an energy consumption of 500 - 800 kWh / [5, 8]. According to the aforesaid dependence, when left over from the previous melt ‘marsh’ 10, 25 and 40%, the power of the furnace required for the next melting process is reduced by (0.25; 0.48; 0.65) \( S_N \). The electrical supply of such furnaces is carried out with the so-called Steinmetz scheme. Due to the low natural power factor, compensation is a must and should not be interrupted during the melting process. Since the consumption of active and reactive energy during the melting process is highly variable, therefore the symmetrical power needs to be altered by a similar load schedule.

Measurements of active, reactive and full power, consumed by the furnace in basic and finishing mode have been carried out. The duration of the process is 6 h. 25 measurements have been carried out, Fig. 1. For the purposes of the research, data from electric
meters with specialized software EMH-Combi Master 2000, [6] are available for graphical representation of the current state of the network (current and peak current and voltage values, active, reactive and full power, power factor, frequency, load schedules).

![Graph showing active and reactive powers](image1)

**Fig. 1.** Active and reactive powers of an industrial-frequency furnace in basic and finishing mode.

![Graph showing voltages and currents](image2)

**Fig. 2.** Voltages and currents of the main-frequency furnace in basic mode.

**Data of induction furnaces with middle frequency research**

This kind of furnaces are mostly used for smaller parts and cold bent steel materials. Compared to induction furnaces with a mains frequency, these furnaces have a higher melting speed at the start of the solid burden process, therefore cos$\phi$ is easier to adjust.

The object of the analysis is the operation of the same type of induction furnace TDM with operating frequency $f = 250$ Hz, rated power $S_N = 2 \times 2505$ kVA, with thyristor rectifier and inverter, capacity of the furnace – 7.5 t. The furnace is controlled by changing the unlocking angle of the inverter thyristors. The researches have been carried out for the following furnace operating conditions: sintering mode - 16 h 30 min, 70 measurements recorded, Figures 4 and 5; basic melting and finishing mode with "marsh" 40% with duration 3 h 15 min, 15 measurements recorded, Figures 6 and 7; basic melting and finishing mode with "marsh" 10% with duration 3 h, 13 measurements recorded, Figures 8 and 9.

![Graph showing active and reactive powers](image3)

**Fig. 3.** An unbalanced induction furnace with a network frequency.

![Graph showing active and reactive powers](image4)

**Fig. 4.** Active and reactive powers of an induction furnace operating with middle frequency $f = 250$ Hz observed in sintering mode.
Fig. 5. Modification of power factor in sintering mode and penalties for bad \( \cos \phi \).

Fig. 6. Active and reactive powers of induction furnace with average frequency in the basic mode and finishing with ‘marsh’ 40%.

Fig. 7. Modification of power factor in basic mode and finishing with ‘marsh’ 40% and penalties for bad \( \cos \phi \).

Fig. 8. Active and reactive powers of induction furnace with average frequency in the basic mode and finishing with ‘marsh’ 10%.
During the setting of the sintering increases to an average value
which is advantageous time for performing compensation and carry out furnaces operation with a mains frequency is the most the range 1300-1500 supply voltage during this mode changes to small limits (varies in operation about 70-75%, which includes this first stage. The amount of electricity consumption is in the basic mode of the metal from the crucible. Thus, it is clear that the greatest crucible furnace with a thyristor converter is minimal. Fragrant temperature and then cos increases, but not enough, because the deflections occur in emergency situations, Fig. 11. This is not the case when using more power at the remaining ‘marsh’ 10%. Total energy consumed for melting and overheating is increased to 3520 kWh, hence about 521 kWh / t of molten metal. Consequently, the specific furnace power drops by 25.4%. In the ‘marsh’ 40% is used almost 55% of the power through the basic mode is maintained average $\cos \varphi = 0.72$. With a ‘marsh’ of 10% this process is maintained with a higher power output of about 70%. During the first stage of the process, $\cos \varphi$ increases to an average value for the basic mode $\cos \varphi = 0.88$.

In the third stage: duration 1.5 hours (about 90 minutes) in this case and active power 380 kW.

The energy required for melting and overheating is 3141 kWh, hence about 698 kWh / t of molten metal - a relatively high value of the specific power. This is not the case when using more power at the remaining ‘marsh’ 10%. Total energy consumed for melting and overheating is increased to 3520 kWh, hence about 521 kWh / t of molten metal. Consequently, the specific furnace power drops by 25.4%. In the ‘marsh’ 40% is used almost 55% of the power through the basic mode is maintained average $\cos \varphi = 0.72$. With a ‘marsh’ of 10% this process is maintained with a higher power output of about 70%. During the first stage of the process, $\cos \varphi$ increases to an average value for the basic mode $\cos \varphi = 0.88$.

If there is a very good symmetry achieved of the furnace with a network frequency (which leads to a high $\cos \varphi \geq 0.9$ ) there are no financial penalties.

4. Conclusions

The load asymmetry in the operating modes of the induction crucible furnace with a thyristor converter is minimal. Fragrant deflections occur in emergency situations, Fig. 11. This is not the case with the power factor. Data analysis shows that drying (sintering) mode is the most severe mode of influence on the power supply and power system due to the deterioration of the power factor. In the case at hand it varies $\cos \varphi = 0.15 \div 0.19$. During the setting of the sintering temperature and then $\cos$ increases, but not enough, because the power supply becomes smooth and reaches only 40% of the installed one. From the load schedules, it is observed that during the induction melting process there is a strong uneven consumption of active electrical energy. The same applies to the the induction melting process there is a strong uneven power factor. In the case at hand it varies $\cos \varphi = 0.15 \div 0.19$. During the setting of the sintering temperature and then $\cos$ increases, but not enough, because the power supply becomes smooth and reaches only 40% of the installed one. From the load schedules, it is observed that during the induction melting process there is a strong uneven consumption of active electrical energy. The same applies to the induction crucibles furnaces with network frequency are clearly expressed, Fig. 3. According to [7] the process can be divided into three distinct stages: 1st stage - melting of the metal pieces placed in the crucible, followed by zero electricity consumption, refining and sampling of the metal to be tested in a laboratory; Stage II - overheating of the metal up to 1520°C, correction of the metal, if needed, followed by zero consumption; Stage III - preheating and spilling the metal from the crucible. Thus, it is clear that the greatest amount of electricity consumption is in the basic mode of operation about 70-75%, which includes this first stage. The supply voltage during this mode changes to small limits (varies in the range 1300-1500V). In this mode of induction crucibles furnaces operation with a mains frequency is the most advantageous time for performing compensation and carry out symmetry of the load.

Data analysis for basic and finishing modes with ‘marsh’

Under Basic Mode (First Stage): duration 1.4 hours (about 84 minutes); active power - an average of 2624 kW; power factor - average $\cos \varphi = 0.67$.

The second and third stages are in the finishing mode.

On finishing mode: overheating time - second stage (1420°C to 1520°C), about 21 minutes; active power 500 kW; power factor - average $\cos \varphi = 0.41$.

References

Abstract: Mathematics is a technological necessity for manufacturing but casting in micro-foundry. The need to describe the first-order phase transition process is based on physical experiments with this transition based on theoretical and mathematical physics. The natural basis of any science is the use of mathematics, which is a basic motivation for its self-development.

Keywords: MATHEMATICS, FOUNDRY, MICROSTRUCTURE, INFRASTRUCTUR OF KNOWLEDGE TRANSFER

1. Introduction

The capabilities of foundries and computational mathematics are presented very clearly in Fig. 1

This communication presents the need to use computational physics through the necessary software for foundry structures of the meso-level (Quantum Mechanics) and in micro-foundry.

2. Computational physics – foundry structure formation

The structure of metals and alloys at the micro-level we present through the location of the atoms in 2D an ideal crystal lattice composed of Wigner-Seitz cells. By definition, it is well known that the volume of this cell may be located only a single atom. The degree of density of the atomic locations in the crystal lattice is represented by the density of the packing density coefficient in Fig. 2:

\[ \eta = \frac{v_s}{v_S} \]

Fig. 2 Scheme – casting structure of meso-level [3]: a) \( \eta \) – packing density coefficient, \( v_s \) – volume of atom, \( v_S \) – volume of cell, where have only one atom; b) 2D an ideal crystal lattice composed of Wigner-Seitz cells.

The calculations of the casting structure at the meso-level are carried out at scales of \( \text{Å} \) and nm. It is well known that a scale of 1 \( \mu \text{m} \) is a macro size. The theoretical model [3] includes the tasks: Stephan and Stephan-Schwarz; the atomic level is the model of Kosel-Stranski-Folmer-Kaishev and the basic equation of Kashchiev with variable thermodynamic driving force and thermodynamics of supesaturation (supercooling). This is the classical theory of crystallization, but an important nuance applicable to a certain minimum scale. The classical theory of atomic crystallization is applied to the nuclei of ten atoms through the Kashchiev equation.

In the [4] mathematical theory of heat conduction it is proposed to use these nuclei sizes when it is possible to apply the postulates of quantum mechanics.

M. Borisov makes the main step for metal science by associating it with the physics of the solid body [5]. In particular, it shows „the metal bond” and the need for quantum mechanics in the engineering of metals and alloys. It should not be forgotten that quantum mechanics arises to describe the properties of metals - Drude's theory.

In the textbook of U. Mizutani is presented the electronic theory of metals [6]. Electrons are responsible for the physical, chemical and transport properties of metals. This textbook gives a complete account of electron theory in both periodic and non-periodic metallic systems.

At the Correlated Electrons: From Models to Materials Conference [7], mathematical modeling and simulation of correlated electrons in the electronic structure of quantum systems in materials is presented.
Def. Electronic correlation is the interaction between electrons in the electronic structure of a quantum system.

Work [8] presents the capabilities of computational physics as a research tool especially and for nano-sized materials. This work has a methodological significance.

Opportunities for observation and measurement of structures of electron microscopy materials are known. At work [9], single atom observation and a specific defect are presented in a 3D aberration-corrected electron microscope, with information being limited to 0.5-Å.

Let us summarize: Fundamental knowledge is needed directly in the details of the market in the particular consideration these are micro-foundries. Knowledge requires specification of the specific requirements for each manufacturer.

3.1 Computational physics in Materialscience

The theory of metals [10] spreads us to the physics of the solid body [5]. The phase transition from the first order creates the structure that carries the working properties of each cast. The description of the first-order phase transition processes requires scientific areas: the classical theory of crystal growth in the present state; quantum mechanics, which is used to describe the chemical bond and structures.

The types of solids according to the chemical bond in the crystal lattice are 5: ionic crystals; valent crystals; metals; molecular crystals. The metallic connection [5]: the crystal lattice is made up of positive ions, the repulsive forces between them being equalized by the free electrons. The description of the chemical bond is obtained after the decision of the amplitude wave equation of Schrödinger we show no relativistic time-dependent (Schrödinger, 1, 2) and time-independent (Schrödinger, 3, 4) view

\[ i\hbar \frac{\partial \psi(r,t)}{\partial t} = -\frac{\hbar^2}{2\mu} \nabla^2 + V(r,t) \psi(r,t) , \]  
(Schrödinger, 1 and 2)

\[ i\hbar \frac{\partial \psi(r,t)}{\partial t} = H\psi(r,t) , \]  
(Schrödinger, 3 and 4)

where \( h \) - Planck’s constant; \( \mu \) - particle reduced mass; \( \nabla^2 \) is the Laplacian; \( \psi \) is wave function; \( H \) - Hamiltonian operator; \( V \) - potential energy; \( E \) - energy of the state \( \psi \).

For real crystals it is necessary to describe the defects [5]: Schottky (1), Frenkel (2) and dislocations (3)

\[ p = \frac{Z!}{(Z-x)!x!} Z^x \]  
(Schottky)  

\[ x = \sqrt{2Z} \exp\left(-\frac{E_x}{2kT}\right) \]  
(Frenkel)

where \( Z \) - total number of atoms occupying places in the crystal lattice; \( Z' \) - number of gaps in the crystal lattice; \( p \) - Schottky’s defects; \( x \) - Frenkel’s defects; \( E_x \) - the energy of the atom to pass from its normal to the intermediate state of the crystal lattice, \( k \) and \( T \) - Boltzmann’s constant and temperature; Degression of ionic crystals from the ideal crystal lattice and the stoichiometric ratio by two parameters [5]: Degree of deviation of ionic crystals from the ideal crystal lattice and stoichiometric ratio by two parameters: \( \mu \) - degree of deviation of the actual grid from the ideal, \( v \) - degree of deviation from the stoichiometric ratio and criteria for observing the stoichiometric number

\[ \mu = (Y_{8d}Z_{M}^2 + X_{8d}Z_{R}) + (X_{8d}Z_{M} + Y_{8d}Z_{R}) \]  
(Grid deviation)

\[ v = (Y_{8d}Z_{M}^2 + X_{8d}Z_{R}) - (X_{8d}Z_{M} + Y_{8d}Z_{R}) \]  
(Stoich. ratio deviation)

\[ v = N_M/Z_M - N_R/Z_R \]  
(Stoichiometric ratio criteria)

where \( X_{8d} \) and \( X_{8d} \) are the number of cations and anions vacations; \( Y_{M} \) and \( Y_{R} \) - the number of ions and metal and the metalloid in the gaps; \( Z_{M} \) and \( Z_{R} \) – the total number of metal and metalloid ion sites in the ideal crystal lattice; \( N_M \) and \( N_R \) – the total number of metal and metalloid ions in the ideal crystal lattice. Example [5]: Let the crystal lattice consist of (m) the number of metals (M) and (r) the number of metalloid (R) ions and the grid composition and that of the molecules of the substance being determined by the formula \( M_{m}R_{r} \).

In pure ionic relation \( m/r = p/q \), where \( p \) and \( q \) are the charges of the positive and negative ion in elementary electric charges.

There are various combinations of point defects in crystal crystals of ionic crystals [5]. For example, [5]: anion vacation with a connected electron called the F-center; pair adjacent in the direction \([e,e,e]\) the F-center (M-center); triple adjacent to the plane \((e,e,e)\) the F-center (P-center), etc.

Other defects in the lattices of real crystals are dislocations [5, 10]. This term means a heterogeneous elastic strain centered on a line to explain the plasticity properties of the crystals. The two simplest dislocations are threshold and screw. Threshold dislocation [5, 10] is characterized by the presence of an "excess" atomic plane in a part of the crystal lattice. Screw dislocations [5, 10]. Crystal in the form of a cylinder with a height \( H \) and a radius \( r \) is cut in a plane defined by the height ... and the radius ... and is perpendicular to the two bases. Then the two crystal parts are slid against each other along the plane of cut, with the outer parallel to the height side being offset at a distance equal to the Burger’s \( \vec{b} \) vector. Finally [5], the two parts of the crystal are glued and the outer forces are removed again. As a result, a non-uniform deformation, centered on the center height of the cage, occurs. As a result, a non-uniform deformation, centered on the center height of the cage, occurs. As a result of the screw dislocation the family of parallel crystallographic planes, perpendicular to the axis of the screw dislocation. When only one screw dislocation occurs, growth is due only to it, because it is much more energy efficient. Random dislocations in crystal lattices [5]: In general, the line of dislocation is a random curve, and the "sliding plane" is an arbitrary spatial surface. Dislocation defects: energy of dislocations such as a hollow cylinder (Dis. Def. 1), occurrence of threshold dislocation (or movement) (Dis. Def. 2), interaction of two dislocations (Dis. Def. 3)

\[ E_z = \frac{\pi r_0^2 t_z}{\ln 2} \]  
(Dis. Def., 1, 2, 3)

\[ F = \frac{\pi}{\ln 2} \]  

\[ dW = (t_z + \tau_z) = (t_z + 2\tau_z + t_z^2) \]  

where \( E_z \) - energy of dislocations; \( t_z \) and \( r_0 \) - outer and inner radius of dislocation; \( F \) - force for occurrence of threshold dislocation; \( \tau \) - the limit voltage required for plastic deformation of the crystal sliding; \( \vec{b} \) - vector of Bürgers; \( \tau_z \) and \( t_z \) - the energies of the individual deformations; \( 2\tau_z + t_z \) - the energy of their interaction.

Crystal lattice of the alloys [5 and 10]: Metal alloys can be regarded as the simplest chemical compounds. They are solid solutions which can be obtained by replacing the atoms of the crystal lattice of one metal with other metal alloys or by introducing atoms of the second metal between the atoms of the crystal lattice of the parent metal.

The shortest can be said that work [5] is the development of work [10] in the direction of fundamental knowledge of foundry. This is confirmed by the current state of economic development - the fourth industrial revolution.

Summary: Fundamental knowledge is needed directly by the market-makers who are the micro-foundries. Knowledge requires specific specification for each manufacturer, which has to be
implemented by a specific infrastructure – such as R. Georgiev's office [14] for transfer of knowledge presented in Fig. 3.

![Principle scheme of Georgiev's office of knowledge transfer to innovation](image)

**Fig. 3** Principle scheme of Georgiev's office of knowledge transfer to innovation the subject of cast technology – Design of structures & Working properties. Knowledge: philosophy – methodology of science of: Mathematics and Foundation of mathematics; Fundamental experiments and Mathematical Physics; Ecology; History and real time of XXI century; Scientists, who teach and work with knowledge; Institutions - Universities and thoroughly Researches Institutes of the Bulgarian academy of sciences; Business branches; Office for transfer of knowledge; full knowledge area are whites and innovations ideas + areas of our transfer are the grays; Target group of companies; Full analysis of generated innovation – micro-founry [14].

**Date for phase transition of first order in foundry process:**

Experiment and measurements: Alloy composition; Obtaining the alloy – fresh or using secondary alloys; Phase transition process of first order: melting; casting – thinness, degassing; pour temperatures, temperature range transferred to the melt; temperature interval of filling the mold cavity; phase transition process of first order: melting; casting – thinness, degassing; pour temperatures, temperature range transferred to the melt; temperature interval of filling the mold cavity; true phase transition – precise thermocouple measurement of the hardening temperature field; Differential thermal analysis – solidification of the alloy in small volume; obtained polycrystalline structure – micro-, macro-grinding and medium grain diameter; measuring the temperature field of solidification in a large volume – an experimental task of Stefan-Schwarz.

Phase Transition Process of First Generation: Classical Theory of Crystal Growth – Mechanism; Contemporary Description Quantum Mechanics - Postulates; The polycrystalline structure of the cast material: mean grain diameter; Crystal lattice - parameters; A full description of the properties of the solid in the alloy, i.e. the working properties of the castings.

Scientific areas related to the description of the processes of formation of the structures of new phases Meso-level is Quantum mechanics. Nano-level are: Quantum nanoscience [11] is the research area and the branch of nanotechnology and physics that uses methods of quantum mechanics to design in new types of nanodevices and nanoscale materials, where functionality and structure of quantum nanodevices are described through quantum phenomena and principles such as discretisation, superposition and entanglement; Nanomechanics [12] is a branch of nanoscience studying fundamental mechanical (elastic, thermal and kinetic) properties of physical systems at the nanometer scale. Nanomechanics has emerged on the crossroads of classical mechanics, solid-state physics, statistical mechanics, materials science, and quantum chemistry. An as an area of nanoscience, nanomechanics provides a scientific foundation of nanotechnology.

On the basis of work [14], the data on the micro-founry are presented on Fig. 4.

**Fig. 4** Date from Knowledge transfer to Ecology-economics complex of "Smart Micro-founry" for Phase transition of first order in Gas counter pressure casting method – Industry 4.

Micro-founry is Open Thermodynamics System (OTS) is describe by stochastic differential equation in the subject of Ito – Stratonovich, which introduce transformation input materials and energies flows, where matrices $\alpha_i, \beta_j$ – physical and constructive parameters, and $i, j = 1, \ldots, m$; matrices column $X(t)$, $Y(t)$ – input, output parameters, and $k, l = 1, \ldots, n$; equation $B$ is operator of controllability of OTS, which is support in zero by change of some parameters of control ; Statistical analysis $\varepsilon_k$ – ecological complexity interaction micro-founry with nature , Date transfer from office to micro-founry.

It is clear that the information interesting for the particular technology should use the infrastructure (see Figure 3) and economic restructuring through serious investments such as the change – INDUSTRY 4.0. Filtering the necessary information is only possible through mathematics.

The methodology is work-based [8]: software for computing physics is continually being created by a new one based on the development of mathematics. Using mathematics to describe the meso-level is working [6, 7 and 8].

An example of the role of mathematics in quantum mechanics is work [13]. From the works [6, 7, 8 and 13] follows that every
question posed by a physical experiment passes a long and complicated mathematical interaction with theoretical and mathematical physics.

Measurements of example structures are works [9 and 15]. It has long been known to see the bottom, according to Feynman [15], the development of measuring instruments follows the development of the necessary technological possibilities, non-standard creation of equipment. A direct example of Bulgarian participation is a work [9], electron microscope with optimized aberration and monochromatic source with high brightness is a significant resolution of the instrument and contrast. Achieved is an information limit of 0.5-Å (angstrom).

Finally, in this paragraph, we need to say that a macro-level (solidification) relation and meso-level (quantum mechanics) is mathematics.

3. Conclusion
Mathematics is a complex technological necessity in the field of education and knowledge transfer infrastructure.

4. Reference


STUDYING SIDE-EFFECTS OF GAMMA-IRRADIATION PROCESSING OF LEATHER MATERIALS

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Abstract: The paper describes part of the results of the first year of the IAEA Coordinated Research Project F23032, Contract № 20567 on “Studying Side-Effects of Gamma Irradiation Treatment for Disinfection of Cultural Heritage Artefacts”. Calf leather, calf suede and pig skin patterns were selected and analyzed by Scanning electron microscopy (SEM), and Thermal gravimetric analysis (TGA) before and after the gamma-irradiation treatment with 5 kGy, 10 kGy and 15 kGy absorbed doses at low dose rate. The irradiation of the leather materials was performed in the gamma-irradiation facility BULGAMMA based on JS-850 60Co type gamma irradiator at Sopharma JSC. No significant changes in the leather morphology and thermal decomposition were observed as a result of the gamma-irradiation treatment. Conclusions on the applicability of gamma-irradiation treatment for preservation of leather items with insecticide and fungicide doses were done.

Keywords: GAMMA-IRRADIATION, LEATHER, LOW DOSE RATE, MORPHOLOGY, THERMAL DECOMPOSITION

1. Introduction

Preservation of cultural heritage artefacts is one of the major objectives of archaeologists, restorers and museum workers. Biological attack of insects, larvae, fungi and bacteria is a serious problem in the preservation and long-term keeping of natural materials (wood, paper, leather, textiles, religious icons, etc.) when stored in improper conditions. Successful application of nuclear techniques (gamma irradiation and electron beam treatment) for disinfection of archives and cultural heritage artefacts has been demonstrated in the last decades. There are several advantages of radiation disinfection, compared to the traditional chemical treatment, including higher effectiveness, reliability, lack of toxic residues, applicability on large amount of objects etc [1-7]. However there are not enough data on the side-effects of gamma irradiation on leather items, especially at fungicide radiation doses. This impedes the development of methodology for gamma irradiation treatment for their disinfection and preservation. Cultural heritage artefacts are often unique and their structure can not be simulated easily. Studies of the effects on irradiated items require the different extent of aging to be considered. Investigations of the side-effects on leather samples will contribute to clarify the structural and morphological changes and select appropriate doses for treatment and allow widening the preservation of leather-containing items by gamma-irradiation. Gamma-irradiation at low radiation dose rate is found to cause accelerating aging of the items, due to radical formations [2, 8]. The radiation induced oxidative degradation is observed to increase at low dose rate values due to increased time for oxygen diffusion [8]. Thus the application of low dose rate gamma-irradiation might contribute to determine the effects of gamma irradiation on artefacts by using model samples.

The Co-60 industrial radiation facility BULGAMMA, situated at Sopharma JCS is used for sterilization of health care products, disinfection of pharmaceuticals, drugs, cosmetics and food irradiation. However gamma-irradiation treatment until now is not regularly accepted for disinfection of cultural heritage artefacts in the country. The aim of the current study is to increase knowledge on side-effects of gamma-irradiation treatment of leather materials in order to implement the radiation disinfection of leather artefacts in the country. This paper presents part of the results, obtained during the first year of Contract № 20567 “Studying Side-Effects of Gamma Irradiation Treatment for Disinfection of Cultural Heritage Artefacts”. Side effects of gamma-irradiation treatment of leather materials with 5 kGy, 10 kGy and 15 kGy at low dose rate (0.006 - 0.06 Gy/s) were investigated. The radiation induced changes in the thermal decomposition and morphology of the samples were studied by using Scanning electron microscopy (SEM), and Thermal gravimetric analysis (TGA/DTG).

2. Materials and Methods

2.1. Samples description

Three natural leather patterns were chosen for this study: calf leather, calf suede and pig skin. Pictures of their both sides are presented in Figure 1. No chemical treatment of the leather samples was performed before and after the gamma-irradiation.

Fig. 1. Physical observation of the selected leather patterns.
2.2. Gamma irradiation

The irradiation of the leather patterns was performed in the gamma-irradiation facility BULGAMMA based on JS-850 $^{60}$Co type gamma irradiator at Sopharma. JS-850 $^{60}$Co gamma irradiator is a wet storage, tote-box irradiator, produced by MDS Nordion, Canada. JS-850 is an elevator type irradiator. It was replenished in 2007 with total irradiator activity 98.484 Ci after source reloading.

The absorbed dose distributions were measured with Ethanol Chlorobenzene routing dosimeters, consisting of dosimetric solution encapsulated in glass ampoule with diameter 10.7 mm and volume 2 mL. The absorbed dose was calculated from a calibration curve connecting it with the electric conductivity of the dosimetric solution measured with oscillograph. This dosimeter consists of an aerated solution of Chlorobenzene and water in ethanol to which a small quantity of acetate was added. The absorbed dose was calculated from a calibration curve connecting it with the electric conductivity of the dosimetric solution measured with oscillograph.

The maximum of the combined uncertainty of dose determination did not exceed 7.2 % (for 2 standard deviations).

Irradiator BULGAMMA is certified by the Quality Management System ISO 9001: 2008, applicable to Processing, decontamination and sterilization of products by gamma-irradiation for industrial, medical and scientific purposes. The samples (calf leather, calf suede and pig skin) were packed in plastic bags separately, closed in paper envelopes and irradiated by: 5 kGy, 10 kGy and 15 kGy absorbed doses at low dose rate (0.037 Gy/s).

2.3. Methods of investigations

The general morphology of the non-irradiated and gamma-irradiated leather samples was studied by SEM. A scanning electron microscope Lyra 3 XMU (Tescan with Quantax EDS detector - Bruker) was employed. Prior to the measurements, the samples were covered with a thin film of carbon. Analysis of the non-irradiated leathers was performed by SEM-EDX in order to obtain information on the elemental composition of the samples and the tanning methods.

The thermal properties of the samples were studied by thermogravimetry (TG/DTG) in pure argon, using Perkin-Elmer TGS-2.

3. Results and discussion

3.1. Morphology

The morphology of carbon-coated leather samples before and after gamma-irradiation at dose rate of 0.037 Gy/s with 5, 10 and 15 kGy was observed in several SEM images, at three different magnification ranges: x 200, x 500 and x 2000. Selected SEM images of the leather patterns before and after gamma-irradiation with 5, 10 and 15 kGy at low dose rate are presented on Figs. 2 - 7.

The SEM images of the external and internal surfaces of the studied leather samples did not show changes of the morphology as a result of the gamma-irradiation treatment. Despite the non-uniformity of the leather surfaces, no irradiation induced damages on them; neither on the fibers could be noticed as a result of gamma-irradiation treatment up to 15 kGy.

The results of SEM-EDX analysis, revealed that the calf suede and the pig skin samples were chrome tanned and contained 4.56 % Cr (suede) and 6.74 % Cr (pig skin). The calf leather did not show elements, untypical for natural leather content and considering that it is light in color, harder and less flexible than the suede and pig skin, we supposed that it has been vegetable tanned.
3.2. Thermal decomposition

The data, obtained from the TG/DTG analysis of the initial leather samples and irradiated samples with 15 kGy at low dose rate (0.037 Gy/s) are presented on Figs. 7-11.

The TG curves of the three leather patterns have similar shapes (Figs. 8, 9). Highest weight percent remained in the calf leather after heating up to 650 °C (33.24 %), followed by pig skin (26.64 %) and calf suede (24.56 %). The irradiated samples of calf suede showed slight increase of the weight percent remained after heating up to 650 °C, as compared to the non-irradiated sample (from 24.56 % to 27.06 %). This effect can be due radiation induced changes in the molecular structure, e. g. cross-linking of the collagen.

As can be seen from Figs. 10-12, the DTG curves of the non-irradiated and irradiated samples practically overlap, which indicates no influence of gamma-irradiation with 15 kGy at dose rate 0.037 Gy/s on the weight loss of the studied leathers. The initial weight loss in the temperature range of 40 – 120 °C can be ascribed to the moisture volatilization or evaporation of some residual tanning solvent. The temperatures of maximum weight loss rate, corresponding to the main weight loss step was observed at 298 °C for calf leather, 317 °C for calf suede and 320 °C for pig skin patterns.
4. Conclusions

The studies on the effects of gamma-irradiation treatment of calf leather, calf suede and pig skin with 5 kGy, 10 kGy and 15 kGy at low dose rate showed no significant changes in the morphology and thermal decomposition of the selected leather materials, as revealed by the scanning electron microscopy and thermal gravimetric analysis. Further investigations on the side-effects of gamma-irradiation on the molecular structure and radical formation in leather materials would contribute to development of radiation treatment methodology for their disinfestation and preservation.

Acknowledgements

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References


INFLUENCE OF SELECTED ATTRIBUTES IN ASSEMBLY SYSTEMS PLANNING WITH USE OF SIMULATION SOFTWARE

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Abstract: At present, there is an increasing emphasis on planning production and assembly systems. In the planning phase, it is important to eliminate as much as possible, ideally all deficiencies and errors of the intended system. Simulation software helps to find shortcomings in production or assembly systems. Using simulation, we can analyze individual parts of production systems in a virtual environment before they are implemented. This all leads to cost savings in the implementation of production systems. The article deals with simulation of production systems and their planning. The case study will illustrate the simulation process in choosing the right manufacturing system.

Keywords: ASSEMBLY PLANNING, SIMULATION, ASSEMBLY SIMULATION

1. Introduction

Based on the competition of the international manufacturing network, it is felt to increase pressure to improve the efficiency of production systems. International logistics networks need a linked logistical concept. These requirements can be managed only by using the right digital business tools in the context of the product lifecycle management environment (PLM). This allows the resulting data to be used as the basic support for cooperation between different departments and offers everyday relevant data for every user who needs them. Simulating a complete material flow, including all major manufacturing, storage and transport activities, is a key component of a digital enterprise in the industry. A 20-60% reduction in inventory and production throughput and a 15-20% increase in the productivity of an existing production process can be achieved in real projects. Reasons for using simulations can be strategic or tactical operational goals.

Simulation models make evaluation of different variant of production and effectiveness measurement possible [1]. In addition, the simulation allows to use new strategies and procedures, verification of the production in the revised system, locate bottlenecks in the flow of materials, increase productivity while reducing inventory and reduce the cost of the implemented changes [1].

“A bottleneck is defined as a workstation limiting the production efficiency of the entire process (Betterton, 2012; Hsiao et al., 2010). It is the enterprise’s workstation or a production cell that is characterized by the lowest level of a specific production parameter among all co-participating parameters in the manufacturing process. This can lead to a situation, in which a workstation before the bottleneck completes processing, but it cannot forward materials, as the workstation that follows it, being the bottleneck of the process, is still engaged in processing earlier orders. Bottlenecks can also extend the time of the standstill in the processes occurring at subsequent stages (Li, 2009), prolonging the waiting time for further orders. Bottlenecks mark the pace of the entire process. All definitions are consistent in one sense – bottlenecks have an adverse effect on the efficiency of production systems, the flow of materials in the process as well as even burdening of workstations. [2]”

Fig. 2 Bottleneck characteristics

Application/ benefit

Plant Simulation (formerly eM-Plant, Simple++) is a standard software for the simulation of highly complex production systems and control strategies. The tool features object-oriented, graphic and integrated modelling, simulation and animation of systems and business processes [3]. It is an important component and entry tool for the Digital Factory in the software portfolio of Siemens PLM.

Typical questions that Plant Simulation can help to answer

- How can investment costs be minimized?
- Is the required output reached?
- What happens in case of quantity changes?
- How can stocks be reduced?
- What is the best control strategy?
- What effect do rush orders have?
- What is the best planning alternative [3]?

Statistical Evaluation

Plant Simulation offers different statistics for model parameters: Interval statistics, overall statistics and momentary statistics. Comprehensive analysis tools such as automatic bottleneck analysis, Sankey diagram and Gantt chart (planning chart) [3]

Structure / Modules

All Plant Simulation basic and user modules are visible and accessible in the modular library, which can be configured freely. Arbitrary user modules are graphically and interactively created from basic modules by the user himself. These include:

- Integrated neuronal networks
- Factor analysis
- Experiment administration
- Automated optimization of system parameters
- Batch size and sequence planning (sequencing)

The complex production lines and manufacturing processes of today’s manufacturers are best understood through a rigorous, analytical framework. It is no surprise that digital modeling and simulations are becoming essential pieces of the manufacturing IT toolbox. Industrial simulation software provides insight into potential problems and presents opportunities for improvement in plant and production line layout, process flow, and other aspects of a manufacturer’s operations [3].

2. Simulation with Tecnomatix Plant Simulate

Tecnomatix Plant Simulation software makes the simulation and optimization of production systems and processes easy and effective. By use of Plant Simulation, material flow can be optimized, utilization of resources and logistics for all levels of plant planning from global production facilities, through local plants, to specific lines is effective and time efficient [4].

Benefits

- Enhance productivity of existing production facilities by as much as 20 percent
- Reduce investment in planning new production facilities as much as 20 percent
- Cut inventory and throughput time by as much as 60 percent
- Optimize system dimensions, including buffer sizes
- Reduce investment risks through early proof of concept
- Maximize use of manufacturing Resources
- Improve line design and schedule Features
- Simulation of complex production systems and control strategies
- Object-oriented, hierarchical models of plants, encompassing business, logistic and production processes
- Dedicated application object libraries for fast and efficient modeling of typical scenarios

- Graphs and charts for analysis of throughput, resources and bottlenecks [4]

3. Simulation case study

In this section will be discussed and shown case study. This case study is aimed on simulation solutions for production lines and systems with use of simulation software Tecnomatix Plant Simulate from company SIEMENS. Tecnomatix Plant Simulate is based on discrete simulation.

Basics of every simulation is to solve some problem or answer some of the questions mentioned before. In this case assembly/production system is tested if there is some room for update or improvement of throughput.

That means for this example that adjusted version of system will be tested and compared with base model of system. The point is to find improvement that would increase throughput or decrease resources.

This case study deals with assembly/production system which consist of input station, pick and place mechanism, three work stations, three assembly stations, four buffers and two conveyors.

First in Tecnomatix Plant Simulate every station, assembly station, conveyor or pick and place mechanism must have time management setting done before running the simulation.
Table 1: Time management of stations

<table>
<thead>
<tr>
<th>Station</th>
<th>Time (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pick and place</td>
<td>50</td>
</tr>
<tr>
<td>Preparation</td>
<td>300</td>
</tr>
<tr>
<td>Assembly</td>
<td>300</td>
</tr>
<tr>
<td>Assembly 2</td>
<td>240</td>
</tr>
<tr>
<td>Assembly 3</td>
<td>240</td>
</tr>
<tr>
<td>Packing</td>
<td>120</td>
</tr>
<tr>
<td>Preparation and handling</td>
<td>120</td>
</tr>
</tbody>
</table>

Time management for stations mentioned in Table 1 is between 50 seconds and 300 seconds. Buffers capacities are 1000 pieces except buffer 3 where capacity is 500 pieces.

Table 2: Capacity management of buffers

<table>
<thead>
<tr>
<th>Buffer</th>
<th>Capacity (pieces)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buffer</td>
<td>1000</td>
</tr>
<tr>
<td>Buffer 1</td>
<td>1000</td>
</tr>
<tr>
<td>Buffer 2</td>
<td>1000</td>
</tr>
<tr>
<td>Buffer 3</td>
<td>500</td>
</tr>
<tr>
<td>Failed parts buffer</td>
<td>1000</td>
</tr>
</tbody>
</table>

Table 3: Speed settings of conveyors

<table>
<thead>
<tr>
<th>Conveyor</th>
<th>Speed (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line</td>
<td>1</td>
</tr>
<tr>
<td>Line 1</td>
<td>1</td>
</tr>
<tr>
<td>Line 2</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Fig. 4 Base model of system (Tecnomatix Plant Simulate)

In figure number 4 is show production/assembly model which starts at input station where pick and place mechanism moves units to buffer. Pick and place mechanism sets the speed of whole input. Next in preparation station, units are prepared for assembly line. To assembly line are units transported by conveyor with speed 1 m/s.

Assembly part of system consists of three assembly workstations with three buffers. At control point are units sorted and failed parts are moved to failed parts buffer, other parts are transported to preparation and handling station to get ready for output.

All the information in tables are parameters that can be changed with respect to technological limits of production/assembly system. By changing parameters, we can adjust model and analyze different output characteristics or behavior of system. Based on that can be chosen the right set up for system.

Fig. 5 Adjusted model of the system (Tecnomatix Plant Simulate)

Difference between base model and adjusted model in figure number five is that failed parts buffer is connected to conveyor. Through conveyor failed parts transport to preparation station again, so they are disassembled and ready for next assembly process.

Simulation models work usually with failure settings of 95% working time to 5% failure. In pick and place mechanism was calculated fail time 1% based on real model information.

Fig. 6 3D model of adjusted system (Tecnomatix Plant Simulate)

In figure six we can see adjusted model in 3D view of Tecnomatix process simulate window. 3D models in simulation will be important in future as concept of industry 4.0 is becoming more popular nowadays.

Fig. 7 Resource statistics of base model
Based on figure seven and eight we can see how working time of assembly stations increased only by managing the material flow and better timing on pick and place and conveyors.

Cycle time of five working days was tested for throughput evaluation. As is shown in table four, throughput in adjusted model is higher by 136 pieces of products.

**Table 4: Throughput of models in five working days**

<table>
<thead>
<tr>
<th></th>
<th>Base model</th>
<th>Adjusted model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throughput</td>
<td>1064</td>
<td>1200</td>
</tr>
</tbody>
</table>

**4. Conclusion**

Computer simulation with IT tools is currently an essential activity to support the design of new production and logistics systems or even existing systems [5]. Simulation methods are used to evaluate different aspects of manufacturing systems or subsystems. Repeatability is an important and fundamental feature of computer simulation. Because of the exact values and parameters that have inherent values, the same process can be executed many times. In real life it is not possible [6].

The application of innovative design methods is one of the factors that has positively influenced the process of introducing fast, modern assembly systems [7].

This article describes the application of Tecnomatix Plant Simulation from SIEMENS in computer design and manufacturing process planning. Simulated production systems, created as examples, have shown that if the production system has some shortcomings, it can be improved by simulation. The simulation experiment can be tested with different characteristics and different modification types. It is a user choice when it is necessary to change the base model or just some features of the production model.

Major benefit of simulation like the one made in case study is that adjustments or improvements of production/assembly systems are made without shutting down the production. Real system work without changes and adjustments are made just after simulation shows that these adjustments will increase production or decrease spending etc.

The information obtained from the simulation results is influenced by the accuracy of the input data and model. The use of simulation methods of different processes in production, logistics or planning of new production systems is an element of Industry 4.0. It simplifies the planning of production systems and the optimization of existing systems.

**Acknowledgement**

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**References**


Managing the Value Added Made by the Entity Using Simulation Modeling

УПРАВЛЕНИЕ ДОБАВЛЕННОЙ СТОИМОСТЬЮ, ПРОИЗВОДИМОЙ ПРЕДПРИЯТИЕМ, С ПРИМЕНЕНИЕМ ИМИТАЦИОННОГО МОДЕЛИРОВАНИЯ

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Abstract: The main issues are considered in this topic: choice of corrective actions; monitoring of values of key indicators and corrective actions; assessment with use of a simulation modeling of an expectation of values of key indicators and the operating influences during the specified periods; determination by means of simulation modeling of change of sizes of corrective actions for transition from "crisis" by the "successful" periods of work of the entity.

KEYWORDS: SIMULATION MODEL; VALUE ADDED; THE SLIDING VARIATION COEFFICIENT; ESTIMATING VECTOR

1. Introduction

The research is directed to implementation of automated control systems for economy of the entity. Three stages of the solution of this task are allocated. The first stage – forming and the forecast of the integrated indicator characterizing an economic condition of system. The second stage – creation of the estimative vector allowing to divide in dynamics an array of initial information into two parts relating to the satisfactory and pre-crisis periods of work of the entity. And the final stage – stay using imitating modeling of the ranges of rational values of financial ratios.

2. Discussion of a problem

In the existing management systems for assessment of an economic situation only the integrated indicator which in principle can be considered in dynamics is calculated. Whether on value of an integrated indicator it is possible to estimate there is an economic situation in the entity in pre-crisis or satisfactory condition. But at the same time the method of determination of the corrective actions allowing to transfer the entity from pre-crisis to satisfactory condition isn’t specified. For the solution of this problem in this work, the estimative vector allowing to divide pre-crisis and crisis conditions of the entity is entered, and values of corrective actions are determined by the found characteristics of distributions for satisfactory condition of the entity.

3. Diagnostics of an economic condition of the enterprise with use of a value added

The value added of products made by it is considered a key indicator of a financial and economic condition of the entity. The value added is a source of economic growth and income formation of owners and employees of the entity and also state. For owners optimization of value added is expressed in a possibility to solve problems of development of the enterprise.

By determination the value added of $S_{VA}$ is estimated based on the ratio of [1]:

$$S_{VA} = NR - M$$  (1)

where $NR$ – the cost of products made by the entity; $M$ – market value of the materials and services spent in case of production.

By simple transformations the formula (1) can be given to the following type:

$$S_{VA} = EBT + S_{CF} + DA + TAX,$$  (2)

where $EBT$ – sales profit; $S_{CF}$ – a compensation phot; $DA$ – depreciation; $TAX$ – the amount of the taxes paid from cost value.

From the given constituting $S_{VA}$ its distribution is clear:
- the employee – the salary and other expenses on compensation;
- to the state – the income tax and assignments on social needs;
- to the persons which provided the equity – dividends, including according to the shares belonging to subsidiary companies;
- remain at the disposal of the company – depreciation and retained earnings.

Essential importance of an indicator of $S_{VA}$ for the specified categories determining this cost follows from told. And for all of them maximization of an indicator of $S_{VA}/M$ is desirable.

We will return to a formula (1). From this formula we receive:

$$\frac{S_{VA}}{M} = \frac{NR}{M} - 1$$  (3)

The equivalence of tasks of maximization of indicators of $S_{VA}/M$ and $NR/M$ follows from a ratio (3) [2]. It is established that there is very high correlation of an indicator of $NR/M$ with coefficient of turnover of current assets ($K_{CAT}$) and current liquidity ($K_{CR}$):

$$K_{CAT} = \frac{NR}{S_{CA}}$$ and $K_{CR} = \frac{S_{CA}}{R_{C} + R_{p}}$, and also with indicators $\pi_1, \pi_2, \pi_4$ – the characteristics determining the strategy of management of current assets of the entity [3]:

$$\pi_1 = \frac{S_{CA}}{NR}$$

$$\pi_2 = \frac{NR - K_{CR} - K_{CAT}}{S_{CA}}$$

$$\pi_4 = \frac{K_{CR}}{B}$$

where $S_{CA}$ – amount of current assets; $B$ – a balance sheet total; $K_{r}$ – short-term loans; $R_{p}$ – an accounts payable; $K_{T}$ – long-term loans; $I_{S}$ – own means.

In works as [2, 4, 5] methods of nonlinear programming a number of tasks of optimization both an indicator of $f/M$, and some corrective actions, in particular $K_{CAT}$ indicator is solved. But the given approach to optimization of value added and finding of rational values of its corrective actions can be used in any one-time researches because of need of accounting of change of key indicators of the entity.

In automated control systems for economy of the entity the stay task in dynamics of rational values of the corrective actions providing maximization, for example, of a value added indicator needs to be solved using imitating modeling. The general scheme of this procedure is as follows. After the choice of the main economic indicator pass to finding of the vector determining its financial and statistical ratios, a so-called "estimative vector" $\mathbf{y} = y_1, y_2, \ldots, y_n$. In particular, for relative value added of $S_{VA}/M$ the financial ratios provided above are chosen as components of an estimative vector: $K_{CAT} = y_1$, $K_{CR} = y_2$, and also indicator $\pi_4 = y_4$. From statistical coefficients the sliding variation coefficient (MSD) is used.
where $\sigma$ – the moving standard deviation of size of relative value added $(S_{VA}/M)$; $M_4$ – expected value.

Further length of an estimative vector is determined:

$$
\|\mathbf{y}\| = \sqrt{y_1^2 + y_2^2 + \cdots + y_4^2}.
$$

Coordinates of a vector are units and zero, that is $y_i \in \{1; 0\}$ .

Number 1 corresponds to a satisfactory situation, and number zero – unsatisfactory. The sizes $y_i$ are determined from the following system of ratios:

- $y_1 = 0$ in case of $K_{CAT} \leq K_{CAT}^{\text{NORM}}$ and $y_1 = 1$ otherwise;
- $y_2 = 0$ in case of $K_{CR} \leq K_{CR}^{\text{NORM}}$ and $y_2 = 1$ otherwise;
- $y_3 = 0$ in case of $MSD > 0.3$ and $y_3 = 1$ otherwise;
- $y_4 = 0$ in case of $\pi_4 < \pi_4^{\text{NORM}}$ and $y_4 = 1$ in case of dissatisfaction of this condition.

Standard measure values are established by the entities.

The given standard values often accept when calculating risk of the entity. As standard value $\pi_4$ it is possible to accept its average for the considered period.

The estimative vector allows to determine to what massif information obtained in every quarter belongs: to work of the entity in a pre-crisis or "satisfactory" situation. In the presence of four indicators if all of them are equal standard, the economic situation is assessed by number 2. If all four indicators don’t correspond standard, the economic situation is assessed by number 0.

In work [6] as an expert way it is established that the pre-crisis situation steps in case of a deviation of length of an estimative vector from maximum on 30% and more. If the situation takes place three quarters in a row and longer, then it is considered crisis.

The final stage of calculations is finding of rational values of the specified financial ratios of $K_{CAT}$, $K_{CR}$ and $\pi_4$ by imitating modeling. As a result of the performed procedures the used massif of basic data is divided into 2 parts: the specified massifs of satisfactory work of the entities and pre-crisis and crisis conditions. The left borders of the found differential distributions of satisfactory work of the entities are also the minimum values of required corrective actions. Parameters of distributions are estimated when using a packet of the application programs "Oracle Crystal Ball".

The given algorithm is implemented for several types of distributions: normal, logarithmic normal, logistic and also Beta. As critical values of corrective actions the maximum values of the left borders of their distribution for satisfactory condition of the entity are chosen.

4. Summary

As a result of the executed research the following results are received:

1. As the most important characteristic of an economic condition of the entity the value added of products made by it is chosen.

2. The general technique of quantitative assessment of an economic situation in the entity using the new operational characteristic – lengths of an estimative vector is offered. The technique includes the following main stages:

- determination of set of the financial ratios and their standard rates characterizing an economic situation in the entity;
- consideration of the estimated coordinates of the vector in which the relevant financial ratio is replaced by the unit if it meet the specified standards and zero otherwise;
- calculation of length of a vector;
- separation of the array of information into two parts – satisfactory and unsatisfactory conditions of the entity.

3. The research of the found data arrays relating to satisfactory and pre-crisis conditions of the entity with use of a packet of application programs "Oracle Crystal Ball, allows to establish the minimum values of rational corrective actions taking into account the left border of distribution of financial ratios for satisfactory conditions of the entities..

5. References

INDICATORS OF STARTUP FAILURE

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Abstract: Startup is a newly established enterprise, or an enterprise at the foundation stage, which is focused on monetizing an idea. According to the European Association of Business Angels there are launched about 50 million new projects every year (137,000 per day), but 90% of them fail. In the paper we analysed 51 startups, which had a minimum viable product and also some investment, but failed. The main aim of the research was to identify the factors leading to the failure of startups. The result has been to create an overview of the mistakes that young entrepreneurs commit at the early beginning.1

Keywords: STARTUP, FAILURE, INVESTMENT, TEAM, FINANCING

1. Introduction

The global development of new technologies has created a trend of small, exponentially growing companies – startups. Steve Blank2, Silicon Valley serial-entrepreneur and academician, defines startup as a temporary enterprise form designed for a repeatable and scalable business model. According to investor and writer Paul Graham3, the startup is a fast growth business. However, only a fast growth does not define the complexity of a startup. Matej Jariabka, one of the leaders of the StartupCamp community, defines startup as an innovative form of high-risk enterprise with the potential for huge growth. The word startup can therefore be labeled as essence of unconventional thinking, creativity and originality4. It can be any start-up enterprise that is preparing some minimum viable product or already exists on a market and meets the following criteria: creates a blue ocean in a industry, has a higher entrepreneurial risk in establishing itself on a market, and after a successful start it is likely a fast grow.

According to the European Association of Business Angels5 (EBAN), around 300 million founders currently have 150 million businesses worldwide. There are launched about 50 million new projects every year (137,000 per day). CB Insight's research, which analyzed the causes of 101 startup failures, has shown that 9 out of 10 startups fail to 1-3 years, what is a 40% riskier than in standard business models. According to Bloomberg's analysis6, 8 out of 10 startups fail over 18 months, mainly due to lack of understanding of customer needs and inadequate revenue generation what also confirms KPMG Startup Survey 20167 which define, that only 37% of startups generate revenue (69% up to 50 thousand euros, 23% more than 50 thousand and 8% more than half a million euros) and others do not receive any money yet. Because the primary goal of doing business is to generate finance for covering company costs as well as for shareholders. So every startup should create an ideal revenue model, which describes8 how a company generates profit and sufficient capital for further investment.

2. Aim of the paper

The main aim of the research was to identify the factors leading to the failure of startups. The result has been to create an overview of the mistakes that young entrepreneurs commit at the early beginning. We divided the main goal into testing three hypotheses in which we analyzed possible failure indicators:

1. Most startups have an inadequately defined product / problem and its solution.
2. Startups do now how to correctly estimate customer, target group and market potential in the industry.
3. Startup failure is mostly caused by incorrect setting of the revenue model.

3. Methodology

In the first phase we compared current knowledge in scientific literature, using resources in the ScienceDirect, Springer and RePEc databases and Google Scholar Search. Subsequently, based on comparisons of literature and scientific research, we created a structured questionnaire that helped us to structure and analyze 51 statements of the startup founders. We received these testimonials from the Autopsy.io database, which was founded by Maryam Mazraei and Matthew Davies in September 2014, and which creates list of blogs, testimonials and analyzes of the startup founders, who evaluate the reasons of their failure. The analyzed startups included: Lumos, RateMySpeech, RewardMe, Udesign, Fastr, GuGo, Wattage, Allmyapps, BitShuva Radio, KOLOS, Bluebird, Secret, Bawte, Patterbuzz, Kiniku, ComboCats, College Inside View, DeviceFidelity, Kinly, Cusoy, Starthead, Poliana, Zagreb Cohousing, Springpad, Keep Fit Stay Sane, Showroom, Amiloom, Wishareit, Emjoyment, Dinnr, Moped, Imersive, 99dresses, Popin, OpTier, Bloom.fm, Manilla, Pumodo, HowDo, Awgyle, orat.io, Stipple, Samba Mobile, Zumbo, Needium, Critica, LayerVault, World Burrow, Mochi Media, Salorix a Exec.

4. Results

The gender analysis showed that 96% of the founders were men. This is mainly due to the fact that most of the startups are created in the technology sector, which is still the main domain of men. From the place of company establishment point of view, nearly 70% come from the US, most of them from San Francisco, California, which not far known as Silicon Valley. A more accurate overview is provided in Chart 1.

Chart 1: Location of analyzed startups

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>68%</td>
</tr>
<tr>
<td>Great Britain</td>
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Analyzed startups were established in 2009-2014 (Chart 2 and Chart 3). The average period of startup existence was 28 months. The fastest failure was reached in 4 months and the longest business time was 55 months. Modus, the most common startup existence period, was 12 months and the median was 24 months.
Startups have created their business models most often in the area of social applications (42%) and in softwares aimed to simplify people’s lives (28%). The least represented startup sectors included robotics, payment systems, gastronomy and artificial intelligence (Chart 4).

An important indicator of a startup business failure was the amount and type of investment (Table 1). The number 84% of the analyzed startups received an investment, mostly in the amount of 10-100 k € and 1-10 mil. €. Only 16% of them did not receive any investment. It follows that the specimen was under the control of investors and other third parties and startup had to have some MVP. Revenues and profits of 80% startups were not published, so we did not analyze them further.

The 5 most serious problems include the following:

1. Lack of money for further development (34%)

One of the key factors behind the startup success is finding enough financial resources to develop an idea, especially in phase when the startup does not generate revenue. Because of this reason, startups must look for financial resources from the external environment - family, friends, banks, venture capital, development capital, state support, or crowdfunding. Branislav Zagorski identified also the positive impact of the higher cost strategy on the pay-as-you-go acquisition. In more than 1/3 of analyzed startups, it was shown that the companies had not defined sufficiently the amount of funds needed for the launch and for the investment time.
schedule. At the same time, they were unable to reach the sales stage and thus obtain additional financial resources from customers. The lack of money led to next problem: reimbursement of capital expenditures, financing of expansion, covering operating costs for staff, offices, infrastructure, etc. and covering other costs.

II. No need for a product / service in the market (28%)

The second biggest problem was the lack of customer interested for the startup solution. The founders defined this problem as a lack of real market testing. Many of them met with customers and asked about their problems, analyzed possible solutions. Preliminary analyzes seemed promising. However, when they came out with the product on the market they found out that people, despite the fact that they had previously said they were interested, did not really want to buy it. The founders called these product “Vitamins” (it’s nice to have it) even though they thought they are going to sell Aspirin (must have it). The founders said that also the timing of product launch was probably not right - either customers or the market was not ready yet, or they came out with the product too late. In both cases, the result was the same.

III. No investors (16%)

It seems, that finance is the biggest problem, because it takes first and third place in our results. In this case, it is more about problems with investors. Founders defined the main issues:

- the startup has hurt its investors several times and failed to fulfill the required goals in the basic series, thereby losing confidence,
- the startup did not produce any evidence to increase its potential to convince the investor of its exponential growth potential (pre-contract with buyers, a large number of applications downloads, sales, success in the crowdfunding campaign, etc.),
- lack of logic of the business model from the investor perspective,
- insufficient investor awareness of all issues,
- time has shown that there is no understanding between the startup team and the investor.

IV. Cost Issues (16%)

One of the main problems was the cost calculations. In these cases, founders did not make accurate finance planning that included both direct and overhead expenses. Incorrectly defined costs have resulted in incorrect price formation and therefore the market price could not cover costs at all. There were more reasons, why founders failed their budgeting:

- acted under the pressure of their investor and defined only preliminary costs,
- did not know which material they will finally use,
- could not define all cost items (material costs, labor costs, investments to technology, etc.),

V. Not the right team (14%)

Most investors evaluate a quality of the team, experience, creativity and cooperation as one of the key factors of success. In most cases, startups need to change their business model several times, and it can only be done by a high-quality team. The most common issues that the startup analyzes were:

- not the right mix of people: in many cases incompatible people and too strong personalities created many conflicts / wrong people , who appeared at first as professionals and then turned out to be incompetent,
- bad team leadership: incorrect team manager caused a feeling of unfair distribution of work and not fair financial reward / in other cases the founders themselves reflect that they were not able to lead their team.

5. Conclusion

The main goal of founding a startup is to discover new marketplaces and create high added value products. At the beginning, startups are low-cost projects mostly created by programmers and designers who want to create something unique and earn a lot. However, in more than 90% of cases, they fail. Three of five main problem deal with finance - either incorrect product pricing, poor cost estimates or lack of capital for further development. The second key issue is the lack of market need – result of inadequate product testing on the real market. The fifth biggest problem is the poor team that cannot solve the problems and cannot develop thertig MVP or business model.

1 The paper is a result of research in scientist project VEGA 1/0609/16