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Key technologies in the era of 5.0

Las principales tecnologías de la era de la industria 5.0

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ABSTRACT

Keywords:

Cobots, Artificial Inteligence, IoT, Industry 5.0.

Currently, the industrial environment and society in general is in the dynamics of Industry 4.0, which is laying the foundations for the next industrial revolution. At the same time, the global health difficulties derived from COVID-19 are causing companies to look for solutions to continue operating, this situation in any case, causing industry 5.0 to take an exponential leap, causing companies to implement new manufacturing processes. Therefore, this new industrial revolution consists of taking advantage of and developing artificial intelligence to give way to the main characteristic that defines it, which is the collaboration between man and machine, working together while machines perform the heaviest and most repetitive tasks. Likewise, people are in charge of monitoring activities. Additionally, one of the fundamental elements of I.5 are industrial cobots (robotic system instituted to work together with humans) although cobots and other elements regardless of the main topic, there are also other very important aspects such as society 5.0 and the bioeconomy. In this way, this is why the main objective of this research is to present the transcendental technologies in Industry 5.0.

RESUMEN

Palabras clave:

Cobots, Inteligencia Artificial, Internet de las cosas, Industria 5.0.

En la actualidad el entorno industrial y la sociedad en general se encuentran en la dinámica de la Industria 4.0, la cual está sentando las bases para la próxima revolución industrial. A la par, las dificultades sanitarias mundial derivadas por el COVID-19 originando que las empresas busquen soluciones para seguir operando, esta situación de cualquier forma, provocando que la industria 5.0 dé un salto exponencial, haciendo que las empresas implementen nuevos procesos de fabricación. Por tanto, esta nueva revolución industrial consiste en aprovechar y desarrollar la inteligencia artificial para dar paso a la principal característica que la define, que es la colaboración entre el hombre y la máquina, trabajando juntos mientras las máquinas realizan las tareas más pesadas y repetitivas. De igual modo, las personas se encargan de monitorear las actividades. Adicionalmente, uno de los elementos fundamentales de I.5 son los cobots industriales (sistema robótico instituido para trabajar junto con los humanos) aunque los cobots y otros elementos independientemente del principal tema, también hay otros aspectos muy importantes como la sociedad 5.0 y la bioeconomía. De este modo, es por ello que en la presente investigación se tiene como objetivo principal en presentar las tecnologías transcendentales en la industria 5.0.

1. Introduction

Industrial revolutions invariably provide novel machinery to facilitate people's labor, as humans endeavor to delegate arduous, monotonous, and occasionally tedious duties to these machines. In the near future, machines, robots, and other forms of artificial intelligence will be responsible for carrying out tasks related to production, transportation, and cleaning [1].

What is more, the rapid advancement of technology has led to the emergence of collaborative robots (cobots), which are now being utilized across several sectors including manufacturing, medical, space, and military industries.

It is worth mentioning that each of these cobots operates with intelligent software, resulting in human-technology interaction. Figure 1 depicts the evolution of the industrial trend over time.

Ultimately, the goal is for humans to retain control over robots responsible for producing goods or providing services, such as transportation [2].

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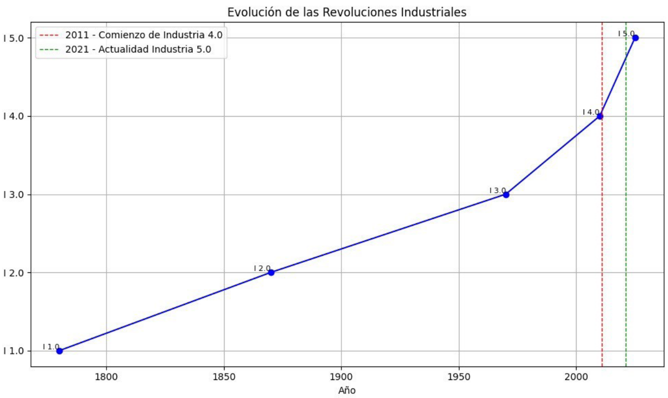

Figure 1. Industry evolution.

Society is currently in the era of Industry 4.0 (I4.0), which is soon reaching an end-stage to make way for the next industrial revolution, known as I.5. The main difference in I.5 is the utilization of human creativity in new industrial processes or else everyday life. However, instead of people performing all the work, it will be done through collaboration with efficient, intelligent, and precise machines aiming to develop personalized manufacturing that maximizes resources and provides a unique experience to society [3].

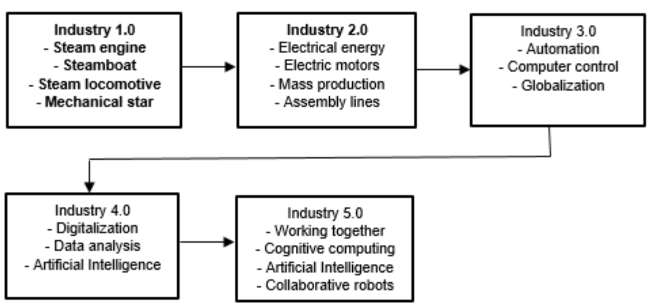

Figure 2. Industrial Revolutions

2. Basic concepts of industry 5.0

The period between 1760 and 1830 witnessed the emergence of the Industrial Revolution in European nations, characterized by the exploitation of steam power in labor and the creation of machinery that ran on steam. This helped some European countries to become manufacturers, exporters, and suppliers of raw resources, which had a significant industrial influence and allowed them to expand globally as technology advanced throughout time [4].

Therefore, the term "industry 5.0" (I.5) was first introduced on December 1, 2015 by Michael Rada in an article. Rada defines I.5 as the collaboration between machines, advanced technologies, robots, and humans to carry out efficiently production and social activities [5].

Nowadays, some numerous products and processes are automated by robots, including self-driving cars equipped with artificial intelligence, robot-assisted supermarkets, and robots used in various industrial activities. While this represents significant technological progress, it raises concerns about the societal implications and acceptance of 1.5-related advancements [6]. Figure 2 illustrates the progression of the industrial revolutions, highlighting the specific technologies associated with each phase. Simultaneously, the graphic represents the disparity between each industrial revolution, in which Industry 4.0 encompasses digitization, data analysis, artificial intelligence, whereas Industry 5.0 focuses on human-machine collaboration, cognitive computing, and cobots (collaborative robotic systems).

2.1 Would 1.5 industry be able to effectively adjust to several job roles?

The COVID-19 pandemic has compelled numerous companies, entrepreneurs, and independent workers to seek strategies for mitigating the adverse labor consequences, which was highlighted in a study conducted by the McKinsey Global Institute, encompassing 9 countries, focusing on the United States. The study specifically examined various occupations and their corresponding tasks, revealing that administrative activities exhibit the highest proportion (refer to Figure 1). Moreover, it underscores the readiness of industrial activities for automation and artificial intelligence [7]. Hence, the primary aim of this article is to provide a concise overview of the pivotal technologies that facilitate the advancement of Industry 5.0.

2.2 Cognitive Computing

Cognitive technologies are being introduced into the scientific sector and are highly advanced as they continuously analyze and handle a substantial amount of data and information [8]. Similarly, Stella [9] asserts that cognitive computing is the direction in which computer science is moving, aiming not only to replicate elements of the human mind but also analyze information at an accelerated rate. Cognitive systems, as described [10], are closely linked to artificial intelligence (AI) as they not only imitate human thought processes, but also engage in reasoning, learning, and assessing the potential hazards of their activities. The rapid evolution of machines in cognitive computing is consistently sparking controversies within the computer world [11], [12].

The objective of cognitive computing is to address problems autonomously, without the need for human intervention. This technology is not limited to the industrial and scientific sectors; it also spans fields such as literature and art, where computer systems equipped with vast amounts of data and algorithms can comprehend human behavior. In society, cognitive computing is evident in devices that utilize voice commands, facial recognition, and digital assistants [13], [14]. Cognitive computing is increasingly becoming a fundamental element for the creation of a more advanced and improved digital world for human beings [15], [16].

2.3 Artificial Intelligence

Artificial intelligence (AI) seeks to develop algorithm-based systems capable of emulating human decision-making and mimicking human behavior, AI research involves studying and analyzing human behavior to gain an understanding, solve problems, and enable autonomous decision-making using computers One example of this is the use of robots that are capable of performing activities with a level of similarity to humans, or even with superior precision. These robots are able to make judgments by evaluating risks and impediments. As long as AI persists in gathering data, its systems and robots will have the capability to carry out a wide range of operations, and potentially enhance them. The references [17] and [18] are provided. From a production standpoint, the industry is integrating with artificial intelligence (AI) to create a smart manufacturing sector. This is achieved through the implementation of automatic programming, computer natural language processing, robots, and intelligent data management and retrieval. The manufacturing industry is being transformed by intelligent multi-agent systems and AI technologies, which enable it to effectively tackle modern challenges by enhancing company performance and productivity through the utilization of flexible robots and systems, combined with AI, to provide customized products, reduce production time, and increase mass production [19].

2.4 Evolutionary Robotics

Robotics is the scientific discipline concerned with the construction of machines, equipment, and robots that are capable of carrying out tasks automatically. The I.5 should rely on a specific subfield within robotics. Evolutionary robotics seeks to develop robots that are more resilient and versatile These robots differ from those that are programmed through simulation. An evolutionary robot employs evolutionary algorithms, enabling it to learn from its environment by processing input data and generating output data, thereby making autonomous decisions [20].

Traditionally, robots have primarily been utilized in the manufacturing sector. However, this is no longer the case. Nowadays, robots are increasingly being employed to assist individuals in their homes and personal lives. Evolutionary robotics, which incorporates cognitive computing, is paving the way for the development of service robots capable of autonomously performing tasks, navigating the real world, and continuously acquiring new knowledge. Evolutionary robotics is a very intricate field; however, by utilizing appropriate software, robots have the potential for continuous evolution [21], [22].

3. Development

3.1 Elements for the implementation of Industry 5.0

3.1.1. Online training. This is a form of instruction where researchers and scientists utilize specialized software to impart particular jobs or abilities to various types of robots in distinct sectors such as industrial, social, construction, environmental, security, and others when relevant. These trainings are conducted in a virtual or simulated setting. By integrating artificial intelligence (AI), trainers have the ability to instruct and educate various entities, ranging from a mechanized arm capable of hoisting a solid mass of concrete to a sophisticated system that replace human drivers and pilots. This form of training effectively minimizes expenses and enables the provision of secure surroundings, cost-efficient services, and precise procedures. It prevents losses and assesses potential incidents that may occur in real settings, without causing hazards to others [23].

3.1.2. Intelligent autonomous systems. These systems utilize artificial intelligence to independently manage intelligent assembly lines. The programming department assigns an objective function, and the system generates its own sub-objectives, by analyzing acquired data, it learns to navigate the environment and constructs pathways to achieve the primary objective. The functioning of AI enables the machines in the system to respond to their decisions, thereby storing the outcomes for future use in devising intelligent solutions to potential difficulties in their surroundings. The expertise and resilient structure of these systems will be a crucial asset that every organization should adopt in the fifth industrial revolution [23].

3.1.3. Cobots, (also known as collaborative robotic systems), are robotic devices capable of manipulating things of varying sizes and weights. Also, they are machines designed to work alongside humans in a cooperative manner and can do a wide range of manual tasks. A Cobot may be able to assist the operator in many activities, such as handling parts, packaging, welding, and others, based on its software programming. The specific activity done depends on the type and model of the Cobot. Cobots are specifically engineered to possess high mobility and adaptability, enabling them to seamlessly transition between various settings, such as providing surgical assistance in hospitals or conducting assembly tasks in automotive factories [24].

Incorporating cobots is crucial for organizations aiming to transform their factories into smart factories. While many companies still rely on robots or industrial machinery that require safety guards to keep operators at a safe distance, cobots may offer a safer alternative. By integrating cobots, companies can effectively mitigate workplace accidents. They are user-friendly and can be programmed to adjust their speed, ensuring safe operations. Moreover, it aims to automate processes, enhancing productivity by eliminating repetitive tasks and minimizing potential hazards [25], [26].

I.5 industry emphasizes the importance of robots and workers working together rather than working independently so that they can coexist and collaborate simultaneously, (as shown in Figure 3). This involves working synchronously, with the robot matching the speed of the operator. Additionally, the robot and the operator should share tasks and learn from each other, fostering a collaborative and supportive working environment [27, 28].

Figure 3. Robots and humans working side by side

3.1.4. The Internet of Things (IoT). IoT is a platform that ensures interoperability between devices, regardless of their physical characteristics, operating systems, service providers, or communication technologies by creating a network that connects everything. Meanwhile, The Internet of Things is currently a popular and influential technology that includes several concepts such as cloud computing, edge computing, communication protocols, electronic gadgets, sensors, and geolocation among others. According to statistics from CISCO, (a telecommunications company), since 2020, there have been over 50 billion internet-connected devices operating in conjunction with the Internet of Things (IoT). These devices serve various purposes to enhance user convenience in different sectors such as automotive, healthcare, industrial, commercial, and social networking. For instance, an intelligent security system can activate a camera and provide lighting upon detecting movement, it then sends an alert signal via the internet to the authorities, recording the incident. Another example involves a machine malfunctioning, which can only be fixed by a company located in another country. In such cases, data can be transmitted or video calls can be made to provide instructions, eliminating the need for physical presence [29], [30], [31].

3.1.5. Smart manufacturing. To meet the demands of real-time operations, all machinery is interconnected over the internet and equipped with state-of-the-art electronics, enabling users to monitor and track processes on a step-by-step basis. Smart manufacturing provides workers with flexibility through extensive human-machine interaction. It encompasses several technologies such as collaborative robots, simulation, the Internet of Things, data analysis, additive manufacturing, and augmented reality [32], [33].

Smart manufacturing poses a future game-changer of industrial production systems, as it is a technical movement, which is transforming lean manufacturing plants into intelligent, digital, and personalized factories that permeate industries such as pharmaceutical, automotive, food, electrical, and military production etc. [34].

3.1.6. Multi-agent systems and technologies. A multi-agent technology system is composed of several distinct characteristics. Firstly, these systems are autonomous, meaning they have the ability to make independent decisions. Secondly, they are cooperative systems that facilitate the collaboration between humans and machines through their functions and tools, which allow them to adapt to various problems. Furthermore, these systems are communicative, as they exchange information with each other and relay the acquired data to humans. Lastly, they are proactive systems that possess fault-tolerance capabilities, enabling them to identify and address issues. They not only learn from these faults but also propose solutions to overcome problems [35], [36], [37].

3.1.7. 5G networks. The I.5 necessitates the handling of a substantial volume of data, which is why the 5G networks play a crucial role in this industrial revolution. The 5G network is a wireless system designed for extensive communication and the transmission of vast quantities of data. If an individual desires to establish a connection between themselves and their phone to remotely control a robot within their work area, the 5G system is the optimal solution. This is due to its ability to offer high-speed communication and ample storage capacity for both the data inputted by the operator and the data generated by the robot's artificial intelligence [38], [39].

4. Advantages

4.1. Self-directed learning

Undoubtedly, one of the most crucial study branches of AI technologies is autonomous learning. This type of learning may be categorized into three distinct types: supervised learning, unsupervised learning, and semi-supervised learning. The first type of learning involves training the computer with algorithms to recognize and solve problems. In the second type, the computer is allowed to observe, analyze, and identify the necessary processes to solve a problem without being given explicit guidance. Ultimately, there is semi-supervised learning, which utilizes data from unsupervised learning to create a more established method of supervised learning [40], [41]. As artificial intelligence increasingly mimics human actions, it acquires more knowledge and improves performance without requiring additional data or inputs. The machine learns to provide recommendations for potential problems, classify them, detect anomalies, and enable predictive maintenance. Consequently, it can prioritize products based on people's lifestyles [42].

4.2. Personalized production

Customization is a prominent trend in the industrial market, encompassing both the manufacture of customized products and the customized manufacturing process. By adopting Industry 5.0, companies can achieve cost-effective mass customization of products, meeting the precise demands of customers, and embracing these new technologies can enhance competitiveness and increase the likelihood of success [43], [44], [45].

I.5 will revolutionize value chains by transitioning from traditional mass production to customized mass production through the use of high-speed production lines that incorporate cobots. However, throughout the entire process and in the end product, there will always be a human element of involvement and control. Through the implementation of these novel procedures, clients will experience a sense of exceptional quality and contentment [46].

4.3. Smart logistics

Smart transformation manufacturing should go hand in hand with intelligent logistics transformation partnerships to enhance their competitiveness. In practice, the collaborative transformation of intelligent logistics involves two crucial elements. Logistics, with the aid of technology, can optimize warehouse operations by thoroughly assessing suppliers and their products through a comprehensive study of their attributes [47], [48].

I.5 collaborates with automated warehouse robots, which belong to a new generation of environmentally friendly storage solutions to enhance productivity and adaptability. Performance evaluation systems are conducted and design guidelines are provided for robot velocity. Open queue models are constructed to analyze the new order fulfillment system and determine the system's performance time based on the number of robots.

5. Disadvantages

5.1 Human Resource Downsizing

The continuous advancement of technology enhances societal well-being and streamlines processes. Yet, this progress also leads to a natural resistance to change. For instance, the introduction of Industry 5.0, which aims to replace human labor with mechanical arms, may raise concerns among workers who fear being replaced by robots as this development could potentially impact their professional and economic livelihoods [49].

In this emerging era of industrial revolution, there is a discernible trend of diminishing human capital. It can be characterized as a competition between humans and machines, wherein machines hold a significant advantage due to their superior performance. Machines, on the other hand, possess the ability to operate round the clock, while humans require some rest. Additionally, machines are capable of executing calculations at a much faster pace than humans. The only advantage humans retain is their unique perspective. Consequently, organizations aiming for faster and higher quality procedures will result in downsizing human staff [50].

5.2. Lack of knowledge

One potential drawback is the need for expertise in handling advanced tools, particularly I.5 robots. Collaborative robots, in particular, require specialized knowledge and skills or otherwise, without these qualities, issues such as production delays and damage to the robots may arise. Therefore, industries and sectors implementing I.5 technology should prioritize training, particularly in the field of programming [51].

The lack of knowledge poses a significant challenge due to the utilization of intricate computer language in industrial robots and new technologies, which is not comprehensible to everyone, and if the operator selects the wrong command, symbol, or button, it can lead to more significant issues, resulting in delays and downtime. These consequences, in turn, translate into financial losses for the company, so if in the event a company considers to successfully implement Industry 5.0, it is necessary to address the lack of knowledge. This can be achieved by hiring qualified personnel, providing training, or enhancing the machine's interface to reduce the number of commands [52].

6. 5.0 Industry and its impact on various sectors of society.

6.1. In medicine field.

The area of robotics has been essential in aiding humans since its inception and is currently being employed to preserve human lives in the medical domain. Robotic arms capable of performing surgical procedures, such as making a scalpel cut, can achieve high precision by relying solely on Cartesian coordinates. Through the use of simulation, visual training, and machine learning, a robotic arm has the potential to outperform a surgeon in terms of accuracy [53]. COVID-19 has prompted the medical community to explore solutions for combating the disease. One such solution is the use of disinfection robots, which efficiently perform disinfection tasks, minimize human interaction, and lower labor expenses. These robots are equipped with an artificial intelligence algorithm and utilize sensors to identify the specific area that has to be sterilized, their implementation includes 3D modeling, which enhances accuracy and coordination, enabling them to navigate around obstacles more effectively. The robot also determines the type of disinfection, quantity of dosages, and timing [54].

6.2. Within Environment

6.2.1. White biotechnology. sometimes known as industrial biotechnology, is a branch of biology that utilizes the biodiversity present in nature to produce raw materials for industrial operations. Industry 5.0 has led to the development of other creative items, including the manufacture of synthetic spider silk as a potential replacement for high-voltage cables, and the manufacturing of highly elastic rubbers from non-rubber tree plants. In conjunction with Industry 5.0, white biotechnology will facilitate the development of novel procedures for acquiring new raw materials, enhancing resource durability, and maximizing the utilization of solar energy. These advancements will have positive implications for the environment [55].

White biotechnology is a crucial sector in Industry 5.0, encompassing various areas that can be classified into four groups: industrial, pharmaceutical, agriculture, and environment. Within these groups, the most notable topics include biosynthesis, nanotechnology, nanoparticles, genetic engineering, environmental biotechnology, and plant and animal biotechnology. Biotechnology is an emerging and rapidly expanding field that has the potential to become a fundamental driver of innovation and societal growth [56], [57].

6.2.2. The bioeconomy. This is a solution to the environmental and social issues caused by the improper utilization of natural resources and the limited availability of supply. The bioeconomy refers to the utilization of renewable resources from the Earth to replace fossil fuel resources and create more environmentally friendly products [58], [59], [60].

In this regard, I.5 has developed two tools for cultivating photoautotrophic algae: raceway pond systems and Packed Bed Reactors (PBR). The raceway pond system is a pond with a specific depth that is exposed to sunlight. Inside the system, water is pumped to prevent sedimentation and restrict the penetration of light into the algae crust. The PBR is another tool used in the cultivation process. PBR reactors consist of a series of transparent tubes that host the culture and a central reservoir through which the microalgae broth is pumped [61].

6.2.3. In Social Environment.

1. 5.0 Society

   When discussing a country that has experienced significant industrial advancements, Japan is undoubtedly a prime example. It is widely recognized as a leader in innovation, research, and technology. Japan is currently introducing the concept of the 5.0 civilization, characterized by a highly intelligent society in which all aspects are interconnected through artificial intelligence. Despite being in the early stages of development, it is anticipated that there will eventually be a ubiquitous presence of robots in households, assisting humans with their everyday tasks and enhancing their quality of life [62], [63].

   The 5.0 society aims to deviate from prevailing patterns by prioritizing security over freedom. Its primary goal is to establish a new way of life that enables individuals to enhance their economic and familial progress. The 5.0 society strives to include all societies and educate them about the benefits of digitalization, which can significantly enhance their productivity [64], [65].

2. 5.0 Hospitality

   The COVID-19 pandemic has had a significant impact on various industries, including the hotel business. Therefore, ensuring hygiene, disinfection, and cleanliness are crucial components for the recovery of their economy. Several hotels are implementing the ideas of the I.5 in their facilities, resulting in the emergence of hospitality 5.0, which offers a "personalized experience" for clients through human-computer interaction. Upon arrival at the hotel, clients can interact with either an interactive robot or an intelligent system with a touch screen. The hotel will have control points where disinfection functions are performed. The rooms will be equipped with artificial intelligence through sensors, touch screens, and voice command capabilities. Lighting and heating in the rooms will also be controlled. During their stay, clients will have access to scanners to evaluate the quality of the food, at the end of their stay, the customer's health will be checked through sensors. All data collected throughout this process will be uploaded to a cloud platform for evaluation and service improvement [66], [67].

   Hospitals must enhance its operational efficiency by leveraging 5G networks to facilitate seamless and robust communication between healthcare facilities and patients. This technology offers unparalleled speed, reliability, and extensive data storage capabilities. Also, hospitals will proactively address the patient's health issue before they arrive at the facility. Hospitals can enhance the quality of life for patients by adopting new technologies including tele-robotics, hospital-patient device communication, augmented reality, 5G printing, unmanned vehicle control, and artificially intelligent robots through the implementation of Industry 5.0 [68], [69].

3. Smart Homes

The introduction of smart buildings is set to revolutionize traditional architectural structures across various sectors, including residential, commercial, industrial, hospitality, and transportation etc. These buildings will be equipped with advanced platforms that enable efficient monitoring and control of various operations, for instance, an intelligent home will offer features such as electric vehicle charging stations and state-of-the-art security systems with built-in intelligence. Every autonomous system within each building will possess the capability to acquire knowledge and autonomously make judgments that will be advantageous to both individuals and overall productivity [70], [71], [72].

First modern intelligent buildings utilize the KNX system (EIB KONNEX), which is the global standard for controlling many building systems such as lights, sensors, buttons, heating, ventilation, cleaning, and general alarms. The KNX system is initiated by the A.I. platform, which oversees the security layers and application interfaces that manage the access doors for various equipment in the building and supervise the actions to be carried out by workers [73], [74].

7. Conclusions

The fifth industrial revolution (I 5.0) will have a more significant impact on the world compared to previous revolutions. Artificial intelligence and autonomous learning will play a central role in this revolution. By allowing machines to perform most of the work, humans will have more time to focus on creating and innovating. The integration of robots into our lives is a significant and exciting change that reflects an improved standard of living in society. Although the COVID-19 pandemic may eventually come to an end, it is important to recognize that similar situations could arise in the future. Consequently, companies are compelled to revamp their production systems as the most effective solution lies in automating their processes through the use of collaborative robots. Additionally, individuals will have the ability to remotely monitor and control these new processes, ensuring that production lines never cease. All in all, to thrive in the emerging industrial era, companies must prioritize both mass production and customized manufacturing as their key features.

5.0 Industry will not only be in the industrial sector with collaborative robots, it will be present in medicine with robots that help to prolong human life with neural systems and synthetic biology. Likewise, the form of education will be different, the new generations will have more interaction with technology in order to continue innovating. The means of transportation will change drastically with the help of drones and unmanned vehicles, the environment will be helped by creating new alternative energies, trade will become a great battle and the winners will be those who exploit personalization the most. In short, man-machine collaboration will be present in every corner of the world and although society is at the end of industry 4. 0. Research reported in the literature indicates that society in general will enter fully with the 5.0 industry in early 2025, where everything we knew will be reinvented. Artificial intelligence is in an unstoppable pace paving the way to the possible sixth industrial revolution in which possibly nanotechnology and the conquest of space would take place and when that happens humanity will no longer see life in the same way.

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