Cobots and the benefits of their implementation in intelligent manufacturing

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Abstract. The perspective of robotics in intelligent manufacturing becomes with Industry 4.0. Increasing the profitability of production is the main goal, which also depends on the organization of safety and efficiently human-robot interaction in a shared work place. Perspective robotic solutions integrated into intelligent manufacturing makes able to contribute an increase of automation in production with safety compliance. The portability and compactness of robots allow to optimize the production process and improve efficiency. An important stage of robotics was the ability to take robots outside of barriers and place them next to humans. This robotic solutions market is growing up every year. This indicates a high demand for the introduction of robots in intelligent manufacturing. Already today we can see how the main players in automated manufacturing have taken the first steps towards Industry 4.0.

1. Introduction
At the beginning of the 20th century, the term robot appeared, this was the first mention that carried the meaning of an automated device [1]. People have always sought to create devices that would help them with heavy and repetitive work. Modern concept of robot rather depends on the level of technology development, by learning which we can explain what a robot is and what its true goals are. The modern engineering industry is changing due to the development of Industry 4.0.

Modern robots in production have moved beyond a separate work area and started working together with humans. There is a new type of robot – collaborative robots (or cobots). There are robots that can work side by side with a human, perform not only sequential tasks, but also parallel ones. The cobots have the following characteristics: ability to interact safely with a human, risk reduction in the implementation tasks, flexibility and learning, possibility of wide use and quick adjustment. Through the integration of collaborative robots into production, it becomes possible to advance from coexistence to collaboration between workers and robots [2-5]. The using of cobots usually calls human-robot collaboration (HRC). HRC is the most perspective technology in modern intelligent manufacturing. This is because robots are easy to program and install in the workplace. Collaborative robots have smart software that helps to allow machine learning methods. Different sensors onboard the cobot and software makes enable to self-learning by technical vision and speech besides movements. With the development of technology, HRC has already a huge potential for modern companies of all sizes and different economic sectors. Collaborative robots can attract more investment in contrast to traditional industrial robots [6].

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In modern factories the main task is how to ensure safety and efficiently human robot interaction in dynamic uncertain environment. On the one hand, there are already exist several cobots in intelligent manufacturing from such companies as FANUC, KUKA, Universal Robots and Rethink Robotics. And today, these robots focus on the technical specification of ISO [7, 8]. On the other hand, we have to work on intellectual and interactive safety during interaction, need to gather information about environment, develop cognitive abilities and action planning.

Traditionally, robotics classification separated into industrial and service [6]. On figure 1 shows the classification, according to the authors, which reflects the modern classification, in which mobile and easily adaptable robots become a part of people both in production and in everyday life.

![Robotics classification diagram](image)

Figure 1. Robotics classification.

Moreover, using robots does not always correspond to the classification, since using of a particular type of robot depends on the task being solved and the capabilities of the robot itself.

2. HRI for intelligent industrial production

For more than 10 years, the development and integration of mobile robotic solutions had a huge impact on industrial production. And today, as a result, have realized flexible methods of automation and reconfiguration of production processes in intelligent manufacturing. Robots are equipped with visual and sound recognition for precise movement and control while robots working with humans.

Industrial production is still the main customer of robot installations. Since 2010 annual robotics installations in intelligent manufacturing increased by 13% on average each year (CAGR), in spite the economic crisis in 2008/2009. Further development of robotics installations including collaborative robotics solutions in production for automated manufacturing will significantly increase by 12% per year on average from 2020 to 2022 [6].

Human-robot interaction (HRI) in a shared workspace could be provided into scenarios: first – perform separate tasks in a workspace sharing, second – jointly perform one task in time-sharing. This interaction for intelligent industrial production can be considered on the model of a multi-agent robotic ergatic system. There are two main agents in model: a person with human factors and cobots working in a human-involved environment. The HRC concept allows to combine the capabilities and effectiveness of robots with human cognitive abilities into a single flexible system.

Safety issues in HRI regulated in standards ISO. The purpose of the standards is to increase the interoperability of cobots and their components. It helps to reduce the cost of their development and maintenance through standardization processes, interfaces and parameters [7, 8].

2.1. Main human factors during HRC
This section of paper describes an important challenge of progressive technologies in robotics. It is human factors that very difficult to make a forecast or find out actually common human behavior in...
HRI. To study the main human factors, we need empirical data that shows statistical information. This will allow to create a basic list of factors that affect HRC. The research works of various scientists has shown the following results [9-12, 16], presented in table 1.

| Factor | Description |
|--------|-------------|
| The credibility of the robots | The lack of confidential relation in robots and the attitudes to them contributes to the reduction of their use. |
| Human mental workload | Incorrect design of a workplace with robots leads to additional human workload. |
| Loss of situation awareness | Loss of awareness of the situation leads to various accidents and injuries of a human. |
| Skill degradation | This factor shows deskill affects the result of HRI and reduces the safety measures of their joint work. |
| Stress, anxiety and safety due to HRC | Direct HRI in proximity can lead to a collision. This will affect the manifestation of effects such as stress, anxiety, and safety interaction. |
| Adaptive automation | Step-by-step automation allows the operator to track the entire process. |
| Positive perception of the robot | The positive perception of the robot can have a positive impact on performance. |

The study of human factors in the process of interaction between a human and a robot will allow understanding what measures need to be taken to ensure safety and productivity in the workplace. Next stage of the study need to conduct a number of studies on real examples. Experiments will test knowledge about human factors and develop measures to improve HRI.

2.2. Collaborative robot safety-oriented methods during HRC

This section of paper describes safety HRC. Examples of collaboration: robot and human in the field of rehabilitation, human and autonomous vehicle on the road, child and robot during study or manipulator and human worker on robotic lane in production. There are two ways to reach the safety interaction between robots and humans: first, changing the robot’s configuration so that it doesn’t cause any harm when it collides with a human (hardware design) [13], second, to make collaborative robot based on safety standards and software design (interactive safety) [14, 15].

For a general understanding, we will highlight the main directions of HRC, which are regulated by the standards: controlled stop of the robot, robot control using human movement, speed and separation monitoring of system, limiting the robot’s power and force [16].

Considering a multi-agent system, each element is defined as a robot agent or a human agent. The goal of the system agents is to perform the task effectively. Thus, for safe and effective interaction between a human and a robot, it is advisable to use methods for solving tasks in game theory with active agents whose actions are mutually determining in relation to each other. Given the cognitive abilities of agents, the optimal solution to this such system determines the Bayesian Nash equilibrium or Stackelberg equilibrium, depending on the available information and the roles of agents. The goal in designing is to find the bounds on robot actions, which are safe for human and back reaction and to maximize the robot’s utility or minimize the robot’s cost within the bounds [17].

The cobot should be designed intelligent enough to conduct social behavior during interaction with humans safety and efficiently even in emergency situations. In the long term, the effectiveness of robots
will only increase. There are three main factors that contribute to the onset of such a turning point moment [15, 19]:

- Improving the economic efficiency of robots in relation to human labor.
- Introduction of such technological advantages in robotics solutions which will allow to effectively implement robots in key industries and economy.
- The rapid development of the robotics market.

3. Collaborative robots: implementation example
With the automation and implementation of the HRC in series production as a major step toward future intelligent manufacturing. Modern cobots are being introduced into manufacture and changing the production process. It becomes cheaper, more flexibility and efficiency. One of the unique opportunities of cobots is the cognitive ability to take decisions independently.

Great results in the field of HRC in manufacturing have BMW Group. Spartanburg plant has succeeded in implementing of cobots that work side by side with human workers – in one team. BMW Group has upgraded the production environment in the automotive engineering. The visual interaction is shown in figure 2 (BMW Group Plant Dingolfing).

![Figure 2. HRC in the axle drive assembly [18].](image)

As a result of innovative production, it allows to reduce the ergonomic adverse and stressful situation. This allows human operators to use their cognitive abilities to maximum effect. Human operators can work together with robots without protective fences. Efficiency and effectiveness at the workplace – more room for creativity. Experts note that after the introduction of HRC in production, the implementation of processes has increased by up to 30% and this may affect many other areas of production in the future in the long term [18]. This ensures efficient distribution of tasks on the production line. This helps to eliminate negative human factors in the work process, leaving time and energy to solve more complex and creative tasks. An important point in production is that the worker is always protected against injuries.

4. Conclusion
Cobots as the element of the progressive future of robotics have become safer and more efficiently. They can perform various tasks. The configuration and programming process become possible at the workplace in a real time. The global demand for cobots is growing every year. In the future, cobots will become the main tool of the production process in the industry. This will help to optimize the process, reduce production costs and increase productivity.
As a result of this work, the human’s factors that affect the HRC and aspects of safety measures in HRI were considered. Further work on the study in this area will allow conducting practical experiments based on the knowledge obtained. Next stage of the research work will consider the effective solutions to the distribution tasks between human-agents and robot-agents of the multi-agent ergatic robotic system in real working conditions. A system focused on safety HRI in a shared workspace during collaboration will be modeled by centralized and decentralized algorithms.

In the future, the research of new materials, the development of technologies and machine learning will make cobots more interactive and intelligent. Their goal will be to interact with a person in a model as close as possible to human-human interaction.

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