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INFORMATION AND COMMUNICATION TECHNOLOGIES FOR THE SOCIETY 5.0 ENVIRONMENT

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Abstract: *Current diameters of digital transformations within the Industry 4.0 paradigm identify significant challenges in enabling individual interactions with end-users depending on user requirements. For this reason, concept of Industry 5.0 appears. It implies the relevant stakeholders (employees, users, and devices) mutual interaction to address the need for personalization and mass customization of products for end-users. Society 5.0, as the latest paradigm, focuses on placing humans at the center of technological transformation and industrial automation driven by Industry 4.0. This paper aims to use analysis and synthesis methods of currently available scientific and professional literature to explore the possibilities provided by the intensive application of information and communication networks and technologies for establishing the Society 5.0 environment. Given that there are not many scientific and professional papers in this field, this paper's results will serve as a basis for understanding this paradigm and possible impact on production processes in the future.*

Key words: *Industry 4.0, Industry 5.0, Digital Transformation, Manufacturing Processes*

1. Introduction

In recent years, the manufacturing industry in the world faces several challenges, of which currently one of the biggest is the aging of society and the automation of production processes. The accelerated development of information and communication technologies (ICT) has contributed to a significant productivity improvement in the Industry 4.0 environment. Given the increase in automation through the progressive use of new information and communication technologies and networks to produce new or improved products and services, companies generate higher revenues, which increase the economic growth of society. Industry 4.0 has made digital innovations, products, and services accessible but has almost eliminated humans' role in a company's workflow. Industry 5.0, the fifth industrial revolution, which is still in its infancy, focuses on man and device cooperation within a production process. Returning

human to the very essence of industrial production leads to workers' training to provide value-added production tasks, thus achieving mass adaptation and personalization of products or services for the end-user. The establishment of a society based on information and communication technologies and focused on the human himself is a fundamental determinant of the environment of Society 5.0, which follows the development of Industry 5.0. This paper aims to explore the possibilities of applying information and communication technologies, networks, and devices to establish solutions based on meeting the Society 5.0 environment's needs. It is expected that the establishment of this environment can contribute to greater involvement of all able-bodied groups of society in production processes since, due to the currently available automation, it is not possible to achieve this fully.

2. Previous research on Industry 4.0 and Industry 5.0 environments

To fully understand the Society 5.0 paradigm, it is necessary to explore what characteristics, i.e., information and communication technologies, networks, and devices, are necessary to establish Industry 4.0 and Industry 5.0 environments. Their differences are a significant indicator of the need to establish a Society 5.0 environment.

2.1. Main characteristics of Industry 4.0 environment

The Industry 4.0 environment is evolving simultaneously as the fourth industrial revolution and represents a digital transformation of production and creating value for the product or provided service [1]. The German government presented n 2011 an idea to strengthen the competitiveness of production through high information and communication technologies strategies [2]. Expectations of the fourth industrial revolution's economic impact are significant given that one of its main goals is to promote increased operational efficiency and the development of entirely new business models, services, and products [3].

It is possible to identify four critical components for the development of Industry 4.0, namely Cyber-Physical Systems (CPS), Internet of Things (IoT), Internet of Services (IoS), and smart factory [4]. The application of Industry 4.0 in production processes so far shows how the established connections between people, objects, and systems lead to establishing a real-time dynamic and optimized network [5]. Such a network allows the creation of a smart factory. It aims to monitor assets and processes in real-time and enables autonomous decision-making processes through early stakeholder involvement, vertical and horizontal integration [6].

One of the conditions for these integrations is the wide availability of sensor networks (for example, Radio-Frequency Identification - RFID) during which smart objects that are created enable real-time communication between all stakeholders in the production system. This technology-driven development serves as the basis for using new business models in smart factories [7].

Intensive Machine-to-Machine (M2M) and Machine-to-Human (M2H) communication take place in a smart factory. Figure 1 shows the CPS used in a smart factory environment and its levels showing the above communication modes.

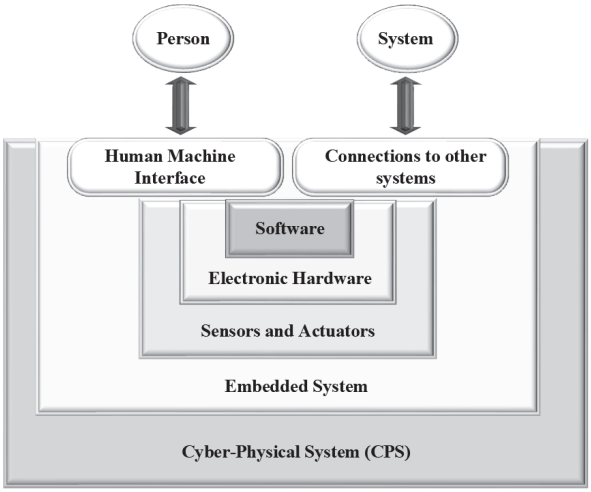

Figure 1. Humans and machines interactions via CPS processes [5]

CPS is the basis of Industry 4.0. As seen in Figure 1, it uses embedded systems with specific components to communicate and connect via IoT. In this way, difficulties between the physical and digital worlds are overcome, and the product or service's personalization is enabled to the end-user. Figure 2 shows the most critical technologies represented in Industry 4.0.

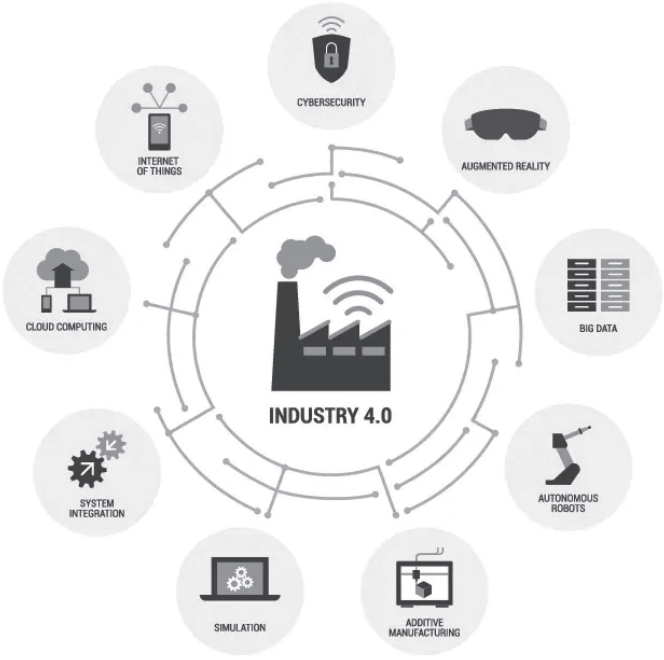

Figure 2. Overview of the main technologies of Industry 4.0 [7]

Although many technologies are part of the Industry 4.0 environment, it is essential to emphasize that Industry 4.0 does not represent or replace a particular technology but focuses on creating intelligent products, processes. Those processes that use the technologies are shown in Figure 2 [8]. End-to-end digitization and data integration in the value chain are achieved by transforming and integrating all activities in manufacturing sectors, i.e., in a smart factory environment [9], [10].

2.2. Main characteristics of Industry 5.0 environment

Mass customization of products enabled by Industry 4.0 technologies is not enough for end-users. End-users require mass personalization of products and services possible only in the case of the return of human contact in production [11]. This can be achieved by establishing an Industry 5.0 environment. Industry 5.0 refers to people working together with robots and smart machines, thus giving the automation and efficiency of the Industry 4.0 environment a personal human touch. The cooperation of man and the device itself within the factory facility increases the man's working ability and his return to the center of the production process [12].

Humans in this environment will have more significant interaction with robots, which will be one of the biggest challenges in Human-Machine Interaction (HMI). In doing so, robots will no longer have an independent role in the production automation process but will become human partners depending on the use scenario they are needed. It is a new generation of robots, the so-called cobots, which, in addition to the main functionality of quick understanding and memory, will also take care of safety criteria and processes related to work risks [13]. In such an environment, cobots will perform repetitive and labor-intensive work while people will have the role of adapting the product or service and thinking *out of the box* [14]. An example of a factory facility, i.e., the production process itself in the factories of the future in the Industry 5.0 environment, is shown in Figure 3.

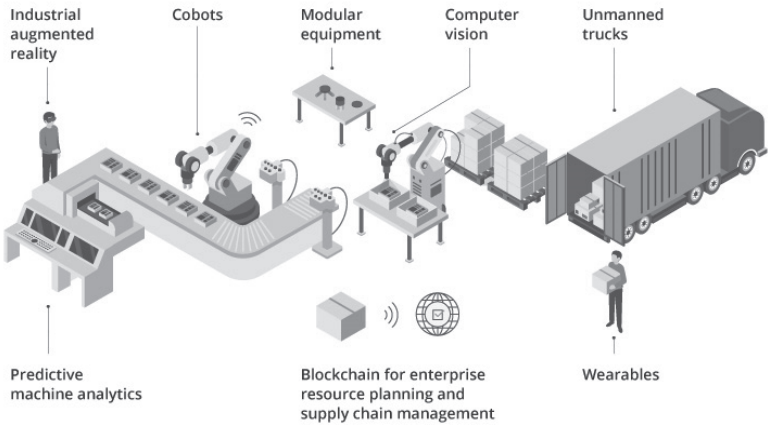

Figure 3. Factory of the future in Industry 5.0 [15]

With the establishment of the Industry 5.0 environment in the future factory scenario, each stakeholder is in mutual collaboration with machines equipped with appropriate information and communication technology. Using augmented reality (AR) technology in such an environment makes it possible to eliminate 3D printed physical models. Modular equipment such as replaceable robot parts or machines would allow a greater variety of machining itself. Predictive machine analytics refers to computers and sensors that take insights with predictive power from data obtained from machines. Computer vision uses machine-learning cameras to categorize and scan products. Wearables refer to high-tech equipment that allows workers to reduce repetitive work drastically. Blockchain technology promises the simplification of supply chain management. However, in the future factory, it could also lead to a better and simpler payment method.

Even though it is a complex environment, Industry 5.0 is based on simple tools such as 6R Methodology and L.E.D. (Logistics Efficiency Design) principles. L.E.D. is designed to improve supply chain efficiency. The main goal of these principles is to eliminate the waste created by the current situation in the customer-supplier business relationship. 6R methodology defines the order of execution of procedures, i.e., defining the model of improving the organization's business. It is not applicable exclusively in one business segment but in almost all life cycles of a business. Its phases are: Recognize, Reconsider, Realize, Reduce, Reuse, and Recycle [16].

Initially, it is necessary to identify the possibilities of industrial development and review the business and production processes in it. After that, it is necessary to understand innovation, i.e., improving the business process. Reducing the use of resources to achieve the most effective results is an essential part of the 6R methodology, as is the reuse of useful materials. Maximum recycling is one of the main results of industrial development efforts.

Industry 5.0 refers to the integration of physical and virtual space to solve both production and social problems. All advanced information and communication technologies, such as artificial intelligence (AI), AR, and data mining, should be used in industrial production and everyday life. Given the above, Industry 5.0 will have a broader and more significant impact on society itself. It is important to note that sustainability is one of the main features of the Industry 5.0 environment. Combining sustainability and mass production leads to a better approach to understanding and efficiency of the production process itself.

3. Society 5.0 environment

The Society 5.0 concept was originated in Japan in 2016. The Japanese government promoted it as an idea based on considering placing man at the center of technological transformation rather than industry. Information and communication technology is the initiator of this concept, which strives for a super-intelligent society [17]. The term Society 5.0 is a continuation of the previous development of societies (Figure 4).

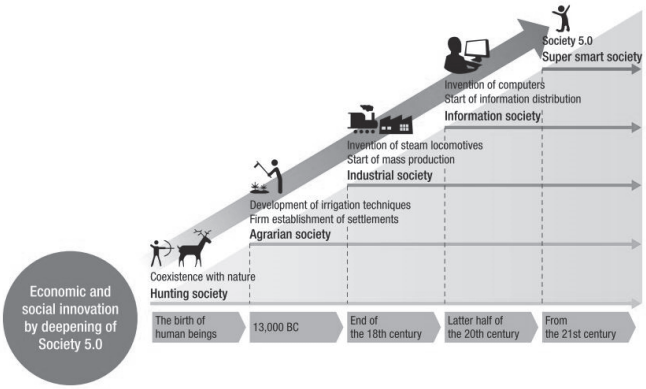

Figure 4. Overview of different phases of societies [18]

3.1. The main differences between Society 4.0 and Society 5.0

In Society 4.0 or the information society, the exchange of information and knowledge within the production environment itself was not sufficient, and the collaboration of workers and machines became difficult. People had to do a large amount of work despite the limitations in individual workers' abilities related to age and varying degrees of ability. Society 5.0 achieves a high degree of convergence between cyberspace and physical space [18].

In the previous information society, data collected from various sensors in a factory facility were stored in the cloud. When analyzing such data, employees accessed the cloud service or databases stored in cyberspace via the Internet and searched for retrieved such data. In Society 5.0, a vast amount of information collected from sensors in factory facilities in physical space and accumulates in cyberspace where AI analyzes such data. The results of the analysis are then returned to the employees in the physical space in various forms. This process brings new added value to the production process in the value chain of delivering the final product or service.

The new value created by innovation allows the provision of products or services tailored to different individual user requirements. The analysis of big data by AI in the manufacturing sector includes different types of information, such as information on suppliers' stocks, information on the delivery of the final product or service, demand for the same, and the like. The following can be achieved [19]:

- Flexible production planning and inventory management in response to current needs,
- More efficient production and labor savings,
- More efficient distribution of products or services,
- Cheaper goods without delivery delay according to the needs of end customers.

There are numerous benefits for society by using such solutions in the manufacturing sector. Some of them are strengthening industrial competitiveness, reducing greenhouse gas emissions and costs, improving customer satisfaction and stimulating consumption.

3.2. Establishing a Society 5.0 environment using information and communication technologies, networks, and devices

Table 1 shows the most critical information and communication technologies, networks, and devices needed to establish the Society 5.0 concept in the production environment and their areas of application for which they were selected for establishment. The subject of systematization is the analysis of previously published scientific research results in books, conference proceedings, and journals.

Table 1. Information and communication technologies, networks and devices for establishing Society 5.0 environment

Name	Division by type	Scope
IoT	technology	Allows varied and voluminous data gathering in the cyberspace
AI	technology	Transform to vast amount of data collected by IoT into a new type of knowledge with added value
Big data analytics	technology	Getting knowledge and value from a lot of wide assortment of information
Edge computing	technology	Innovation that empowers expanding speed and enhancement of real-time processing at the real system area, which is fundamental for expanding the usefulness of IoT.
Cloud computing	technology	Comprises a huge number of servers that are dispersed physically
Robotics	device	Facilitate work in manufacturing system
Drones	device	Improve distribution and logistics efficiency
Blockchain	technology	Critical technology for ensuring the integrity of the system as a whole
Sensor networks	network	Wireless networks of sensors at the devices that collect vast amounts of manufacturing data
Cybersecurity	technology	Backs up safe data and communication thus protecting the Society 5.0 environment from malicious attacks
Device technology	technology	Empowers fast, real-time preparation of extensive measures of information with low power utilization
Network innovation	technology	Technology that appropriates large measures of data at high limit and rapid speed
Quantum computing	technology	Developing quantum secure cloud technology by integrating quantum cryptography and secret computation into a network
Wearables	technology	Able to monitor location, body position and vital signs for learning the wearer's movements to identify anomalies
Virtual reality	technology	Remote support and demonstration of equipment installation and servicing

By searching scientific databases such as *Scopus, Web of Science, Science Direct, IEEE Xplore*, and *DOAJ* and by a selection method based on public availability criteria that directly address the Society 5.0 paradigm topic, the authors selected 20 scientific papers on which to base their analysis. These papers have been published in

scientific journals such as *Data, Industry 4.0, AI & Society, Kybernetes, Journal of Asian Public Policy, Business and Economics Journal* published by *MDPI, STUME Journals, Springer, Emerald Publishing Limited, Taylor & Francis, and Hilaris SRL*.

Also, the authors analyzed chapters in the books published by *Springer* and *Penerbit CV. Pena Persada* and …Who else? included in their analysis papers published in the conference proceedings *Quality Festival 2019, Transport and Logistics 2019, Quality Management, Transport and Information Security, Information Technologies (IT&QM&IS) and Behavioral, Economic and Socio-Cultural Computing (BESC)*.

Of all the technologies and networks listed in Table 1, AI is a crucial technology for the Society 5.0 paradigm [20]. According to the Japanese Artificial Intelligence Technology Strategy, there are five pillars of the strategy: answers to how, where, for how long, and which companies can collect, store, and share customer data [21]. Everything from the technologies, networks, and devices for establishing the Society 5.0 environment originated from the Industry 4.0 and Industry 5.0 environments. Their interaction can achieve the best results in establishing a Society 5.0 environment applicable to the production sector scenario because they enable the integration of man into the production process center. Today's incorporation of new elements into existing technologies and knowledge leads to the design of hitherto unknown business services. Also, the traditional divisions of the producer of a service or product and the end-user who uses them are lost, contributing to the creation of the Society 5.0 environment. In the future, innovative technologies based on digitized information, such as IoT, AI, and robotics, are expected to impact generating new added value in production processes significantly. Society 5.0 concept is based on these expectations, laying the foundation for innovation in the manufacturing sector in the future.

4. Conclusion

The transition of the production process from the Industry 4.0 to the Industry 5.0 environment highlights an evident change from mass automation to the process of mass personalization of products or services. The Society 5.0 environment and Industry 5.0 face the same challenges in integrating information between different industries or sectors, and they relate to standardization, overcoming regulatory and technical difficulties, and establishing information security for the construction of these architectures. One of the biggest challenges in establishing a Society 5.0 environment will be to establish an optimal balance of society's needs with individuals' needs. However, with the proper use of information and communication technologies, networks, and devices listed in this paper that enable the integration of man into the center of the production process, such a thing will be possible. The research conducted in this paper was made to better understand the paradigm of Society 5.0 and information and communication technologies, networks, and devices that can be used to establish such an environment. It is necessary to apply the identified information and communication technologies, networks, devices, and complex solutions in all possible business cases to establish Society 5.0 based environments in future work. Based on the identified technical and technological characteristics, possible application scenarios, perceived advantages and disadvantages based on previous research results, it is necessary to

achieve synergy effects and contribute to the quality of human work by establishing Society 5.0 in today's business environments.

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Sadržaj: *U dosadašnjim aktivnostima digitalnih transformacija unutar paradigme Industrije 4.0, identifikovan je značajan izazov omogućavanja individualne interakcije sa krajnjim korisnicima u zavisnosti od korisničkih zahteva. Iz navedenog razloga pojavljuje se koncept Industrije 5.0 koji podrazumeva zajedničku interakciju relevantnih učesnika (zaposlenih, korisnika i uređaja) s ciljem rešavanja potrebe za personalizacijom i masovnim prilagođavanjem proizvoda za krajnje korisnike. Society 5.0, kao najnovija paradigma, fokusira se na postavljanje čoveka u središte tehnološke transformacije kao i industrijske automatizacije podstaknute od strane Industrije 4.0. Cilj ovog rada je da metodama analize i sinteze trenutno dostupne naučne i stručne literature istraži mogućnosti koje pruža intenzivna primena informaciono-komunikacionih mreža i tehnologija u svrhu uspostavljanja Society 5.0 okruženja. S obzirom da trenutno ne postoji veliki broj naučnih i stručnih radova u ovoj oblasti, rezultati ovog rada poslužiće kao podloga za razumevanje same paradigme i mogućeg uticaja na proizvodne procese u budućnosti.*

Ključne reči: *Industry 4.0, Industry 5.0, digitalna transformacija, proizvodni procesi*

INFORMACIONO-KOMUNIKACIONE TEHNOLOGIJE ZA SOCIETY 5.0 OKRUŽENJE

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