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Present state and future application of smart technologies in manufacturing processes

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Abstract
The paper concentrates on the issues of applying smart technologies in the manufacturing processes. The author includes in it brief descriptions of the smart technologies that contributed to the emergence of Industry 4.0 concept. Additionally, based on reports and surveys conducted on a global scale regarding the application of intelligent technologies, the author analyses the current state of implementing these technologies in manufacturing processes and provides forecasts regarding the adoption of the solutions based on Artificial Intelligence in global enterprises in the near future.

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1. Introduction

The observed in recent decades globalisation of the world and the growing number of people inhabiting the planet have produced numerous challenges related to economic development, increasing consumer demands and capacity of the production sector to satisfy them. According to the data by the United Nations Organisation the world's population continues to grow. In 2019 there are already 7.7 billion people worldwide. The estimates show that the global population could reach around 8.5 billion in 2030, 9.7 billion in 2050, and 10.9 billion in 2100 (UNITED NATIONS DEPARTMENT FOR ECONOMIC AND SOCIAL AFFAIRS, 2019).This also means that soon the production sector will have to face the threat of resource scarcity and a need will arise to optimise manufacturing processes so as to make them more efficient and less labour- and energy-intensive. Actually, this shift is already taking place as most industries have already noticed that the future of industrial value creation is closely related to sustainability. Thus, the production sector has already started a transition towards the fourth stage of industrialisation, commonly known as Industry 4.0., which provides a number of advantages over the previously applied methods of production planning and executing. For example, unlike the conventional production planning based on forecasts, Industry 4.0 not only enables real-time planning of production plans but also their dynamic self-optimisation. Additionally, it can also largely contribute to improving efficiency and quality of manufacturing processes , increase safety, preserving at the same time sustainability of production and creating a positive image of the industry. On the other hand, advanced manufacturing processes and technologies can significantly increase the already complex levels of manufacturing processes. They are also responsible for introducing a high level of dynamism into them creating in this way so-called smart working environments, characterised by complexity and interaction of many components in a network structure. These components can be physical and cyber-physical, can function heterogeneously, can be organised in a hierarchy of subsystems, and contribute to system as a whole (Brocal et al., 2019).

However, the current implementation of advanced manufacturing processes would not be possible without a revolution that has taken place in the area of Information and Communication Technologies, which has paved the way for the present fourth stage of industrial revolution. Earlier, the advances in the area of computer systems and the application of the Internet led to the era of Artificial Intelligence development and large-scale use of Big Data. Then, further advances in this domain allowed for communication among things, which enabled the development of the Internet of Things and finally communication among the three elements of what is known today as the Internet of Everything: things, people and spaces.

All the abovementioned factors have led to an emergence of a new manufacturing model - intelligent manufacturing. It can

be defined as a model of manufacturing combined with the technical means by which new information and communication technology, intelligent science and technology, large manufacturing technology (including design, production, management, testing, and integration), system engineering technology, and related product technology are integrated with the whole system and lifecycle of product development (Li, Hou et al., 2017).

The underlying objective of the paper is to present, based on the literature review and secondary data the latest advances in the area of manufacturing processes automation, which translates directly into the improved production capacity as well as quality. The author describes in brief the most important features of the solutions that have led to the emergence of the Industry 4. 0 concept, which has transformed the face of the current manufacturing processes, optimising them and being in line with the sustainability concept contributing to a decrease in resource-, energy- and labour-intensity. The paper also includes an analysis of data acquired from reports regarding application of the Internet of Things, cyber-physical systems and Artificial Intelligence, which demonstrates its high potential to be used in manufacturing processes management. As a whole, the paper may constitute a valuable source of information on utilising recent technological advances in contemporary enterprises.

2. Application of smart solutions in the Industry 4.0 concept and manufacturing processes

Cyber-physical systems constitute one of the major steps forward as far as the development of computer science and information and communication technologies are concerned. They are systems of collaborating computational entities which are in a constant connection with the surrounding physical world and the processes occurring in it, simultaneously providing and utilising services of accessing and processing data with the use of the Internet. There are numerous concepts of applying the potential offered by CPS in almost all aspects of life, e.g. autonomous cars, robotic surgery, intelligent buildings, smart electric grid, smart manufacturing or implanted medical devises to mention just some of them. What is more, presently, the new generation of the IoT components is able to execute the functions of cyber-physical systems that thanks to data processing, which occurs in the cyberspace and requires no human involvement, provides for the control of movements in the real world. This in turn combined with the common use of the Internet in practically all business process in organisations, utilisation of big data, incorporation of sensors into a vast number of consumer devices as well as interconnection and fusion of data and knowledge in society, physical space, and cyberspace, has led to a new a new evolutionary stage: AI 2.0. Therefore, the emergence of new technologies has contributed greatly to application of AI in new areas, such as manufacturing processes (Pan, 2016).

Consequently, it can be stated that the development of AI and cyber-physical production systems (CPPS) that on one hand make use of the recent as well as future developments of computer science and information and communication technologies and on the other hand of manufacturing science and technology have contributed greatly to the 4th industrial revolution, frequently referred to as Industry 4.0. (Monostori, 2014).

The paradigm of Industry 4.0 itself is believed to consist in the three dimensions, which include: horizontal integration across the entire value creation network, end-to-end engineering across the entire product life cycle and vertical integration and networked manufacturing systems. The underlying characteristics of these dimensions have been aggregated in Table 1 below.

Table 1. Dimensions of Industry 4.0

Dimension	Characteristics
Horizontal integration across the entire value creation network	Describes the cross-company and company-internal intelligent cross-linking and digitalization of value creation modules throughout the value chain of a product life cycle and between value chains of adjoining product life cycles;
End-to-end engineering across the entire product life cycle	Describes the intelligent cross-linking and digitalization throughout all phases of a product life cycle: from acquiring raw materials to manufacturing system, product use, and the product end of life;
Vertical integration and networked manufacturing systems.	Describes the intelligent cross-linking and digitalization within the different levels of aggregation and hierarchy levels of a value creation module from manufacturing stations via manufacturing cells, lines and factories, integrating the associated value chain activities such as marketing and sales or technology development as well.

Source: own elaboration based on: (Stock et al., 2016).

The technology that has influenced the development of cyber-physical systems and their application in smart manufacturing processes is the Internet of Things. The IoT provides physical objects with an ability to see, hear, think and perform jobs, making use of their ability to communicate one with another and in this way share information and coordinate decisions. The IoT transforms these objects from being traditional to smart by exploiting its underlying technologies such as ubiquitous and pervasive computing, embedded devices, communication technologies, sensor networks, Internet protocols and applications (Al-Fuqaha et al., 2015).

The fusion of ICT technologies has transformed both the scope of manufacturing functions and the interactions among them. The application of the IoT enables unified communications among manufacturing system components, cloud and mobile computing, which means that manufacturing functions once implemented at different levels of the hierarchy are now available without even knowing where they are executed. Smart components and smart systems on the shop floor can run advanced analytics and simulations, and make decisions beyond the lower functions defined in ISA 95. In order to put

the idea of smart manufacturing in practice, where systems respond in real time to changing demands and conditions in the factory, in the supply network, and in customer needs, the classical manufacturing system architectural paradigm based on a hierarchical control model had to evolve giving way to a new one, reflected in the concept of Industry 4.0. (Lu & Ju, 2017).

It is worth noting that the systems based on the concept of CPS were previously applied only in some of the industries such as the semiconductor manufacturing process and chemical plants, but they initially did not offer cost effectiveness because of high costs of their introduction and maintenance. However, as a result of diversification, complexity and digitalisation of the main structure of each sector of society and industrial systems, CPS have begun to be used more extensively again providing a way to optimize and utilise them (Kim et al., 2017).

3. Advantages of implementing smart solutions in contemporary enterprises

The conducted by the author literature review demonstrates that the market for smart technologies such as robotic process automation (RPA), which is software applied to automate manual tasks in manufacturing processes is growing at 20 percent per year and it is expected to reach $5 billion by 2024. According to the data by Deloitte 41% of the respondents to the 2019 Global Human Capital Trends survey admit that they are already utilising automation extensively or across multiple functions. The data concerning automation technologies being implemented in the surveyed enterprises has been presented in Figure 1.

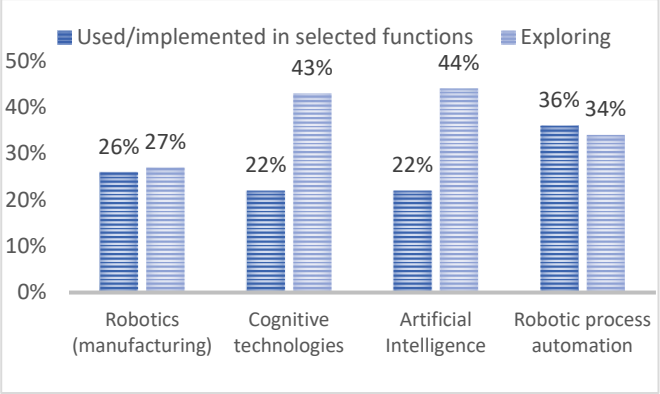

Fig. 1. Automation technologies in organisations

Source: own elaboration based on: *(*DI_HC-Trends-2019.pdf, *n.d.)*

As Figure 1 demonstrates the most dominant ways of work automation includes application of robotic process automation – 36%, but 26% of the survey respondents are using robotics, 22% admits using AI, and 22% are using cognitive technologies. Moreover, 44% of the respondents declared that presently their organisations are exploring the possibilities to implement artificial intelligence and cognitive technologies, 44% and 43% respectively, 34% of them are exploring the potential of utilising robotic process automation and 27% robotics in manufacturing processes. According to the estimates these numbers are going to change in the near future. For instance, 64% of the survey respondents foresee growth ahead in robotics, 80% of them predict growth in cognitive technologies, and 81% predict growth in AI. More importantly the manufacturing sector has already started appreciating the benefits of smart solutions in manufacturing processes and is willing to make significant investments into them (*DI_HC-Trends-2019.pdf*, n.d.)

The abovementioned facts find their reflection also in the global survey conducted by KPMG International. Although according to the survey enterprises are not scaling intelligent automation technologies, which include artificial intelligence (AI), advanced analytics, and robotic process automation (RPA) fast enough to achieve desired objectives and returns, yet, those enterprises that have already started scaling IA technologies have recorded strong financial performance. More than 30% of the survey respondents admitted that their companies have allocated $50 million or more to smart automation projects and over 50% of the surveyed companies have already spent at least $10 million. These initiatives include: robotic process automation (RPA), artificial intelligence, machine learning, cognitive computing and analytics. It is worth observing that the technology that organizations are experimenting with or piloting the most is AI – 36% of the surveyed companies (‘Scalability of intelligent automation technologies directly linked to financial performance, finds KPMG survey—KPMG Global’, 2019). It is also worth stressing that according to the survey Intelligent Automation is going to be implemented on a much larger scale at enterprise level in the years to come. The detailed data regarding Intelligent Automation has been demonstrated in Figure 2.

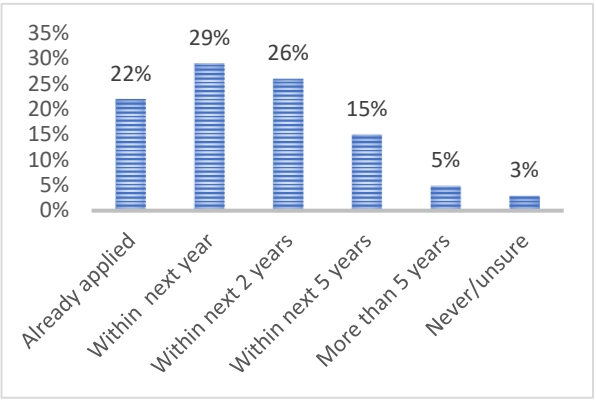

Fig. 2. State of Intelligent Automation at enterprise level

Source: own elaboration based on: *(‘Scalability of intelligent automation technologies directly linked to financial performance, finds KPMG survey—KPMG Global’, 2019)*

As it can be observed in Figure 2 in case of 22% of global enterprises that participated in the survey have already implemented Intelligent Automation in their manufacturing processes, 29% of them are going to introduce it within one year

and 26% of them within two next years. This means that Intelligent Automation will be in use in 77% of these enterprises in just two years. Interestingly, while other enterprises participating in the survey declared their readiness to introduce Intelligent Automation into their manufacturing processes within 5 years or more (20%), only 3% of them are not planning or are unsure whether they are going to make a decision on IA implementation at the enterprise level. As the survey respondent included business leaders from all over the world, it can be concluded that there is a strong conviction that application of smart solutions will grow fast among the enterprises worldwide, which will have a significant impact on manufacturing processes management in not-so-distant future.

The findings of the survey by KPMG seem to be confirmed also by the conclusions of the report by Microsoft *Artificial Intelligence in Europe: Outlook for 2019 and Beyond*. respondents of the survey conducted by Microsoft according to which 57% of the European companies expect AI to have either a high or very high impact on business areas that are referred to as entirely unknown to the company today. While referring to the core of their business present activity 65% of the European companies believe that AI will have a high or a very high impact on their core business. Also, according to the report the enterprises that apply smart technologies in their activity expect to benefit in the following four domains that have been outlined in Microsoft's Digital Transformation framework: optimising operations, engaging customers, transforming products and services and enabling employees. Brief characteristics of the abovementioned domains have been aggregated in Table 2.

Table 2. Benefits of AI application in business domains

Business domain	Characteristics
Customer engagement	Provides customers advice, shortens conversion cycles, and reduces time of resolution,
Enabling employees	Increases employee efficiency through pre-dictions, enabled support, and automation of repetitive tasks,
Product and services transformation	Speeds up product innovation cycles, enables new value add services, and provides real time support,
Optimising operations	Improves planning and reduces costs through intelligent prediction, operational efficiency, and deep insights, predictive maintenance.

Source: own elaboration based on: (*WE_AI_Report_2018.pdf*, n.d.)

Each of the domains utilises the basic functionalities of AI, namely: reasoning, which occurs through learning and forming conclusions based on imperfect data; understanding through interpreting the meaning of data including text, voice, and images; and interacting with employees, customers and other stakeholders conducted in natural ways. As the report concludes application of AI to these domains results in a transformation of a business, leading to a change in the landscape of the business itself and also the industries and eco-systems in which it operates (*WE_AI_Report_2018.pdf*, n.d.).

Application of AI in the manufacturing processes has also a significant impact on improving manufacturers' efficiency and profitability. The measure of manufacturer's productivity relative to potential - Overall Equipment Effectiveness (OEE), varies widely by industry, ranging from 75% to 91%. As the performance of companies within the same industry also varies widely, the application of AI can translate into a competitive advantage. AI can boost OEE and profitability by predicting equipment failure, which reduces the unplanned downtime, improving assets' operational efficiency and reducing utility supply costs. Additionally, implementation of AI produces very good results as far as predictive maintenance is concerned. This is particularly useful in case of predicting failures of production assets, which can be very costly. It is estimated that one hour of unplanned downtime on an automotive assembly line can cost a manufacturer £1.5m. Thanks to AI application subtle patterns in data from vibration, temperature, pressure and other sensors can be identified, which ultimately allows to distinguish leading indicators of equipment failure. By predicting more accurately which components are likely to fail, and when, parts can be proactively replaced failures to manufacturing equipment can be prevented and money saved. (*The-State-of-AI-2019-Divergence.pdf*, n.d.).

According to the report by Digital Orbit in order to apply smart technologies in manufacturing processes it is of key importance to assess the impact of their introduction on business efficiency as well as the readiness of enterprises to incorporate them across six technologies: – IoT, blockchain, AI, Cloud, 5G, video, and six verticals – Automotive, transport and logistics; consumer goods and services; healthcare; manufacturing; telecom; power and energy. The report uses scoring from 1 to 7 indicating the least and most ready technologies to be implemented in organisations. In the graphic form the scores have been presented in Figure 3.

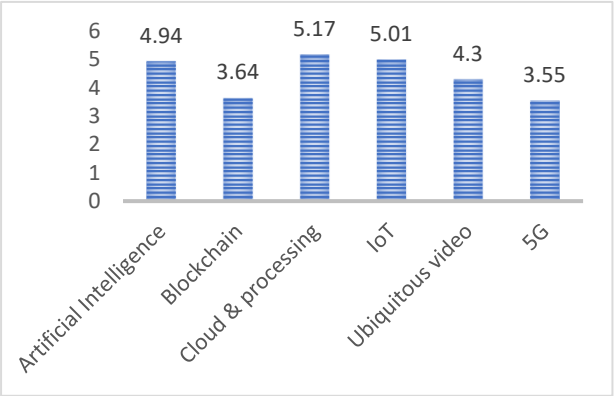

Fig. 3. Readiness score for transformative technologies

Source: own elaboration based on: *(*Ihs-markit-digital-orbit-brochure.pdf, *n.d.)*

Based on the data presented in the figure one can state that the overall readiness scores indicate that the six transformative technologies fall within three broad categories. With scores

4.9 or higher, AI, cloud & virtualization, and IoT were considered to be the transformative technologies most ready for adoption by the industries covered in the report. The less ready ones included blockchain and 5G, which receiving scores in the mid 3.0s were considered to be less ready for widescale adoption at this time. Ubiquitous video, scoring 4.3, fell somewhere in between these two groups (*Ihs-markit-digital-orbit-brochure.pdf*, n.d.).

IA is supposed to have a huge impact on the operations and nature of work in the future. However, concerns appear alongside that refer to IA being the main cause for massive jo losses. Yet, it is predicted that IA in fact will play a key role in addressing skills shortages in aging workforces, enhancing worker skills and automating the mundane to free up worker time to focus on value-added services ('Scalability of intelligent automation technologies directly linked to financial performance, finds KPMG survey—KPMG Global', 2019). In fact, in a number of industries tasks previously performed by humans can be successfully automated. In manufacturing, for example, performing physical activities or operating machinery in a predictable environment accounts for one-third of the workers' overall time. These activities range from packaging products to loading materials on production equipment to welding to maintaining equipment. As such predictable physical work dominates it is predicted that about 60% of all manufacturing activities could be automated, depending on technical feasibility, which varies for particular industries. In case of manufacturing it has been considered that 90% of welders, cutters, solderers, and brazers work represents the technical potential for automation. However, in case of customer-service representatives that feasibility is below 30 percent ('Where machines could replace humans—And where they can't (yet) | McKinsey', n.d.). Figure 4 presents the top five industries where human work can be already automated.

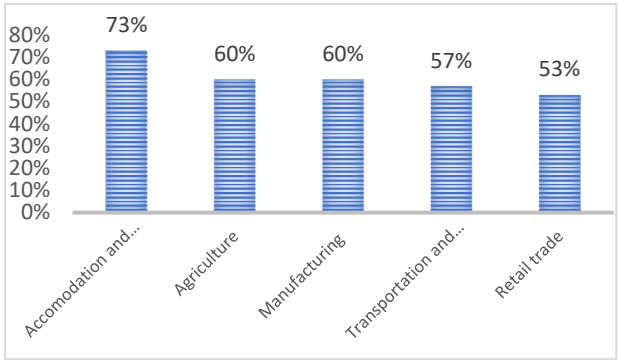

Fig. 4. Industries where tasks can be automated

Source: own elaboration based on: ('Where machines could replace humans—And where they can't (yet) | McKinsey', n.d.)

As demonstrated in the figure the industry with a possibility to automate most tasks is accommodation and food industry – 73%, followed by agriculture and manufacturing – 60% each, transportation and warehousing – 57% and retail trade – 53%. The findings of the report confirm one more time the high potential of manufacturing processes to be heading towards automation in the future, which is a meaningful indicator for manufacturing enterprises to address this issue if they wish to take advantage of the fourth industrial revolution and compete successfully on the changeable, global markets.

4. Conclusion

Advanced manufacturing processes that are being increasingly implemented across industries owe their current stage of development to a revolution in the area of Information and Communication Technologies. By offering real-time planning of production plans as well as their dynamic self-optimisation smart technologies can to a great extent improve efficiency and quality of manufacturing processes. The results of the conducted analyses demonstrate that intelligent automation technologies such as artificial intelligence (AI), advanced analytics, and robotic process automation (RPA) have produced substantial gains for the enterprises that have already implemented them. It has also been confirmed by the results of the analysed surveys that Intelligent Automation is going to be used extensively in a great majority of global enterprises in the near future. The European companies believe that AI will have a high or very high impact on business operations, even though it may concern the areas that are unknown to them today. Application of AI in the manufacturing processes influences significantly an improvement in manufacturers' efficiency and profitability, which translates directly into gaining a competitive advantage. Additionally, IA is also supposed to have a huge impact on the operations and nature of work in the future playing a key role in addressing skills shortages in aging workforces, enhancing worker skills and automating the mundane tasks.

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智能技术在制造过程中的现状和未来应用

關鍵詞
人工智能
智能自动化
网络物理系统
物联网
机器人过程自动化

摘要
本文集中讨论了在制造过程中应用智能技术的问题。 作者在其中简要介绍了有助于工业4.0概念出现的智能技术。 此外，基于在全球范围内对智能技术的应用进行的报告和调查，作者分析了在制造过程中实施这些技术的现状，并提供了在全球企业中采用基于人工智能的解决方案的预测 在不远的将来。