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Chapter

COBOTS in Industry 4.0: Safe and Efficient Interaction

Javier F. Castillo, Jesús Hamilton Ortiz, María Fernanda Díaz Velásquez and Diego Fernando Saavedra

Abstract

Cyberphysical systems will have a great development with the digital transformation known as industry 4.0. Cyberphysical Systems systems are devices that integrate capabilities to control and interact with a physical process. Among these are the Cobots, robots that perform tasks directly in conjunction with humans within a shared or nearby space. Safety is a fundamental issue when talking about Cobots, because there are requirements in terms of materials and design, kinetic limitations, and the implementation of sensors and algorithms that guarantee a safe workspace. Therefore, the potential risks of Cobot applications within the boom of industry 4.0 in cyberphysical systems are presented. Defining the fields of: Safety inspections; Routes and algorithms to avoid obstacles; Human-machine interfaces; Humans and Industry 4.0; Cyber security. Framed within the human-machine standards and protocols, within the safety functions and performance of a Cobot (ISO 10218-1 and ISO 10218-2 and ISO TS 15066). In this chapter, we discuss the different problems that are in the application of Cobots, in conjunction with different proposals for improvement and aspects to consider.

Keywords: Cobots, Industry 4.0, Safety, security, cybersecurity

1. Introduction

Contextualizing, industry 4.0 is the integration of cyber-physical systems in manufacturing and logistics processes, the use of the internet of things and services in industrial processes [1]. Creating significant changes in the manufacturing industry, in consumer behavior and in the way of doing business, through technologies that work together, such as additive manufacturing, 3D printing, reverse engineering, big data and analytics, artificial intelligence, autonomous robots that when working together, cause [2].

The term industry 4.0 was mentioned in 2011 at the Hannover fair. The "4.0" refers to a fourth industrial revolution due to the cyber-physical production systems that integrate the real and virtual [1]. Initially, the first Industrial Revolution, between the XVlll and XlX centuries was based on introducing mechanical production equipment powered by water vapor. The second Revolution in the twentieth century allowed mass production, thanks to the division of tasks and the use of electrical energy, which facilitated the manufacture of products for mass consumption. At the end of the twentieth century there was the third revolution based on

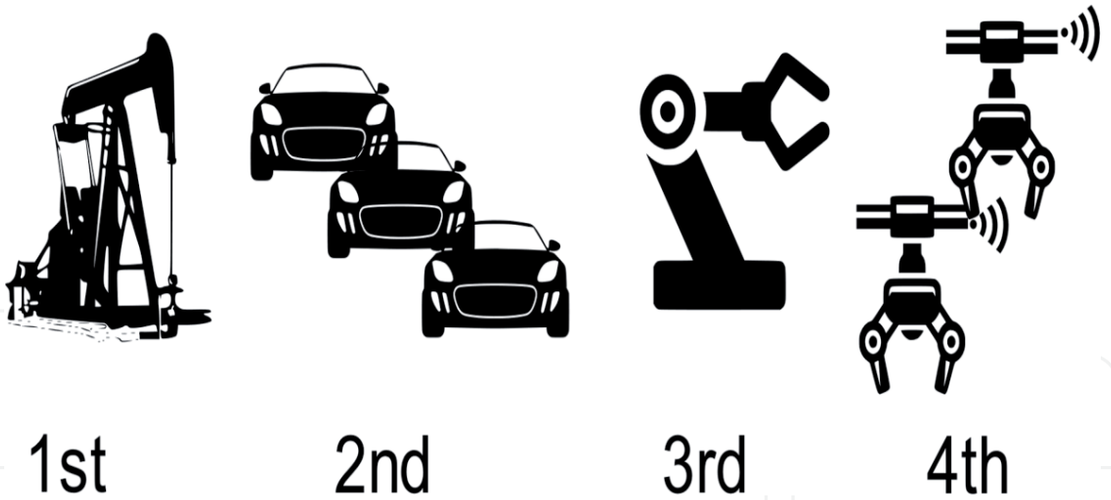


Figure 1.
Four industrial revolutions.

electronics and computer science to make automated production possible. Finally, industry 4.0 emerges as a new industrial revolution incorporating the new technological advances of the time [3].

In **Figure 1**, it is observed how the 4th industrial revolution, has a presence with robotics, intelligent technology and interconnectivity, thus giving way to collaborative robotics.

2. Cyber-physical systems

Cyber-physical Systems (SCF) incorporate and coordinate physical processes with computational elements, communication networks and remote storage of information, both interact at different scales of space and time, with different operation processes and configuration and reconfiguration resources. In addition, SCF works through "systems of systems" that interact and communicate with each other, through networks and software.

The key functions of Cyber-Physical Systems in the industry are the development of sensors and actuators to perform control actions, monitoring, generation of new knowledge, self-learning and reconfiguration based on the condition of the process. The mobile internet and the internet of things (IoT) have allowed to extend the adaptability, capacity, resilience, scalability, usability, and security of current industrialsystems. For example, wind-solar energy systems are an application of Cyber-Physical systems in industry, these wind and solar farms have their physical share while the data is obtained through monitoring sensors. The data is transferred through communication networks and processed by software in operation centers to monitor and control the physical environment, and thus obtain the most benefit from renewable sources. Also, CFS have been applied in different fields such as in the manufacture of intelligent robots, to perform human welfare services, in medical or healthcare equipment, vehicular and transport systems, surveillance systems, smart cities and video games.

The SCF contributed significantly to the industrial revolution, because in the former there were no intelligent factories where components, people and production systems communicated with each other through a network and their production was autonomous. In today's industry, CFS allow the monitoring of the condition of machines or processes in real time, the detection of anomalies, the predictions of failures, the cloud as a service increasing the realization of more productive, sustainable and efficient factories [4].

3. COBOTs

With the rise of the industry due to the introduction of cyber-physical systems (SCF) and the Internet of Things (IoT) within manufacturing and automation systems. SCF represent self-controlled physical processes, with strict network capabilities and efficient interfaces for human interaction. The interactive dimension of SCF reaches its maximum when defined in terms of natural human-machine interfaces (NHMI), i.e. those that reduce the technological barriers required for interaction [5].

A collaborative robot or Cobot is defined according to ISO/TC 299 as a robot designed to interact directly with humans in a defined collaborative space. Cobots are systems or robots of an industrial nature, designed to work in robot-human environments, that is to say that it is in contact with human operators, which allows the operator's work to be complemented with the characteristics of the machine. The automotive industry, surgery, training devices and rehabilitation are some of the applications in which Cobots have been used.

The industry is currently looking to take advantage of mass customization, a task that industrial robots pre-programmed for large-scale production are not focused on, so Cobots aim to address the changes that occur in large-scale customization processes. Companies are using them because they can work alongside humans on the same assembly lines using small spaces, the necessary security measures are much less than in simple robots, they are very flexible to work on short consignments without having to invest much time in programming them and they are ideal to replace operators in repetitive or poorly ergonomic tasks.

The digitization and intelligence of the manufacturing process is the need of today's industry. Rapid advances in manufacturing technologies and applications in industries help increase productivity. Industry 4.0 as a new level of organization and control over the entire value chain of the product life cycle; it is geared towards the requirements of increasingly individualized customers. Industry 4.0 is still a hypothetical concept, but with real development that includes the Internet of Things, industrial Internet, smart manufacturing, and cloud-based manufacturing. Industry 4.0 refers to the strict integration of the human being in the manufacturing process to have a continuous improvement and focus on value-added activities and avoid waste [6].

The collaborative robotics of industrial automation has adapted to the context of rapid industrial development. The collaboration of humans and robots in close proximity in a single workspace is a novel concept of Industry 4.0. Research topics in the field of industrial robotics include safety in human-machine interaction systems, due to the close collaboration between humans and robots many of the problems of industrial robotics are associated not only with technical issues, but also with social aspects. They also include the optimization and automation of production through the introduction of robotic solutions, with which it is expected that in the future Cobots will become the basis of a large commercial development [7].

Robots are tough, fast and very accurate machines that can complete their tasks faster, with better quality and for a lower price than humans. However, some operations must be adapted to real events, but robots are not able to think, execute commands and performpre-learnedmovements, being limited by their programming. Manipulation robots are usually designed to have six or seven degrees of freedom (axes of motion), while the upper extremity of the human body has around thirty. This results in another precise manipulation limitation with a wide range of motion.

With mass custom production becoming mainstream, agile manufacturing strategies have been adopted by small and medium-sized industries (SMEs), driving the use of collaborative robots in today's factories. The main challenges in

the adoption of Cobots in the industry are the lack of a highly skilled workforce to program the robot to perform complex tasks and the integration of robotic systems to other smart devices in the factory. In addition, teaching and simulation by non-robotics experts of many collaborative robot systems is a great challenge, because these systems are designed to be programmed by experts and not by ordinary workers [8].

The main goal ofhuman-robotcollaboration (HRC) is to create an environment for safe collaboration between humans and robots. There is an area between manual manufacturing and fully automated production where a human worker comes into contact with the machine. This area has many limitations due to security restrictions. The machine can be in automatic operation only if the operational staff is outside their workspace. Collaborative robotics establishes new opportunities in cooperation between humans and machines, where staff share the workspace with the robot helping with non-ergonomic, repetitive, uncomfortable, or even dangerous operations. The robot monitors its movements by using advanced sensors so as not to limit, but mainly not to endanger the worker [9].

3.1 Programming a Cobot

The programming process of a Cobot involves the ability to understand the state of the environment and perform actions that advance the system towards a planned goal of collaboration. The programming characteristics of Cobots identified are [10]:

- Communication: an operator controls an Cobot through a communication channel that can be verbal (speech) or nonverbal. The programmer's offline function is to program and define possible actions of Cobot and the underlying motion control.

- Optimization: Important aspects of an Cobot senvironment, such as obstacles and tool positions, are mathematically modeled based on the actions of the Cobot. Those form cost functions that are optimized to generate desirable performance. The Cobot program can be carried out to minimize the operator's workload, energy consumed and lost time, or maximize physical comfort and confidence, product quality, etc.

- Learning: An Cobot Clearns a skill like what a human would, for example, by observing demonstrations, trial and error, receiving feedback, and asking questions. The role of a programmer is to design the learning algorithm and provide initial data for the Cobot to learn. That could be in the form of demos, trial-and-error iterations, training data, etc.

3.2 Cyber security

Digitization strategies in cyberphysical production systems (CPPS) are one of the key factors in Industry 4.0. Its integration into a hyperconnected system facilitates the production of goods and services. In addition, these industries are characterized by automation, as well as unmatched levels of data exchange across the value chain. The topic not only addresses data preparation, real-time data processing, big data analysis, visualization, and machine interface design, but also cybersecurity. In particular, unauthorized access to protected data (personal or business) or unauthorized control of production facilities involve risks in terms of digitisation, with digitisation having an impact on security. Cybersecurity risks are crucial as

the prevalence of these information and operation technologies has changed the appearance of cyber threats. Addressing the premises and realities of cybersecurity in Industries 4.0 and 5.0 is crucial. The risk mitigation strategies provided by various organizations are crucial to reducing risks. Given the gaps and vulnerabilities generated by interconnections, cybersecurity is vital for the advancement of digital industrial transformation [11, 12].

3.3 Standards

Industrial regulations that incorporate the risks related to the use of collaborative robots by workers include the international standard ISO 10218 and the Technical Specification ISO/TS 15066: 2016, the American ANSI/RIA R15.06, the European EN 775 that is adapted from ISO 10218, and standards such as the Spanish UNE-EN 755 adapted from EN 755 by the Spanish Association of Standardization and Certification. To prevent accidents, the selection of a safety system should be based on the analysis of the aforementioned risks. Commonly in the past, security systems have separated workspaces from robots and humans. An instance of this separation was reflected in the UNE-EN 755: 1996 standard. It stated that sensor systems should be incorporated to prevent people from entering a hazardous area, where the operational state of the robotic system could have caused dangers to workers. According to traditional standards, authorized personnel can only be inside the robot workspace if the robot is not in automatic mode.

The latest update of ISO 10218-1 and ISO 10218-2 provide details on collaborative work requirements and typologies of cooperation tasks. The first includes, for example, start-up controls, operation of the safety control system, motion braking, speed control, while the second includes, for example, manual guidance, interface window and cooperative workspace. The international standard ISO: 8373–2012, specifies the vocabulary used in relation to robots and robotic devices. New terms involved in the development of new collaborative tasks in industrial and non-industrial environments, such as human-robot interaction and the service robot, are defined, as well as more established terms, such as robot and control system. The recent Technical Specification ISO/TS 15066: 2016, attempts to further specify human-robot collaboration by complementing the requirements and guidance set out in ISO 10218.

3.4 Rules and types of cooperation

Iso EN 10218 for robots and robotic devices defines four basic types of HRC. For some types of cooperation, the use of special collaborative robots with integrated sensors is required. Other types of applications have a conventional robot with improved sensors and controls.

The supervised *stop* with safety rating is the simplest type of collaboration. There are applications in which the robot share's part or all its workspace with an operational team. If a worker appears in the robot's work area, the machine stops and remains on hold until the man leaves. In the shared area, the robot and the operator can get to work, but not at the same time.

During the operator's manual control process, the robot's load is compensated to maintain its position. The operator can move freely with the manipulator in space without exerting a force majeure. The human being comes into direct contact with the machine, but the movement is not initiated by the robot, only controlled by the operator. For safety reasons, the speed of the robot is reduced and updated with safety functions. The robot must be equipped with a measuring device to monitor the impact load. Some robots have sensitive elements (torque sensors) embedded

directly in the joints. For this type of collaboration, it is also possible to use a standard robot. The robot must be equipped with a sensor that can detect external loads. This sensor is placed on the robot's wrist between the output interface and the final effecter. Measure and evaluate the load and verify the robot's compliance.

With speed control and separation, the robot cell work area is divided into different areas. These areas are inspected with scanners or a vision system. In areas beyond the range of the manipulator, where the operator is not in contact with the robot, but could run the risk of a manipulated object falling, the robot slows down to a safe speed. If the robot's workspace is interrupted, the robot will stop. If these two areas are free, the robot can work with the maximum parameters. The speed and position of the robot are continuously monitored. A recommended application may be a workplace where the robot works with the maximum parameters, but the operator must enter the area at a certain time. For example, for logistical reasons, to place or remove the product.

Force and power limitation is a type of cooperation where special collaborative robots are needed. The movement parameters of the robots are controlled with high precision and even a small deviation from the actual position compared to the programmed one can be determined. Accurate encoders with high resolution allow the robot to control its speed and position with high precision. The forces and pairs are measured and evaluated with sensitive torque sensors in the robot joints, checking the electric current consumed in the actuators, measuring the reactions transmitted to the ground or implementing tactile sensors. Therefore, the robot is able to identify the impact on an obstacle, analyze it in a short time and react. The robot can brake after the collision and stop immediately, alternately moving in the opposite direction in the opposite direction to decrease the energy of the impact as much as possible.

3.5 Efficiency in interaction

The field of collaborative robot research is constantly evolving. There is no particular approach to increasing the efficiency of intelligent human-robot robotic systems. This is due to the complexity of ensuring a coordinated interaction between the two parties [12]. For this reason, adaptive control systems for the robot, intelligent human-robot interface, sensor systems and information processing algorithms, the basic elements of robotic and mechatronic systems, efficient forms of interaction of the robot with the external environment, bionic and biomedical technologies in robotic solutions, control of multi-agent robotic systems with secure and reliable communication, continues to be constantly developed.

Figure 2 shows the difference between interactions and presence with robots. In collaborative robotics, the task or work objective is performed in the company of an operator or worker of the company. In an industrial process where tasks are automated, the machine is the one who performs the tasks individually or sharing objectives with other machines. Finally, manufacturing is done directly by people; this is because they are craftsmanship or they are only achievable manually, although somewhere in the process, robots can get involved and become collaborative robotics.

With the aim of identifying the factors of effectiveness of the implementation of robotic solutions according to the use cases in companies that have introduced robotics in their production processes. Based on the opinions of experts with experience and knowledge of the robotics market, the following factors were formed in descending order of importance in the article [12]:

1. Increased productivity.

2. Quality improvement.

3. Reduction of labor costs.

4. Elimination of dangerous operations.

5. Increase production flexibility.

However, in the modern trend of implementing collaborative robotic solutions in a shared workspace and in everyday human activities focuses on the person and the effectiveness of their direct contact [13].

Collaborative robots successfully achieve their goal of reducing ergonomic risks and improving employee safety. In addition, important levels of productivity improvement were identified, and the collaborative robot managed to stabilize the behavior of the assembly station, since its performance and pace of work are more consistent than those of a human operator.

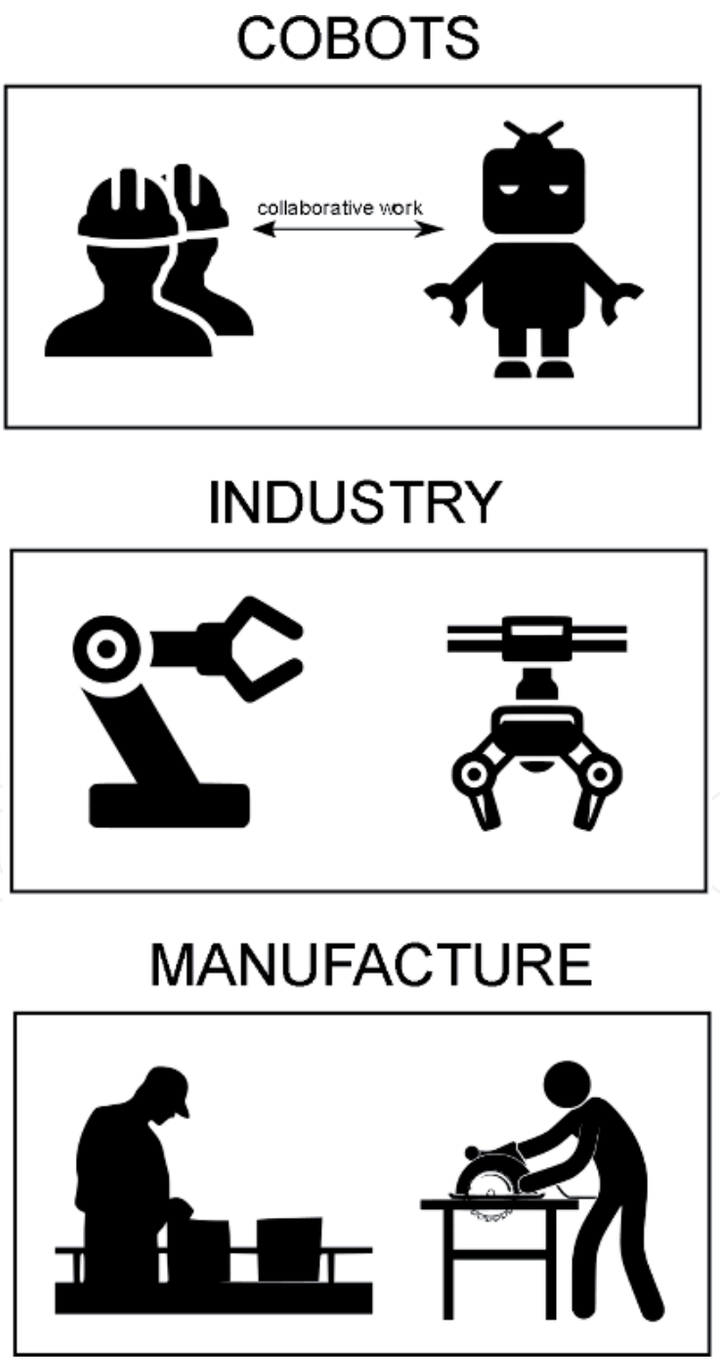


Figure 2.
Comparison of cobots, automated industry and manufacturing.

1. Perform a risk analysis associated with the use of the collaborative robot: Two important sources of risk were identified: mechanical entrapment and shocks, which are caused by the movements of the collaborative robot. In this sense, it is important to implement the necessary security measures to minimize the incidence and severity of these risks.

2. Validate the integration of the collaborative robot with the assembly station: The use of the collaborative robot on the production line was validated according to the evaluation and validation procedures of the company.

3. Train technicians and operators in the maintenance and collaborative operation of robots, respectively: The two trainings were given and documented in accordance with the company's policies [14].

3.6 Risks

In the current industry 4.0 the tools are divided into two groups, one which bases its operation on capturing and processing data, and the physical and tangible tools [15].

The latter can present a series of risks such as:

- Risk in the planning and organization by the company, for the acquisition of a new technology

- Psychosocial risk, in terms of psychological, emotional, and social involvement of the team

- Safety, hygiene, and ergonomic risks generated by staff interaction with new technologies.

- Cybersecurity, in terms of vulnerability of companies' information due to data exchange and technological connectivity.

Safety: Mechanical contacts that generate physical damage because I) adjustments, programming, or tests of the robot, II) access to restricted areas during automatic operation, III) During cleaning or maintenance, IV) During collaborative work. As well as electrical risks, when contacting active parts, by poorly insulated elements, incorrect voltage during maintenance. Thermal risk burns and danger from flammable atmosphere. Projection of materials, sparks, or particles.

Safety: Mechanical contacts that cause physical damage through I) configuration, programming or testing of the robot, II) access to restricted areas during automatic operation, III) during cleaning or maintenance, IV) during collaborative work. In addition to electrical hazards from contact with living parts, poorly insulated elements, incorrect voltage during maintenance. Thermal hazard burns and danger of flammable atmosphere. Projection of materials, sparks, or particles.

Hygiene: Exposure to I) Vibration that endangers the operation of the cobot or the health of the operator, II) Ionizing and non-ionizing radiation, III) Materials or chemical elements harmful to health, IV) Noise, V) Magnetic fields.

Ergonomics: Due to repetitive movements that must be done with the arm or hand, prolonged forced postures, overexerted by the weight that is loaded, postural changes by the reduced space.

Psychosocial: Problems in adaptability with COBOT, change in work rhythm, overload, and mental fatigue.

Workspace	Action	Algorithms	Hardware and sensors
separate	Restriction on staff	none	signage and delimitations. Light, acoustic, optical, etc. indicators.
separate	Change in robot behavior. Stop the robot or slow it down.	control algorithms	Combination of passive systems and security assets. Interlocking device, proximity, and touch sensors.
shared	Quantification of the level of risk per collision	none	Estimation of pain tolerance, assessment of the level of risk. Human arm emulation system, Standard car crash test
shared	Minimize risk from collision or deliberate contact	none	technical mechanical compliances, lightweight structures. Viscoelastic coating, elastic absorption systems, use of carbon and aluminum fibers.
shared	Minimize risk from collision or deliberate contact	Safety strategies for collision detection	Touch sensors, proprioceptives, encoders, force sensors, optical and RGB-D sensors.
shared	obstacle avoidance, stopping or changing trajectory, speed, force	preclusion analysis strategies	Motion capture systems, local information, computer vision, distance sensors, RGB-D. Capacitive sensors, ultrasound, laser, IR, cameras, etc.

Table 1.
Human-robot symbiosis [16].

It is important to keep in mind that, in collaborative robotics, there are different ways to interact or work with robots, in the **Table 1** is described these interactions. It may be the case in which the machine is isolated from the operator, this for the safety of the latter. Another case is when both the machine and the operator are isolated; process in which greater security is required for the person. And finally, when the machine needs direct handling or is not risky for the operator, then there is no separation between these. **Figure 3** depicts these separations.

3.7 Applications

The prevention of collisions between humans and robots is fundamental in collaborative robotics and in the framework of Industry 4.0. It plays an important role in meeting safety criteria, as people and machines work side by side in an unstructured and time-varying environment. Autonomous guided vehicles (VGA) implement techniques for navigating through mapping, location, route idealization, and route tracking. This technique allows that, if there are any obstacles in the way, the transport does not have to stop. Instead of stopping the machine, by using point-to-point motion logic, a tool was implemented to avoid obstacles. Often, the only hardware available in VGA is PLCs. This hardware limitation is a prominent feature, as not all computers support large computing capabilities [15].

Some applications of Cobots expressed in [17] are:

- Industrial application of *Universal Robots,* Collaborative robots on BMW assembly lines. Robots are used on the production line to wrap a layer of protective film over electronic components inside a door, which can cause repetitive strain injuries to workers when executed manually.

- Audi's human-robot cooperation in production processes is based on the "*PART4you*" robot. It incorporates a camera and suction cup to help human

workers pick up the components of the boxes and pass them on to the assembly workers, without safety barriers, at the right time and in an ergonomically ideal position.

- *KUKA's* collaborative robots are used on an assembly line to help workers install shock absorbers: Instead of using a heavy damper installation tool, workers have the robot automatically lift and place the damper on the wheel arch before pressing a button to install the component.

- Universal Robots' robotic arms are also used at the Volkswagen factory, where they handle delicate incandescent spark plugs on cylinder heads, allowing for ergonomic design of the factory's workplace, where the employee can complete the task of repairing spark plugs.

- *ŠKODA* production employees work together with robots on high-precision tasks such as inserting the piston of the gear actuator, which is one of the most delicate processes in the manufacture of transmissions.

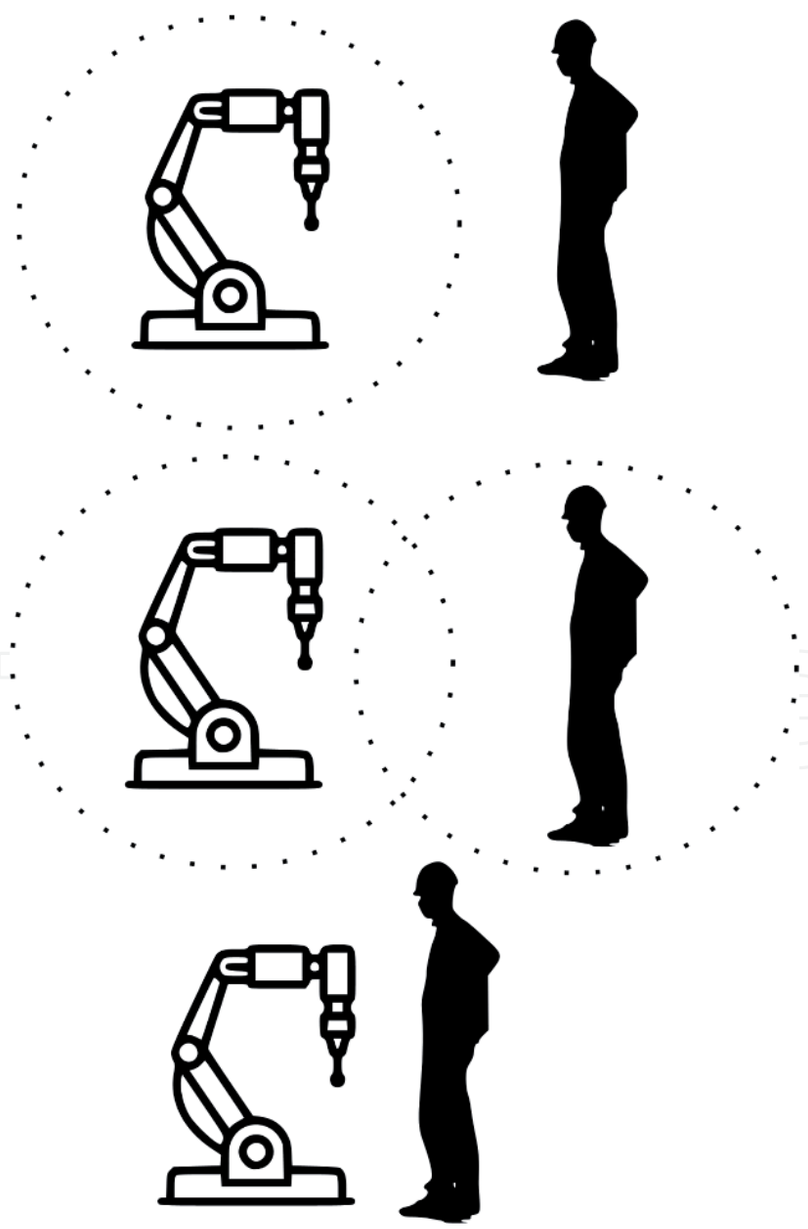


Figure 3.
Types of interaction with the robot.

3.8 Future applications

Although existing industrial robots can work in challenging environments, perform high-precision tasks, and help improve and increase productivity, most of this is still driven by pre-designed robot commands and programs. Given labor costs and intense competition, there is a huge shortage of autonomous and intelligent robots and physical cyber systems capable of perceiving and deciding in the next application of Industry 4.0. These intelligent robots can analyze their tasks by selecting the right tools, planning their movements, and performing the right operations in the same way that a trained human worker would [17–21].

With the constant advances that occur in robotics and with the demand for new needs that occur in industries, the presence of collaborative robots is increasingly noticeable, especially in those processes that are repetitive and can be divided between a machine and a person.

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References

[1] C. J. Bartodziej, "The concept industry 4.0," in *The concept industry 4.0*, Springer, 2017, pp. 27-50.

[2] C. B. Y. Cortés, J. M. I. Landeta, and J. G. B. Chacón, "El entorno de la industria 4.0: implicaciones y perspectivas futuras," *Concienc. tecnológica*, no. 54, pp. 33-45, 2017.

[3] J. L. del Val Román, "Industria 4.0: la transformación digital de la industria," in *Valencia: Conferencia de Directores y Decanos de Ingenier{\'\i}a Informática, Informes CODDII*, 2016.

[4] A. Villalonga Jaén, F. Castaño Romero, R. Haber, G. Beruvides, and J. Arenas, "El control de sistemas ciberf{\'\i}sicos industriales: revisión y primera aproximación," in *XXXIX Jornadas de Automática*, 2018, pp. 916-923.

[5] M. A. R. Garcia, R. Rojas, L. Gualtieri, E. Rauch, and D. Matt, "A human-in-the-loop cyber-physical system for collaborative assembly in smart manufacturing," *Procedia CIRP*, vol. 81, pp. 600-605, 2019.

[6] S. Vaidya, P. Ambad, and S. Bhosle, "Industry 4.0--a glimpse," *Procedia Manuf.*, vol. 20, pp. 233-238, 2018.

[7] R. Galin and R. Meshcheryakov, "Automation and robotics in the context of Industry 4.0: the shift to collaborative robots," in *IOP Conference Series: Materials Science and Engineering*, 2019, vol. 537, no. 3, p. 32073.

[8] V. V. Nair, D. Kuhn, and V. Hummel, "Development of an easy teaching and simulation solution for an autonomous mobile robot system," *Procedia Manuf.*, vol. 31, pp. 270-276, 2019.

[9] A. Vysocky and P. Novak, "Human-Robot collaboration in industry," *MM Sci. J.*, vol. 9, no. 2, pp. 903-906, 2016.

[10] S. El Zaatari, M. Marei, W. Li, and Z. Usman, "Cobot programming for collaborative industrial tasks: An overview," *Rob. Auton. Syst.*, vol. 116, pp. 162-180, 2019.

[11] T. Komenda, G. Reisinger, and W. Sihn, "A Practical Approach of Teaching Digitalization and Safety Strategies in Cyber-Physical Production Systems," *Procedia Manuf.*, vol. 31, pp. 296-301, 2019.

[12] A. Clim, "Cyber security beyond the Industry 4.0 era. A short review on a few technological promises," *Inform. Econ.*, vol. 23, no. 2, pp. 34-44, 2019.

[13] Iberdrola, "'Cobots': Los nuevos robots colaborativos." [Online]. Available: https://www.iberdrola.com/innovacion/cobots-robots-colaborativos. [Accessed: 09-Jun-2021].

[14] A. Realyvásquez-Vargas, K. C. Arredondo-Soto, J. L. Garc\'\ia-Alcaraz, B. Y. Márquez-Lobato, and J. Cruz-Garc\'\ia, "Introduction and configuration of a collaborative robot in an assembly task as a means to decrease occupational risks and increase efficiency in a manufacturing company," *Robot. Comput. Integr. Manuf.*, vol. 57, pp. 315-328, 2019.

[15] S. Salimbeni and D. Mamani, "Marco de referencia para la incorporación de Cobots en l{\'\i}neas de manufactura," *Podium*, no. 38, pp. 159-180, 2020.

[16] S. Robla-Gómez, V. M. Becerra, J. R. Llata, E. Gonzalez-Sarabia, C. Torre-Ferrero, and J. Perez-Oria, "Working together: A review on safe human-robot collaboration in industrial environments," *IEEE Access*, vol. 5, pp. 26754-26773, 2017.

[17] V. Villani, *F. Pini*, F. Leali, and C. Secchi, "Survey on human--robot

collaboration in industrial settings: Safety, intuitive interfaces and applications," *Mechatronics*, vol. 55, pp. 248-266, 2018.

[18] P. S. d. l. Reyes, Gestión de la producción en la Industria 4.0 (tesis de grado), Sevilla: Dpto. de Organización Industrial y Gestión de Empresas I - Escuela Técnica Superior de Ingeniería, 2020.

[19] F. Cassioli, G. Fronda y G. Fronda, «Human–Co-Bot Interaction and Neuroergonomics: Co-Botic vs. Robotic Systems,» Frontiers in Robotics and AI, 2021.

[20] International Federation of Robotics - IFR, «IFR presents World Robotics Industrial Robots,» 2019. [En línea]. Available: https://ifr.org/ifr-press-releases/news/robot-investment-reaches-record-16.5-billion-usd.

[21] S. Bragança, E. Costa, I. Castellucci y P. M. Arezes, «A Brief Overview of the Use of Collaborative Robots in Industry 4.0: Human Role and Safety,» Occupational and Environmental Safety and Health, vol. 202, pp. 641-650, 2019.

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