THE HUMAN - ROBOT COLLABORATION STAND IN A UNIVERSITY LAB

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Abstract: *This paper is the result of a study conducted in the faculty's robotics laboratory. The study had a principal objective: to develop a working station with the help of which the possibility of human-robot collaboration in industrial applications would be tested; other indicators were also tracked, such as labor productivity.*

In the last couple of years, a new concept has been introduced, namely industrial robots working alongside factory workers. This way the tasks are shared between the humans and the robots. The robots even begin to look more and more human over the years, the so called cobots. The authors have as an example the collaborative robots produced in the last couple of years such as the robot produced by the Danish company Universal, the LBR IIWA robot produced by the company Kuka Robotics, etc. For the authors it is obvious the fact that industrial robots producers will keep developing more and more in the future in order to increase companies' performance, especially because many industrially developed countries have reported a decrease in the workforce in the last couple of years. That is why we proposed a working station which will be used in the university's lab, but which will also be given as an example to regional companies representatives. The work had several steps. The oldest but the dearest robot in the laboratory has been used, namely SCORBOT, predominantly meant for didactical laboratories, because it is a versatile, reliable robot, which is suitable for teaching and training students in robotics. The working stand has as components a robot, two deposits containing tools such as scredrivers, callipers or pliers, two deposits for assembly pieces and one deposit for finalized pieces. The tools' presence is identified by the robot due to infrared rays emitted by these tool due to the fact that every tool holder has been equipped with presence sensors. The robot offers the worker tools, pieces, measurement devices in the order of the technological assembly process. Measurements for determining the time it takes the worker to assembly the pieces without the robot have been performed, then the same measurements were taken for when the robot was involved. A great improvement in productivity has been noticed. Another benefit of involving the robot is decreasing the level of tiredness for the worker if the time unit is chosen favorably. Needless to say, the robot's implication means a higher productivity level which depends very much on the robot's technical capabilities as well as the worker's physical ones. However the real challenge and the essence of the robot- human collaboration is the avoidance of accidents. The workplace must be built in a way that would protect the human from the robot's movements. The authors believe much will change in the industry due to the human- robot collaboration in the future.

Keywords: *collaborative robot, industrial robot, human-robot collaboration*

1. INTRODUCTION

In recent years, a new concept has evolved for production engineers, which is robots that collaborate with the operator. The concept is related to the industrial robots introduction to the manufacturing lines or to the flexible manufacturing cells alongside the workers. That way, the tasks are shared between the worker and the robot. More recently, the robots have even

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started to take the appearance of a human even more, hence why a new term for this kind of robot was invented: the collaborative robot. It looks like things will change drastically in the production industry due to the human-robot collaboration.

The present paper had several steps: documentation, constructive design, making the components, assembling the pieces, designing the technological process, organizing the workplace as well as programming the robot.

It is well known the fact that one of the objectives of robotics science is to improve the robots' use in order to increase their productivity as well as the processes they are involved in. Needless to say, this holds for a big variety of industries, [1].

In the faculty's robotics lab there are several types of robots, from didactic ones to those meant for industrial purposes. There have been several inquiries coming from companies in the region regarding using these robots, in order to develop ways in which the worker could collaborate efficiently and safely with robots.

2. THE HUMAN - ROBOT COLLABORATION IS NO LONGER A NOVELTY FOR THE ENTERPRISE ENGINEERS

So far, in the majority of enterprise processes, the human has been the main "actor". For several years, the production has been based on work solely performed by people. Many times this work has meant intense physical effort, exposure to industrial emissions (noise, dust, toxic substances, unusual temperatures etc.) Machines have eventually replaced manual work. Automation exists in pretty much all manufacturing processes. However, in the last part of the 20th century, automation reached a new level: robotics. Industrial robots took over some of the activities performed by workers, especially the dangerous, hard and repetitive ones. The manufacturing processes have become complex, but the unemployment rate is also something that worries our society. Therefore, in the last couple of years the involvement of robots has taken a new perspective, that of collaboration with humans. Figure 1 presents the situation where a worker from the mechanical industry works alongside an industrial robot produced by the company Universal. Universal Robots is a Danish company, founded in 2005, which focuses on producing user-friendly robots, or to be more precise robots that adapt easily in collaboration with humans [2]-[3].

When we built the work station, we had to make it clear from the beginning that the robot is not meant to replace the human, it is in fact only meant to work alongside him/her in order to improve the worker's abilities and to free him/her from difficult tasks, such as lifting heavy objects or performing operations that require high precision. Up until recently, robots and people were working in different areas of the manufacturing process. In completely automated areas, the human's presence was either no longer needed or the worker was just a supervisor. In the industry's future, it is assumed there won't be a separation between automated and manual workstations. Humans and robots will work together without affecting the safety of those involved. This collaboration is clearly revolutionizing the industrial production and has clear benefits such as:

- increase in productivity;
- maximum flexibility in production;
- improved workers' posture by eliminating processes where workers had to work in less ergonomical positions and the reduction in accidents risks.

Our research has highlighted the fact that collaborative robots are produced under different forms and sizes. Some of them have a human like appearance, others have been built based on the industrial robots' current image, others are a combination of the two.

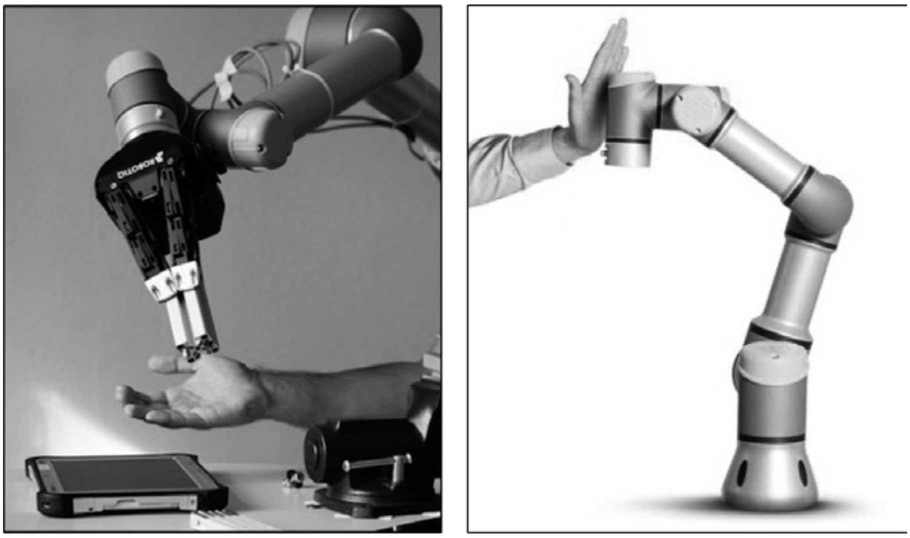

Figure 1: Human-robot collaboration, Universal Robots, collaborative robot, [2]-[3].

The Kuka Robotics company from Germany has recently developed the collaborative robot LBR IIWA (industrial intelligent work assistant). It is built differently compared to other traditional Kuka robots. The structure which contains sensors in each engine makes the human-robot collaboration possible in the most delicate and interesting manufacturing processes. In this way, LBR IIWA paved the way for a new era in the human-robot relationship, making it more direct. The robot can be considered as the worker's 3rd hand and it can work directly with people, without the need of a protection mechanism, since the robot's speed can be reduced based on the distance between the human and the robot, so that the robot is always staying still whenever the worker is approaching it, figure 2, [4].

Figure 2:Collaborative robot **LBR iiwa** Kuka. [4]. Figure 3: the „Baxter" robot, [5].

In 2012, Rethink Robotics innovated the robotics world by designing the collaborative robots with a human like appearance. The company built the most well known collaborative robot, „Baxter". Baxter is an industrial robot with a friendly face and human like gestures, equipped with a big variety of sensors. It moves and it does different things safely and carefully around the workers. It has sensors on its head and on its body which allows it to sense people's presence. The head also has cameras with artificial views, which constitute the robot's eyes. The contact sensors are sensitive to any unpredicted touch. Industrial robots producers will keep developing this concept in the following years in order to increase companies' performance, much more so because the human workforce is decreasing in many industrially developed nations, [5].

3. THE HUMAN - ROBOT COLLABORATION STAND IN A UNIVERSITY LAB

In order to gain experience in this domain of industrial engineering, we tried several applications with the robots already existent in the lab. We were conscious of the fact that in the industry, the need for recent generation robots with geometry and parameters that would be in favour of human robot collaboration is very obvious. Our experience goes from simple to more complex. We believe that a stand would be useful in order to develop the idea that the operator can work with the robot and in order to encourage the engineers in that sense. The first stand used the robot Scorbot. The Scorbot robots, produced by RoboGroup TEK, formerly known as Eshed Robotec, are meant especially for didactic labs, since they are simple and pretty versatile, suitable for training and teaching students. The programme Scorbase controls the Scorbot robot in order to have the ability to execute precise movements, controlled by the remote. The Scorbot robots were built in various forms, their evolution in time being based both on the mechanical part development as well as the programming part.

Scorbot ER-III is a robot capable of similar applications to the ones industrial robots do. It has 5 degrees of freedom and it exists in the faculty's robotics lab, the same place where the work station is as well.

The assembly process of a group of pieces, using screws, has been analyzed. Both the pieces as well as the assembly process were specific to the manufacturing process of a company in the region. The worker was doing the assembling using screws from several pieces and specific tools and in the end he was doing the measurements (figure 4). The operation itself wasn't technologically complicated, but the work place was suitable for automation. We decided we wouldn't remove the worker from the manufacturing process, but to increase the productivity. The work pace had to be established by the robot, but periodic breaks were defined as well.


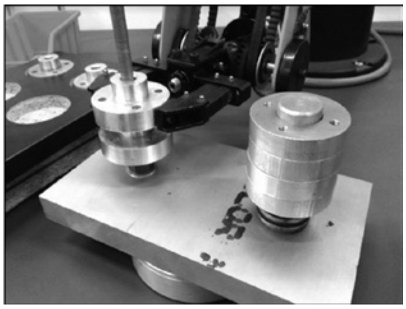

Figure 4: The operator assemblying pieces with screws using screwdrivers and makes specific measurements using measure and control instruments.
Figure 5: Deposit for some of the pieces that need to be put together

In this part of the paper a stand specific to assembly processes is presented. The idea was to develop a human - industrial robot collaboration in real time based on the assembly process previously mentioned. The application does not involve a collaborative robot.

Following the analysis of the steps needed to be taken, a deposit meant to host all tools, pieces and screws was put in place. In figure 6a and 6b, parts of this deposit can be seen, such as a primary deposit for tools (screwdrivers for different purposes), measure and control instruments, boxes for the tools used in the different stages of the technological process and a secondary deposit for tools. The robot will be in charge of dealing with the tools, transferring them from the deposits before and after they have been used by the worker.

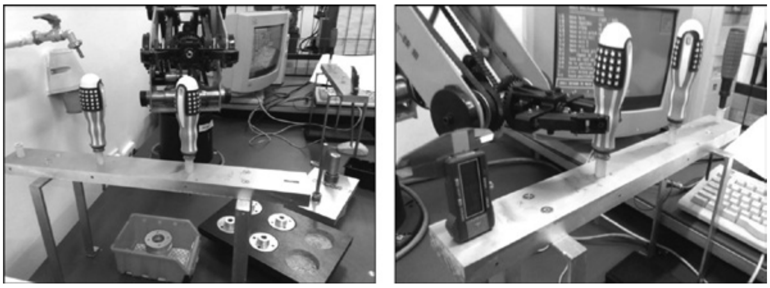

Figure 6. a: Deposit for pieces and measurements and control instruments;
b: The robot deals with the tools and the measurement and control instruments
(photo from the lab).

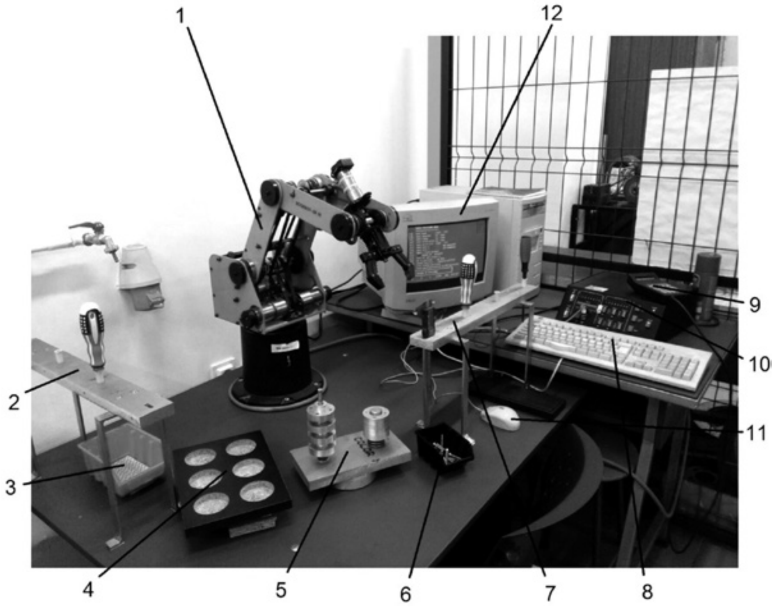

Figure 7: Working station with human robot collaboration. Photo taken in the robotics lab.

The deposits used for the work station have been equipped with presence sensors. That way, the presence of each tool and of the measurement instruments is controlled by these sensors.

A couple of the elements that appear in figure 7 are: the robot Scorbot ER III (1), the primary and secondary deposit for tools and measurement and control instruments (2 to 7), the robot's controller (10), tech pendant (9), display (12) control, its teach pendant, the monitor and the PC.

The tools and measurement and control instruments placed in the deposits by the worker after their utilization are transferred in the primary deposit by the robot. This transfer is done while the worker does the assembly using the screwdrivers.

Measurements for how long the assembly process takes have been made both for when the robot is participating and for when it is not. The conclusion is that without the robot's participation the worker's assembly time is around 7-8 pieces per hour. That is the equivalent of around 44-46 pieces per 8 hour shift. Unforeseen breaks have been noticed as well.

When the robot got involved, the productivity increased, since in this case around 12 pieces were made per hour, which meant about 86-90 pieces in an 8 hour shift. The productivity went up due to reducing useless breaks. In both situations however, the necessary breaks were taken into consideration. In the first couple of days, the worker reported on the intense working pace. In reality, the working process was just much better controlled. Breaks of 5-8 minutes were allowed every working hour. Recommendations for periodic replacement of the workers that worked in this system were made in order to avoid the tasks' routine.

Noise level measurements have been performed in the lab. The noise level without the robot was at 60-70 db on average, sometimes being out of this range due to wrongful manipulation of the tools and pieces. The noise level when using the robot was around 75-80 db. This was measured with the help of a professional sonometer. In both cases, however, the noise level stays within the normal limits imposed by the work safety and security regulations.

CONCLUSION

In the next period, we intend to transfer the application to engage with a robot Kuka 6, a robot that is in the ROBFELX laboratory. We expect higher performance and greater confidence from the regional industry in human-robot collaboration.

In this article, a collaboration application between worker and robot and not a production application with real cobot is presented. This will be a preoccupation for our laboratory in the next years. After designing and creating this workstation, we tried to show that the assembling process of pieces can be done on adapted stations, equipped with specific elements and with the implication of industrial robots. It isn't always necessary to have the latest generation of robots, since they are still quite pricy and the return on investment isn't always a sure thing in the short run.

However, the real challenge and the essence of the human-robot collaboration is due to the protection mechanisms against collision which translates into the robot's capacity to work alongside the worker in a friendly way. It must be avoided at all costs that the robot cause any harm to the worker in the production process. It is noted that this type of human-robot collaborations have gained the interest of those who design manufacturing lines and lead the production process and they will become more and more popular in the industry in the next few years.

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