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The Role of Industrial and Service Robots in Fourth Industrial Revolution with Focus on China

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Abstract

In the last ten years, digital technology has significantly contributed to the change of people's lives worldwide, because its application has caused a rapid transformation of all aspects of human life, and especially fast transformation in the design, production, operation and maintenance of the production system, which caused an unexpected jump in productivity. It can be said that fourth industrial revolutions ongoing process, which can be labeled in a variety of ways, such as "intelligent factory", "smart industry" or "advance manufacturing". Development of the digital technologies in the last twenty years has introduced us from third in the fourth industrial revolution. The first time the term "Industry 4.0" appears in the Germany in year 2011 whose government promotes automation of production processes by introducing digital technologies. Germany is one of the most technologically developed countries in the world and it is logic that this revolution begins there. This example follows the other countries in the world. Fourth technological revolution depends on a number of new and innovative technological achievements. It is necessary to integrate production processes in all production phases and further applications by using ICT technologies for digitalization. The automation of production processes must include advanced sensors and intelligent robots that can be self-configured to be able to make specific product. It is necessary to collect large amounts of data to be analysed and used in the production processes. It is also necessary to realize network communication (include mobile and internet technology) between machines in the production process, the production system and the operator, as well as suppliers and distributors. Application of previously mentioned leads to the intelligent manufacturing processes that have a wide range of change of production processes. To intelligent process we can come only by applying intelligent industrial robots because they represent one of the cornerstones of the fourth industrial revolution. In this paper an analysis of industrial and service robot application in production processes. With the implementation of digital technology, robot technology and other advanced technology we, as a society, strive for intelligent automation, and intelligent factories, and thus create a society in which wealth, created through the strengthening of global competitiveness, will serve for resolving social issues in society.

Keywords: industry 4.0, digital technology, production processes, M2M, intelligent automation, industrial robot, service robot.

1. Introduction

Automation of production processes in the industry began in sixties of the last century when in the automation industrial robots have been included and continues to this day. However it must be recognized that it was rigid and not flexible automation. Reason for this is the fact that if another product is in the same production line, it was necessary to reprogram each robot, change the tools and end effectors etc. This required a delay in production. It lasted long as it meant the additional cost in production. We have to mention the fact that industrial robots have been fenced off for reasons that would hurt operators who worked in the production process. In the last 20 years digital technologies have been developing that are being implemented and in production processes.

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Many believe today that we are on the beginning of the new industrial revolution. It is considered that this is for humanity fourth step which can be entitled fourth industrial revolution or "Industry 4.0".

This term first time have been emerged in 2011 in Hanover Fair in Germany. This is development concept which is mostly coincides with development in European countries. Can be called as "Intelligent factories", "Smart industry" or "Advance manufacturing". Fourth industrial revolution is nothing else then set of rapid transformations in design, manufacturing, work and maintenance of the manufacturing systems, which causes sudden jump in productivity and change of human life in whole world. Fourth industrial revolution is successor of three earlier industrial revolutions (Figure 1). As already known, first industrial revolution begins with year 1784 in the middle of the 18th century when steam engines had been implemented in manufacturing processes. The second industrial revolution begins in year 1870 in the end of the 19th century when electrical energy had been used significantly. Mass production is implemented on the moving lines driven by electrical motors. The thread industrial revolution begins in year 1970 in 20th century by implementation of electronics and informational communication systems and industrial robots which additionally automatize manufacturing processes. Currently we are in the beginning of fourth industrial revolution which is characterized by so-called "Cyber-physical systems" (CPS).

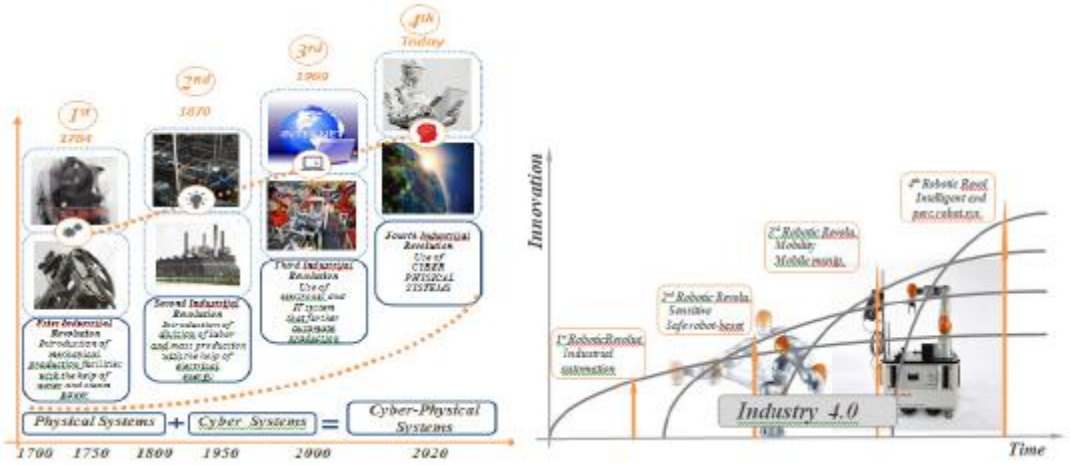


Figure 1 Technology industrial revolutions in time periods and development of robotic technology

Potential for transformations of manufacturing processes in Europe and whole world in upcoming period is in using digital technology, sensor technology, robotic technology and other advanced technologies which leads to applications of new sensors, expansion of network communications, layout and networking of robots and machines, increase of computer capacities by lower prices. The fourth industrial revolution gives us greater flexibility in production processes, maximum adjustment of production to rapid change in the direction of customer requirements, increasing the speed of production, better quality and increased productivity. Companies to stay on the market and to be competitive need to use these advantages, invest in new equipment, information and communication technology (ICT) and perform data analysis that will be on hand throughout the global value chain. The development of digital and advanced technologies, as well as innovation in production processes represents a challenge for the development of all technologies including robotic technology [1,12- 21,23,24,25,26]. The convergence of digital and other technologies, primarily referring to the sensor technology have influenced to develop robotic technologies as indicated in Figure 1.The first generation of industrial robots is the first robotic revolution that occurs in sixties to seventies of the last century, and it is the industrial automation that is most implemented in the automotive industry, and many other manufacturing processes. Digital technologies, ICT technologies, sensor technologies and many advanced technologies change this situation which led to development of second generation robots. Today we are in second generation of robots where robots have more power to sense environment and there is no need to separate them with fences. Humans collaborate with robots. Fourth industrial revolution "Industry 4.0"has contributed to the development of the robotic technology because strategies of the leading courtiers are to go to the full automation of production processes or "intelligent automation". This leads to the fourth robotic revolution in robotic technologies when all robots is going to be intelligent. The second generation of robots has created new requirements for increased productivity and surpassed the industrial robots of the first generation.

The reasons for this are many: making robots easier to program and use, enhanced the ability to manipulate (does a diverse array of tasks), reduced size and cost of the robot, robots are working in a wide range of dynamic environment and work together with people. Challenges for the development of robot technology from the first generation of industrial robots to service robotics, or most important technology for shaping the future ability of robots lie in the direction of three technical areas as indicated.

Figure 2.The first technical area is knowledge which gives the robot the ability to perceive, understands, and plans to move into the real world. This feature improves cognitive robot capabilities so that the robot can operate independently in different complex environments. The second technical area is manipulation which gives to robot precise control and a competence to perform manipulation of objects in his environment. In this way, a significant improvement exists in the robot control, which gives the possibility that the robot can assume a greater variety of performing tasks in a variety of manufacturing processes.

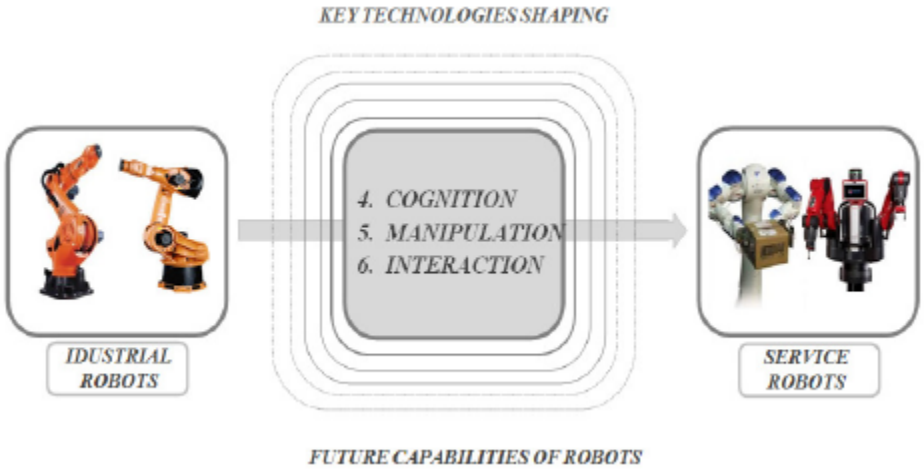
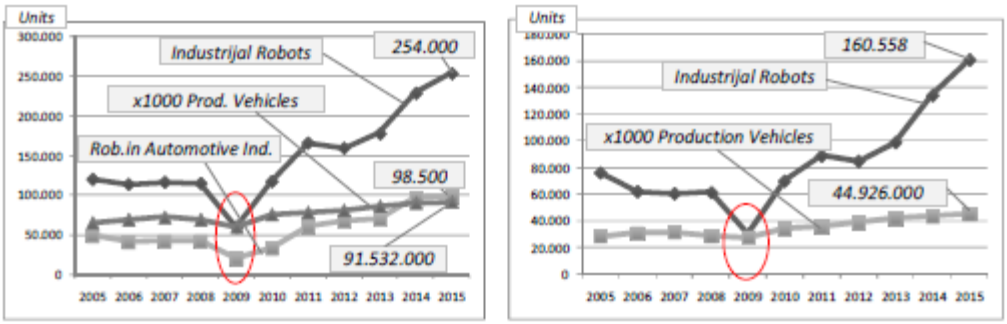


Figure 2 Significant technologies in capability shaping of the future robots Third technical area is interaction. Represents one of the most important areas because it gives the robots to learn and collaborate with people. Also improving interaction robot - human for the verbal and non-verbal communication. The robot has the ability to observe and copy human behaving and learning from experience. Safety first is the absolute prerequisite for the operation of robots with people in the neglected environment. Digital technology made possible the development of many digital devices (microprocessors that are the brains of digital devices and systems) tremendous acceleration through the Internet in the industry by: video cameras, RFID readers, mobile phones, tablets, computers, improving the quality, safety, production, maintenance plants, increase efficiency and effectiveness in all areas.

2. Implementation of Industrial Robots in Production Processes in the World and China With Reference to Automotive Industry

Today it is impossible to imagine the production process in any industrial branch without industrial robots. In order to get an actual idea on the modernization and automation of production processes in the industry, and given that we are in the 21st century, but also that we are currently in the fourth industrial revolution called "Industry 4.0", it is necessary to make a review of the representation of industrial robots in the past ten years. The statistical data for the above analysis of the number of industrial robots were taken from the International Federation of Robotics (IFR), the UN Economic Commission for Europe (UNECE) and the Organization for Economic Cooperation and Development (OECD) [2-11, 22,24], whereas the data on the number of produced vehicles were taken from the Verband Deutscher Verkehrsunternehmen (VDV) [11, 12, 22, 24], which are graphically shown in Figure 3a). Having in mind that the largest companies for vehicle production are located on three continent Asia/Australia as well as the fact that the highest number of industrial robots has been installed in the automotive industry production processes, we have conducted an analysis of the representation of industrial robots and vehicle production on the three continents in the period 2005-2015, as shown in Figure 3b).



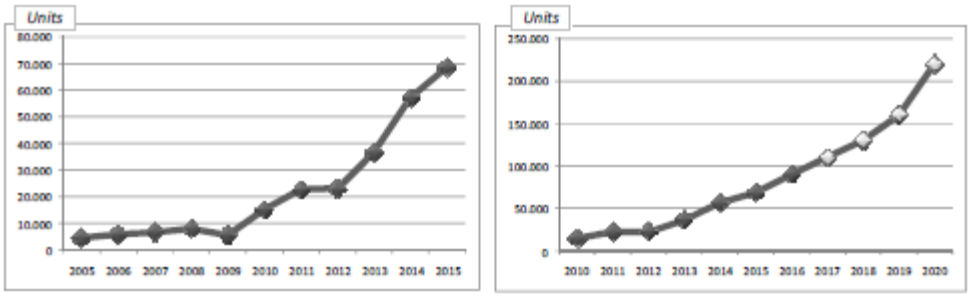
a-World *b- Asia/Australia*

Figigure 3 The tendency of representation of industrial robots and vehicle production in production processes in World and, Asia/Austarlia in period 2005-2015[2-11,24]

Analysis of the diagram displaying the representation of industrial robots in the world in the period 2005-2015 (Figure 3a) brings us to the conclusion that the presence of industrial robots in the world for the period 2005-2006 was nearly constant and was about 115.000 robot units. In 2009 the application of industrial robots has dropped significantly to around 60.000 robot units as a result of economic and industrial crisis in the world. In the period 2009-2015, the representation of industrial robots is growing on annual basis and in 2015 it reached the value of about 254.000 robot units. The diagram of the representation of industrial robots in the world in the automotive industry and the tendency of application of industrial robots in all industries are completely similar, except that application is lower, ranging from 32-40% of the total application of robots depending on the year. Thus, in 2015 industrial robots in the automotive industry are represented with about 98.500 robot units which is about 38.75% of the total application of industrial robots in the world in this year. As can be seen, the largest number of industrial robots is represented in the automotive industry in the automation and modernization of production processes, which resulted in the number of vehicles produced in the world, as shown in the third diagram in Figure 3a). When the vehicle production is in question, the tendency is growing annually, so that from 66 million vehicles produced in 2005, in only ten years the production increased to 91.5 million vehicles. We can conclude that with the increase of the representation of industrial robots in the automotive industry in the world in ten years, vehicle production increased for 40%, which seems logical as the automation of production processes in the automotive industry such as body welding, body painting, assembly and control, lead to decrease of the processing time and increase in vehicle production. Based on the diagrams in Figure 3b), the representation of industrial robots in manufacturing processes in all industry branches on all three continent of Asia/Australia in the period 2012-2015, we see that there is a growing tendency of application of industrial robots on all three continents. In 2009 world recorded the lowest representation of industrial robots (as shown in diagram 3a), because there was the economic and industrial crisis in the world that also affected the application of robots on all three continents. We can conclude that in period 2009-2015 all three continents experienced a growing trend of representation of industrial robots in production processes, with the exception of a slight decline in the application of industrial robots in 2012 in Asia .

In the period 2005-2009 the tendency of application of industrial robots in Asia/Australia is declining. The highest representation of industrial robots in the world is on the continent of Asia/Australia for example, in 2015 they applied 160.558 industrial robot units in all production processes. Such high representation of industrial robots is reflected in the production of vehicles, thus making Asia/Australia the first in the world in the production of vehicles. The tendency of vehicle production in Asia/Australia in the period 2005-2015 is continuously growing from year to year, so that in 2015 the production of vehicles reached the amount of approximately 44.926.000 units of vehicles. The consequence of the tendency of increasing vehicle production in Asia/Australia is continuous increase in the representation of industrial robots during automation of production processes and in the automotive industry. In addition, the fourth industrial revolution is leading to "smart factories" that are expected in a decade, for which the most responsible is the application of robotic technology and information technology (IT). Since we came to the conclusion that Asia/Australia is the first place in representation of industrial robots, as well as the first in the number of produced vehicles in the world, we need to conduct an analysis of the representation of industrial robots in the country that produces the most vehicles in Asia. On the continent of Asia, China is in the first place by the representation of industrial robots in production processes, particularly in the automotive industry, a result of which is that China is the first in the world in the vehicle production annually.

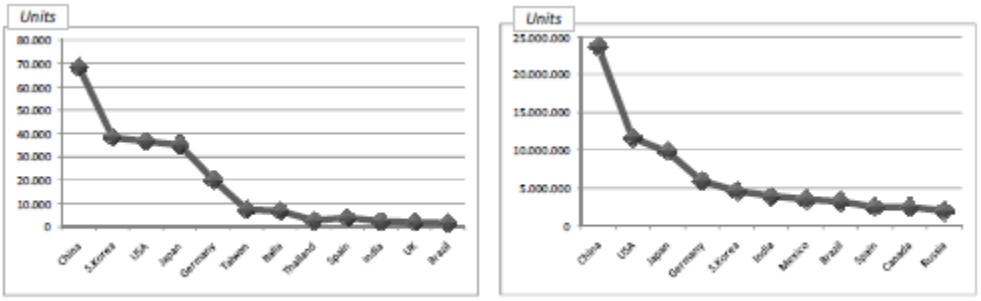
This is not random tendency because China adopted a national ten-year strategy named "Made in China 2025" which aims to make China the leading country in technology development in a few years. In order to see the tendency of representation of industrial robots and vehicle production in China, we used statistical data given in the literature [2-11, 22], while diagrams are shown in Figure 4



a-Industrial robots *b-Predicting the representation robots*

Figure 4 The tendency of representation of industrial robots in production processes in China in period 2005-2015,and the tendency of predicting the representation by 2020 [2-8]

On the continent of Asia, China is in the first place by the representation of industrial robots in production processes, particularly in the automotive industry, a result of which is that China is the first in the world in the vehicle production annually. This is not random tendency because China adopted a national ten-year strategy named "Made in China 2025" which aims to make China the leading country in technology development in a few years. In order to see the tendency of representation of industrial robots and vehicle production in China. If we analyze the representation of industrial robots in production processes in China (Figure 4), we can conclude that China is consistently implementing its national strategy "Made in China 2025", because the representation of the robots increases annually. The increase is not per linear function, but rather exponential function, so that in the last six years th representation increased from 5.525 robot units in 2009 to 68.556 industrial robot units, which is the increase of almost twelve times, which in the last ten years has not happened, nor recorded in any country in the world. The tendency of application of industrial robots in China is growing in the period to come. The predictions are that in 2020 China will reach 220.000 industrial robot units, which presents over 45% of the total representation of industrial robots in the world in that year.



a-Industrial robots *b-Production vehicle*

Figure 5 The representation of industrial robots in top twelve countries in the world in the period 2005-2015, as well as vehicle production in top twelve countries in the world in 2015 [2-8,22]

Among twelve countries in the world that have the highest representation of industrial robots in production processes in 2015 are the following: China, North Korea, USA, Japan, Germany, Taiwan, Italy, Spain, India, UK and Brazil. As we can see based on Figure 4a), the first place is held by China with 68.556 industrial robot units, followed by the countries in which the automotive industry is highly developed, such as North Korea, USA, Units Japan and Germany. If we look at the representation of industrial robots in production processes in China in the last ten years, Figure 5a), we see that it holds the first place in the last years, the reason being the strategy developed by China named "Made in China 2025", which aims to make China the leading technology country in the world. Based on the image 5b), we conclude that China has installed most industrial robots in production processes in the automotive industry because they are the first in the world in vehicle production [18,23]. In 2015 China produced close to 25 million vehicle units, followed by countries that are among top five countries in the representation of industrial robots in 2015: USA, Japan, Germany and North Korea.

In addition to development and increase of application of industrial robots in production processes, the development and increase of application of service robots in the production process.

3. Digital Technology as a Development Generator in Machine to Machine Communication M2M

As is well known, leading paradigm in every automation of the production process is limiting of human intervention, and hand tasks to the machine, robot, devices and systems. Digital technology with information and communication technologies with microelectronics, sensors, actuators and fixed and wireless networks give possibility of creating communication machine with the machine. This digital interaction between and within the machine and the systems is nothing but the heart of the fourth industrial revolution. Strategy of industrial development of any country in the world are moving towards industrial automation of manufacturing processes using digital and advanced technology and define M2M communication in the context of human and machine. Companies engaged in robotic technology have developed second-generation of robots that have the ability to work together with humans, where human during the work are safe. Industrial robots of the first generation had to separate by fences because of the safety of workers and other plants. Human-Machine Interface (HMI) and Machine-to-Machine communication is expected to be a key element in the expansion of production automation systems. With these applications are come to the "intelligent automation" which is the goal of the fourth industrial revolution, i.e. to improve performance by increasing the total efficiency of installed capacity (equipment) [12-30].Here we must note that it is not only the goal communication machine with the machine in a manufacturing process in the industry, but the goal is the application of digital and other advanced technology for communication of all sorts of devices and systems. In other words M2M applications can be directed to individuals, companies, communities, organizations in the public and private sectors, as shown in

Figure 5. This is about a pioneering industrial internet which will cover all production machines, apparatuses, devices and systems which perform certain tasks. This systems can communicate with each other just by implementing the above digital technology, so that in this communication may, for example exchange the following information: I produced 20 units and I have to stop because my inbox is empty, I have the ability to work 12% faster in how my inbox is always full, of produced 30 pieces of products two products have been discarded, i waited for 20 minutes to produce because the inbox was empty ,i am able to reduce its energy consumption for production as much that my equipment was idle while waiting. Please check? To the right temperature I worked five minutes, etc.

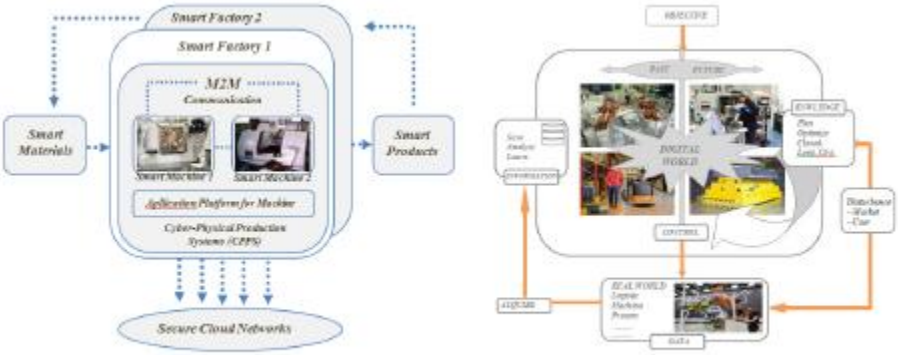


Figure 6 Concrete example of application M2M in production process in industry

This type of communication between M2M machines, appliances, devices and systems forms the basis for "intelligent automation" or "intelligent factory", and applications can be in heavy industry, food industry, production of goods, and in all segments of society and different sectors. Modern M2M applications using micro-electronics and wireless digital technology, with which these devices can collect and distribute data in real time.In this way, can be accessed at dozens of billions of connections at will and at any time. M2M applications use sensors and counters for different events in the range of temperature, through the communication network (fixed, wireless or hybrid), to the application software that converts the raw data into meaningful information. Telecommunications companies in particular recognize the opportunity to expand their services and to gain access to operational aspects of their clients. At the stage of the research are different architecture for M2M systems and technologies that enable the development and deployment of these systems.M2M communication systems are in development when it comes to its integration and adaptation of existing technologies and communications systems that are currently used different processes.

It is necessary to train the algorithms to ensure functionality, effectiveness, reliability and safety of the M2M system. Predictions are that by 2020, in the world, 20 to 50 billion devices will be able to communicate with M2M systems. It is essential when using M2M system to expect uberisation, and this is one of the sub-category of "disruption". The term used for the enormous changes which the new companies through technological innovation will cause in every industry branch. Convergence of digital technologies with other technology created the second generation of industrial robots. We think that rapidly will come the third generation of industrial robots which will be smaller, cheaper, more autonomous, flexible and fully cooperative compared to previous generation of robot with simplifying programming so that they can be programmed by workers. The third generation of industrial robots is intelligent and autonomous robots whose improvements will be in the direction of: identifying specific objects, manipulation, knowledge, increase computing performance, numerically controlled remotely, working with miniature and complex products that require adjustment in the assembly, reliability and precision which exceeds human ability. For these reasons the industrial and service robots are at the center of automation of production processes today, and in the future, and it is impossible to make "intelligent automation" and "intelligent factory" without the participation of a new generation of robots. The second generation of industrial robots can be very easily programmed so they can be usedby the average workers who are without knowledge of robotics and computer science, in other words we do not need professional developers that are very expensive. Some companies for development of robots developed autonomous industrial robots so that they can work together and automatically adjust their activities in making other products. Also some second generation industrial robots perform tasks by imitating workers. The advantage of the second generation of robots is that it becomes a tool that improves efficiency. They are very affordable, easy to install, have a very low rate of investment in them, it is not necessary to reorganize the manufacturing process for its installation because it is not necessary to separate workers with fences and they are without special safety equipment.

4. Conclusion

The fourth industrial revolution accelerates exponentially. This is the third phase of acceptance of digital technology, but it was preceded by digital competence and digital use. Digital transformation enables innovation and creativity in a single domain, not just the application of traditional, but adopted technologies. IoT (Internet of things) represent new ways in which we communicate with machines, as well as the manner in which the devices that we use at home, at work, transport, to be connected. From communication M2M is expected to be a key element in the expansion of automation in the manufacturing process, which will, with the participation of sensor and robotic technology lead to "intelligent automation". Also new way to communicate with devices that are used in the home, transport to work, etc., is the key to the implementation of the fourth industrial revolution, so it is estimated that by 2020, about 50 billion devices will be interconnected, of which will be about 10 billion traditional computer devices. In the next five years, the largest application of digital technology will achieve global companies, hence they will reduce costs, increase productivity, and allow extension of the implementation to the new areas. With digital design and virtual modeling of the production process we are able to reduce the time between the design of a product and its delivery to the market. In this way we come to the great improvements in product quality and a significant reduction of defects in manufacturing. Intelligent automation allows greater flexibility in the production, so that different products can be produced in the same production facility. In the first place in the world in representation of industrial robots in the automotive industry is China, but also the first in the world in the production of vehicles. It is expected that in the following period there will be an increase in the representation of industrial robots in production processes worldwide, with new types of industrial robots that will be able to work together with workers, and in particular in the automotive industry because the current structures of industrial robots are such that they need to be separated by the compartments in order not to harm the workers. The predictions are that China will still be the leader in the world in terms of the representation of industrial robots, as well as the production of vehicles. The fourth industrial revolution which includes digital and other technologies bring us to the "intelligent production" in the next 10 years. Fourth industrial revolution provides technology available to everyone. It is assumed that technology in the future will not provide a competitive advantage, but competitive advantage will be in manner in which we used it.

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