

The Role of Collaborative Service Robots in the Implementation of Industry 4.0

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Abstract: The implementation of the fourth industrial revolution Industry 4.0 is based on the following technologies: internet of things, cloud computing, big data, robotics & automation, intelligent sensors, 3D printers and radio frequency identification – RFID. The robotics is considered as the core technology. Second-generation industrial robots – collaborative robots have been implemented in the last two years. Their implementation is increasing every year and has reached about 3% of the total application of industrial robots in the world. The development of new technologies has contributed to the development and implementation of collaborative service robots AGV (Automated Guided Vehicle), which is one of the most significant qualitative shifts in the automation of logistic in production processes, assembly lines, warehouses and all other operations where transport is necessary. Their application is motivated by technical and economic reasons, such as: improving the quality of finished products, reducing the production of the finished product, increasing the homogeneity rate - constant quality, reducing the number of workers to carry out tedious transport, increasing the safety of workers in the work process, minimizing production costs and overall maintenance. The paper describes the trend of implementing service robots for professional use, with particular reference to collaborative service robots in logistics. Some design solutions for collaborative service robots in logistics already implemented in the industry are presented.

Keywords: Service robot, industry 4.0, logistics, automation, implementation of robots.

1. INTRODUCTION

In 2016, the WEF - World Economic Forum named the changes happening in the industry and environment in the world as the fourth industrial revolution, "Industry 4.0". Industry 4.0 is a vision of advanced industrial production that is already being applied by implementing new technologies in the automation of production processes, the exchange and processing of data. Unlike Industry 2.0 and Industry 3.0, where not everything was available and related to Industry 4.0, the development and application of new technologies, everything becomes available and connected at any time and place, which is an advantage over the previous two industries. Within the fourth industrial revolution, a new value chain is being formed that relies primarily on Cyber-Physical Systems (CPS), which is also the second name for the Internet of Things, and its associated service most commonly implemented in the cloud (Cloud Computing) [1,2,3,5,6]. Discussion and analysis of the fourth industrial revolution aims to increase awareness of the comprehensiveness and speed of the technological revolution and its multiple impact. An Industry 4.0 thinking framework needs to be created that outlines key questions and highlights possible answers. In other words, it is necessary to create a platform for achieving public-private collaboration and partnerships on

emerging issues related to the technological revolution. Industry 4.0 is based on a number of new technologies, some of which are: internet of things, cloud computing, big data, robotics & automation, intelligent sensors, 3D printers and radio frequency identification – RFID, etc. The robotics is considered as the core technology. The development of robotic technology has introduced new generation robots, such as collaborative industrial robots and collaborative service robots for AGV (automated guided vehicle) logistics, which are already in the process of implementation.

2. THE DEVELOPMENT OF INDUSTRIAL AND SERVICE ROBOTS

Industrial robots have first been used in the 1960s in industrial production processes. The development of all technologies, primarily computer, sensor and information and communication technologies, contributed to the development of robotic technology. The evolution of robotic technology is shown in Figure 1.

At the very beginning, industrial robots were installed in production processes so that the work space of an industrial robot had to be separated by the fence from the workers in the production process to ensure that the robot would not injure them. The task of each robot was defined and the program was automatically executed. The development and implementation of the aforementioned technologies in robotic technology leads to the automatic path

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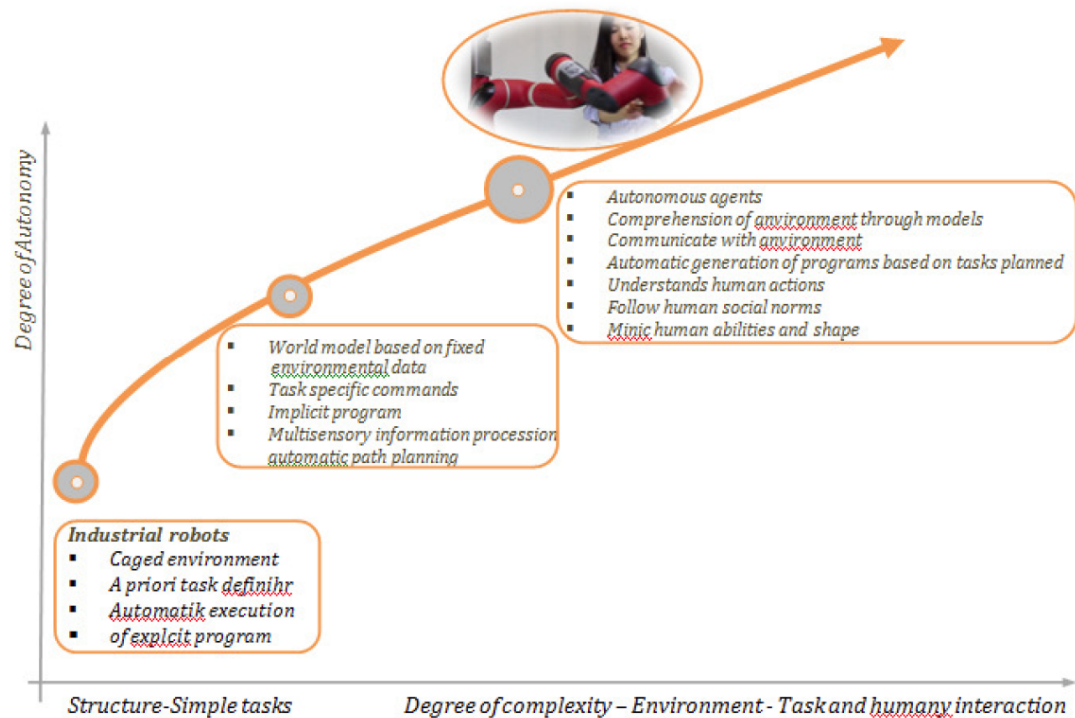


Figure 1: The outline of the development (evolution) of robotic technology in the world.

planning. The model is based on physical data about the robot environment, the commands become specific to each task, and we conduct the processing of multisensory information as well as implicit programs [6-9]. There is an evolution and advancement of industrial robots into second-generation collaborative robots (COBOs) that communicate with the environment, understand the environment through models, automatically generate a program based on planned tasks, understand human actions and follow human social norms. The advantages of implementing second-generation robots, i.e. collaborative industrial and service robots, into production processes are enormous, to name a few:

- They are characterized by simple and repetitive handling tasks,
- They have significantly improved performance, when dividing operations between workers and robots,
- The possibility of different levels of automation in the production process, so that tasks can be partially automated in cases where complete automation is too complex or not economical,
- Robots play a major role in "Industry 4.0" that connects the real-life factory to virtual reality,

which opens up greater prospects for application in global manufacturing,

- Non-ergonomic workstations can be significantly improved with collaborative robots, where we must keep in mind that worker safety is an absolute prerequisite,
- Increasing product diversity and reducing product lifecycle require flexible automation, which will result in increased use of collaborative robots, etc.

When using second-generation industrial robots (collaborative robots), companies have the following motives: reducing operating costs, reducing capital costs, improving product quality and consistency, improving work quality for workers, respecting health and safety rules, increasing production rates, increasing flexibility manufacturing products, space savings, etc. It is to be expected that in the future, the trend towards the use of collaborative robots will be growing.

3. THE IMPLEMENTATION OF SERVICE ROBOTS IN THE PAST TEN YEARS

The statistical data on the implementation of industrial and service robots were obtained from the International Federation of Robotics (IFR), the United

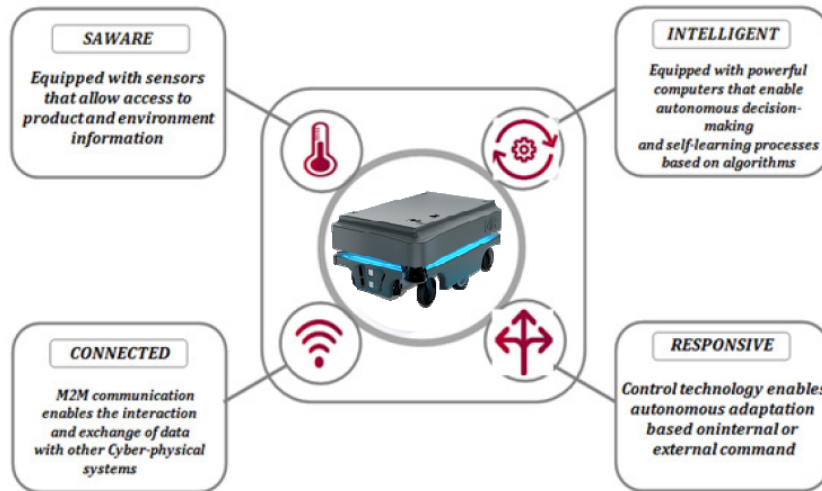


Figure 2: A new-generation robot for application in Industry 4.0.

Nations Economic Commission for Europe (UNECE) and the Organization for Economic Co-operation and Development (OECD). The annual and total application of industrial robots worldwide in all branches of industry is shown in Figure 3. [9-18]. Industry 4.0 will install next-generation industrial robots or collaborative robots that are aware, connected, responsive to the production process and intelligent, as shown in Figure 2.

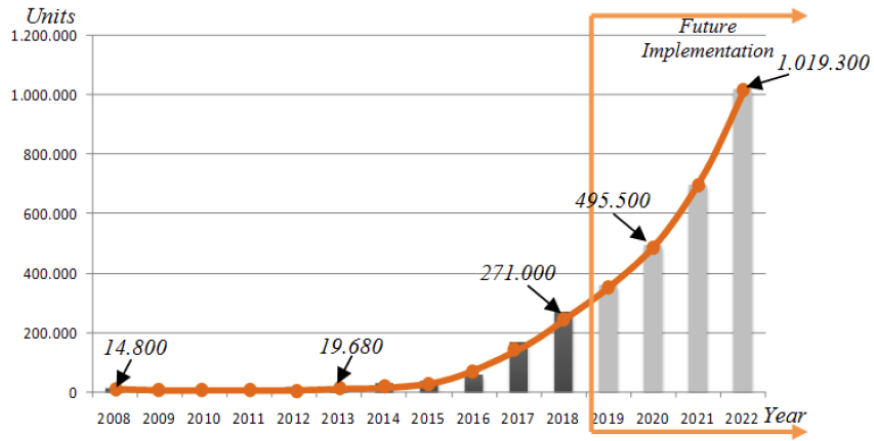
The latest generation industrial robot must be aware, as shown in Figure 2. It must be equipped with smart sensors that allow access to information about the state of the product they are manipulating or operating and the environment in which they perform operations. It must be connected by M2M communication that enables the interaction and data exchange with other machines in the environment and with other cyber-physical systems. Control technology must allow it autonomous adaptation based on internal or external command. Ultimately, it must be intelligent, or in other words it must be equipped with a strong computer that enables autonomous decision-making and self-learning processes based on algorithms. Industrial robots designed in this way will accelerate the implementation of Industry 4.0 in production processes. All the technologies listed so far are responsible for the development of robotic technology, so there was an enormous increase of use of service robots for professional use and service collaborative robots for logistics, as shown in Figure 3 [9-18].

Figure 3a indicates that the trend of application of service robots for professional use is continuously increasing. In the last five years the trend of application has gained exponential function, so that in 2018,

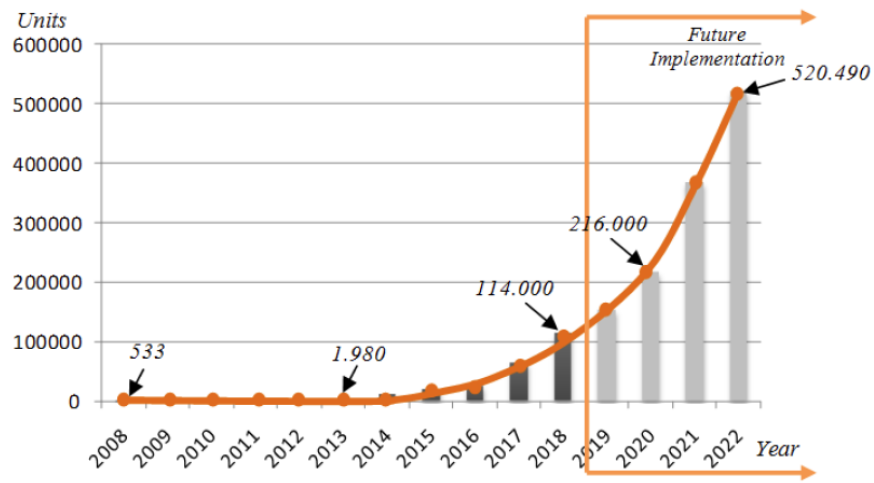
271.000 service robots were applied. It is estimated that the trend of application will grow in the following years. The analysis of the trend of implementation of logistics service robots, Figure 3b, shows that until 2014, the implementation of these robots was negligible in the world, and only 3.404 logistics service robot units were implemented. The growth trend increased enormously in the following years, and in 2018 about 114.000 logistics service robot units have been implemented. This trend of implementation of service robots for logistics is due to the aforementioned technologies that make the basis of Industry 4.0 and its implementation in the production processes. It is estimated that the trend of implementation of logistics service robots will increase in the coming years, and it is expected that in 2021 around 485.300 logistics service robot units will be applied in production processes.

Many companies driven by the implementation of Industry 4.0 in production processes have developed different designs of service robots for logistics. In order to get a more complete picture of the implementation of Industry 4.0 and the robotic technology responsible for its implementation, we will illustrate the solution of only one company that is implementing service robots for logistics (although other solutions of other companies deserve the same analysis). In addition to company MiR- Mobile Industrial Robots, which has developed various designs for collaborative service robots for logistics (some are shown in Figure 4), several other companies have also developed collaborative logistics robots, some of which are shown in Figure 4.

Mobile Industrial Robots-MiR has developed software solutions and service robots for logistics to



a- implementation of service robots for professional use



b-implementation of service robots for logistics

Figure 3: Implementation of service robots for professional use and logistics worldwide in the last ten years and estimated implementation by 2022.

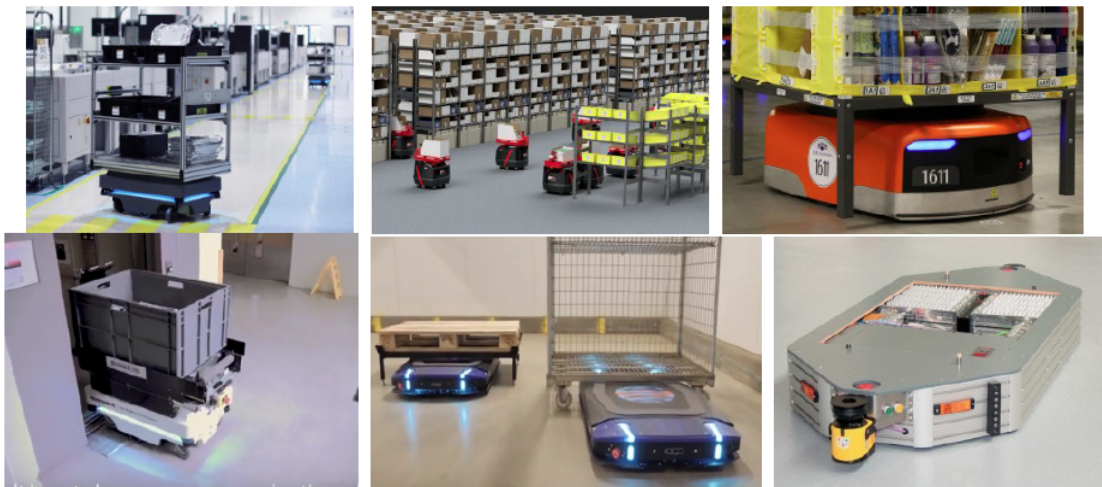


Figure 4: Different designs of collaborative service robots for logistics by company "Mobile Industrial Robots" and other companies [19-24].

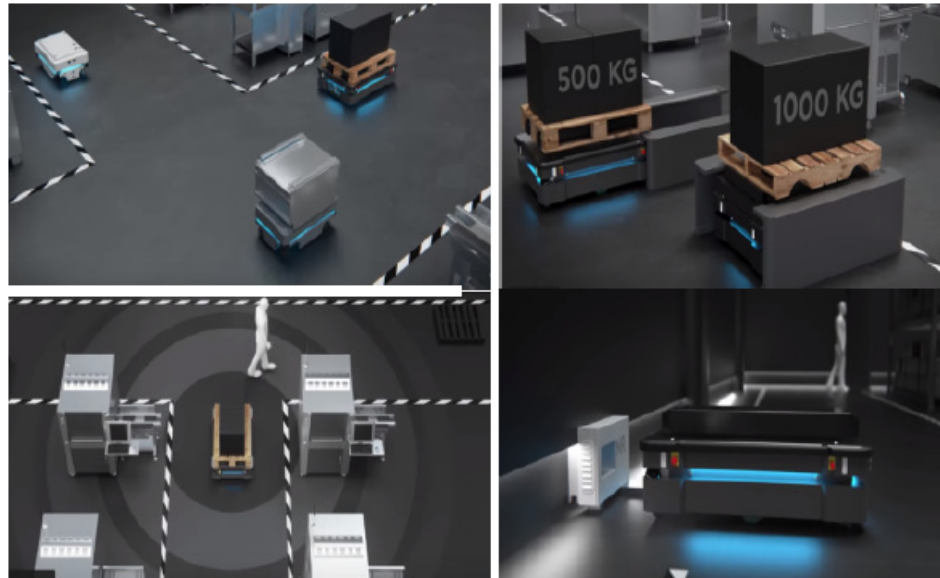


Figure 5: Transport with service robots for loads up to 1000 kg [19].

optimize internal transport for heavy cargo pallets up to 1000 kilograms, as shown in Figure 5.

Mobile Industrial Robots-MiR service robots are collaborative and autonomous: they maneuver safely around all kinds of obstacles. If a person comes out in front of them, they will stop. Advanced technology and sophisticated software allow the robot to navigate independently and choose the most efficient route to its destination. When it encounters an obstacle, it automatically moves around it and can divert the route to avoid stopping or delaying material delivery. The service robots are equipped with the latest laser scanner technology and provide 360-degree visual image for optimum image security. 3D front-facing cameras have a range of 30 to 2000 mm above the floor level, and two sensors at each corner ensure that this robot can see pallets and other obstacles, which

robots usually have trouble seeing. Service robots consume energy from the battery during operation, and after the battery has been discharged, it is necessary to recharge it. Battery charging ports are installed in the workspace, and the service robot comes to the connector and switches on to charge the battery. When the battery is charged it is ready to process the next order. Batteries have all the benefits of lithium-ion battery technology, have a long service life (about 1000 cycles) and very low self-discharge (<5%/month). Many companies are developing service robots for logistics which increases the application, and in addition to other core technologies of Industry 4.0, all companies will implement "smart transportation".

In addition to logistics, next-generation service robots have been deployed in many areas such as agriculture, medical, construction, defense, cleaning,



Figure 6: Application of professional service robots in medicine, agriculture, defense, underwater systems and construction [25,26].

inspection and maintenance, underwater systems, rescue and safety, as well as public relations. The following figure shows certain service robot designs due to limitations in some areas only.

We have to mention here that the most used are service robots in defense, and every day there is an increase in the possibility of application by the implementation of these technologies in operation.

4. CONCLUSION

The fourth industrial revolution is already present in all industries, from production to selling finished products. The introduction of technologies that form the basis of the fourth industrial revolution "Industry 4.0" changed the processes and technologies, as well as the organization of production and sales. With the application of "Industry 4.0" in the production processes of all industry branches, the linear production process is transformed into a network production process. In other words, it is transformed into a closed loop production process, where we have complete information on the production of the product at all times. By using a large number of smart sensors in the production process, at any given time, we have information about manufacturing devices and machines, based on which we decide when to replace the devices and machines, or conduct permanent maintenance. Use of these technologies enable us to monitor customer demands in the global market. The implementation of second-generation collaborative robots turns rigid automation into flexible automation. Every year the number of industrial and service robots implemented in industry and all segments of the environment is increasing, which will continue in the future, as we have demonstrated in the paper. The development of service robots for logistics enables us to perform logistics in all segments of production processes completely autonomously without human presence. We can conclude that some companies have developed systems of service robots for logistics that perform "smart logistics", that can be implemented in all segments of the company where it is necessary to solve the logistics of goods.

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