Collaborative Robots and Human Robot Interaction: A Review on Two Revolutions of Industry 4.0

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Abstract - *Industry 4.0 is filled with number of repetitive and dangerous manufacturing tasks. The major problem in industries also concerns with the accuracy and productivity of the robots. The most promising solution to these problems is the utilization of technologies such as collaborative robots and human robot interaction. These technologies enable operators to complete a particular work with much higher production rate and minimum risk to human life. The level of freedom given to these robots eventually generates the need of safety as well. This paper discussed the role of collaborative robots and human robot interaction in revolutionizing industry 4.0 along with its safety, various applications, challenges and future trends.*

Key Words: Collaborative robots, human-robot interaction, safety, applications of cobots, future of cobots and HRI.

1. INTRODUCTION

Industry 4.0 has introduced various modern technologies in order to enhance the automation as well as to increase the safety of human lives. Human robot interaction (HRI) and collaborative robots are two of such technologies. With increase in demand of productivity, safety and accuracy in today's world, technologies such as HRI and ultimately cobots have gained considerable attention.

There has been a great progress in the work of research and development of these intelligent machines in the last 30 years. There still exists various tasks in today's industries where it is too complex for robots or too expensive to be fully automated. Hence, combine working of both humans and robots is the most promising and affordable solution for this problem. A cobot is a robot intended for direct human robot interaction within a common space, or where humans and robots are in close proximity. Whereas HRI is a common term for all form of intercommunication between robots and humans.

The use of cobots has been a great asset in the fields such as manufacturing, agriculture, medical and many others. Flexibility and reduced risks to human lives are its cons which can be used in the sector of space exploration in the near future. This paper is fully dedicated to the study of cobots which uses HRI to perform different tasks in industry 4.0 according to various researches done in the past years.

In this paper, the fundamental working and features of collaborative robots (cobots) and Human Robot Interaction (HRI) is explained in the section 1 and section 2 respectively. Further, the role HRI in enhancing the performance discussed in section 3. As the powers of interaction and restriction free movements is given to the robots, safety concern is equally important in this area. As a result, basic laws of robots and methods which minimizes risks while working with these machines are stated in section 4. Lastly, the sectors where cobots and HRI is used (section 5) along with their challenges and future trends are mentioned in section 6 and 7 respectively.

2. Collaborative Robots

A robotic system that coexists and intercommunicates with their human counterparts in a common space is known as collaborative robots or cobots. Cobots are the new generation of robots which are usually unbounded by any kind of fencing. The major difference in cobots as compared to that of robots is the presence of direct interaction with human workers. Using this interaction enables organizations, at least in theory, to leverage the strengths and endurance of robots with the tacit knowledge and agile decision-making skills of humans. [3]

Cobots contains a lot of sensors and are highly active towards detecting human intervention. They are used to assist or replace human workers in life threatening or exhaustive activities. Hence, HRI plays a significant role for cautious completion of a particular job. Abilities such as flexible to deploy, safe and cost effectiveness makes it easier to automate various processes using cobots. Pick and place, packaging, finishing tasks and quality inspection are some of the major applications of cobots.

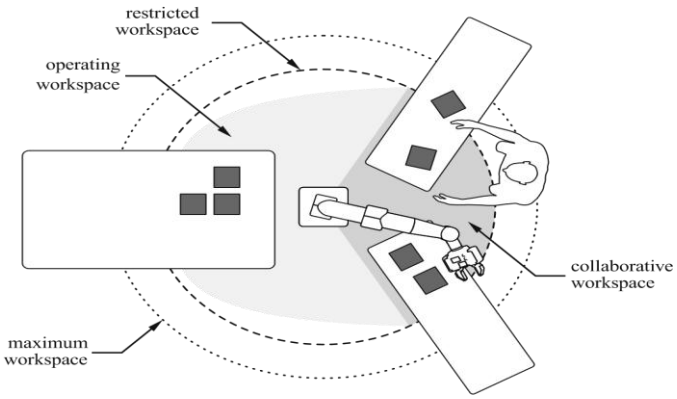

Fig 1. Maximum workspace (limited by dotted line), restricted workspace (limited by dashed line), operating workspace (grey areas), and collaborative workspace (dark grey area) [1]

- Maximum workspace: space which can be swept by the moving segments of the robot, end-effector and the workpiece.

- Restricted workspace: portion of the maximum space restricted by limiting devices that sets up the limits which cannot be exceeded.

- Operating workspace: portion of the restricted space that is used while performing all motions in the task program.

- Collaborative workspace: portion of the operating space where the robot and a human can perform tasks simultaneously during production operation. [1]

Traditional robots	Collaborative robots
Robot and workers are separated through fence	Common workspace
Fixed installation	Flexibly relocated
Interacts only during programming with the workers	Interacts frequently with the worker
Profitable only when the size of lot is medium to large	Profitable even at single lot production

Table -1: Various characteristics of traditional robots and collaborative robots. [6]

3. Human-Robot Interaction

Human–Robot Interaction (HRI) is a field of study which is dedicated to comprehending, designing, and evaluating robots used by or with human beings [4]. The purpose of HRI is to feed robots with all the information and skills needed to intercommunicate with humans. This interaction gives rise to collaborative robots or simply cobots.

The purpose of research and development throughout last decade was to establish simple, easy and reliable interaction between human and machines. HRI has gained a lot of significance and importance in recent times. Some the major applications of HRI include automotive industries, rehabilitation and medical sector and in the field of agriculture [5].

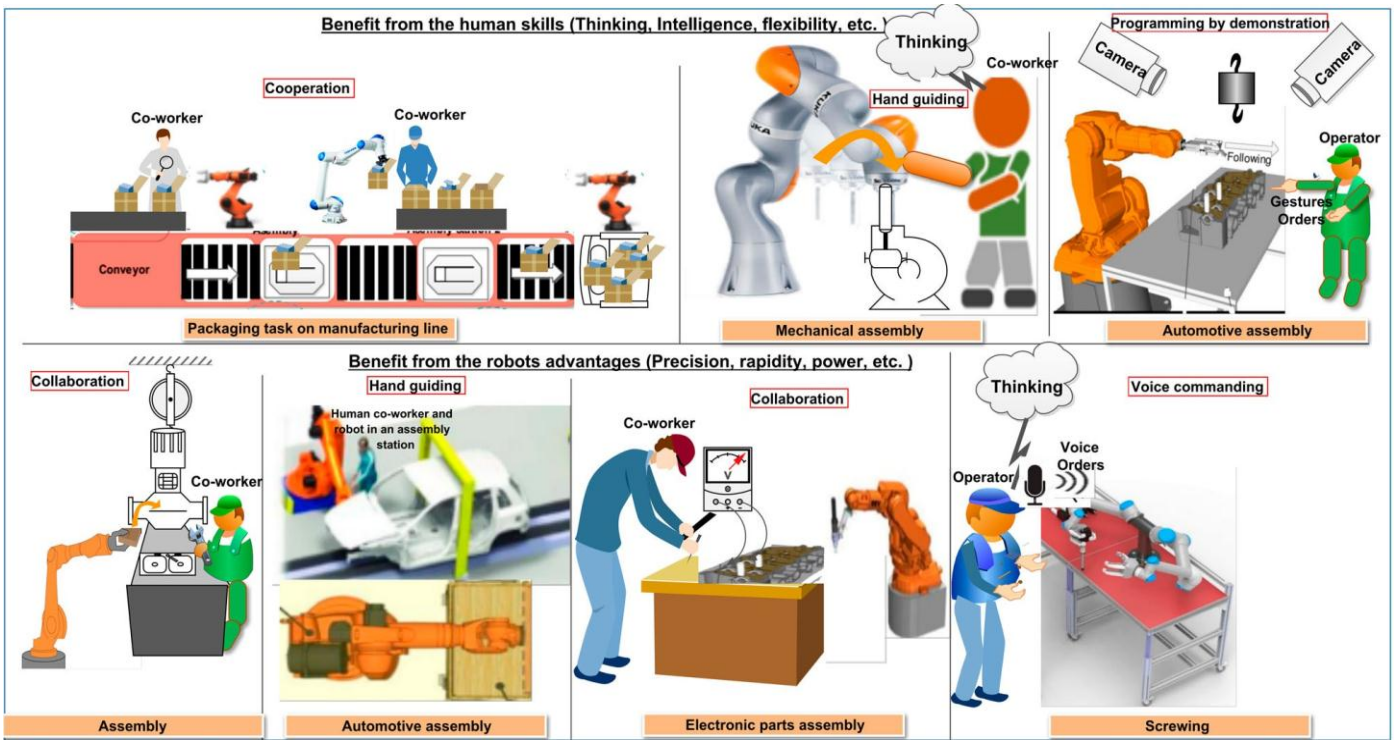

Fig 2. Examples of Human robot interaction and cobots tasks. [2]

The above picture depicts the working of humans and robots in collaboration with each other.

Human Contributions	Robot Contributions
Knowledge of executing the task	Precision
Flexible in tasks	Superior speed and force
Understanding of control strategies	Reliable performance of repetitive activities
Easy adaptation and learning	Handling and hazardous and heavy components

Table -2: Various contributions of humans and robot.

4. Enhancing performance of cobots through HRI

The ultimate goal of various researches in present decade is to fully automate the working of cobots. In order to fulfil this goal, it is essential for a cobot to understand human emotions. HRI makes it possible to enhance the working of cobots. According to previous researches, the ability of collaborative robots to understand human signals can be improved by using three major techniques which are facial animation, arm/hand gestures and arm motion.

At a high level, prior work has primarily considered the robot's geometry to resemble an "arm" structure. Drawing inspiration from human morphology and human arm behaviors, this approach augmented the robot's interaction capabilities with a face animated on a screen or used arm gestures and motions to communicate the robot's internal states or intent. [9]

5. Safety bounds in cobotics and HRI

Safety is a fundamental prerequisite and should be considered as the most important factor while working with collaborative robots. The dangerous and shape tools of these machines along with their brute force and speed can end up as a threat to the human workers around them.

The three basic laws of robots considering the safety of human workers in its surrounding are as follows.

1. First Law:

A robot should not injure a human or allow a human to come to harm.

2. Second Law:

A robot should obey orders given it by a human, except when the orders is conflicting with the 1st Law.

3. Third Law:

A robot must protect its own existence as long as such protection does not conflict with the 1st and 2nd Law. [8]

The existing features which minimize the risks in HRI and cobotics are as follows.

1. Perception.
2. Cognition enabled control.
3. Action planning for safe operation next to humans.
4. Hardware safety features.
5. Societal and psychological factors.
6. Risk assessment and safety analysis through hazard analysis techniques. [7]

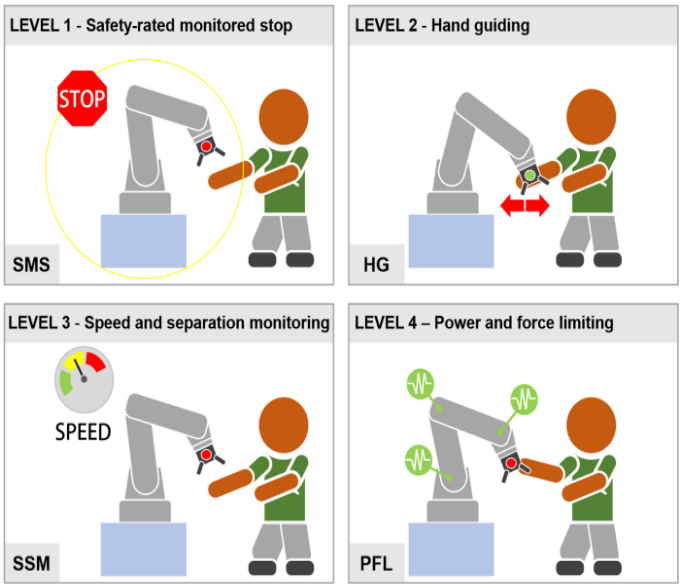

Fig 3. The four collaborative operative modes identified by robot safety standards 102181/2:2011. [6]

6. Applications

In the past decade, the areas of cobotics and HRI have gained considerable attention in many industries. Increased precision and faster completion of work are the reasons behind it. Greater productivity and increased revenue gains are the outcomes of these technologies. Currently, the sector of manufacturing uses the technologies of cobots and HRI on the largest scale. Other such applications along with manufacturing are discussed below.

I. Manufacturing Industry:

In manufacturing industries, repetitive work and task where heavy and bulky components and lifted are completed using cobots. An example of such task is the implementation of robot workstation in the BMW plant in South Carolina. Here, cobots are used in the process of door assembly which has ultimately increased the assembly rate in the plant. The picture depicting the same is shown below.

Fig 4. Cobot helping in the door assembly operation in BMW plant of South Carolina. [10]

Other operations which are included in the list of applications are picking, packing and palletizing, product inspection, welding and material handling. Since the working of cobots and humans is in close proximity and the chances of potential injuries is much higher, safely is essential in such environments.

II. Agriculture:

The implementation of HRI and cobots can provide solutions of complex problems, increase comfort and productivity in the field of agriculture. It can help in numerous agriculture related tasks such as seeding, spraying, harvesting, protecting plants, hauling, fertilizing, and mowing. The superior accuracy in operations such as spraying and fertilizing in cobots as compared to humans is one of the reasons behind adoption of this technology in the sector of agriculture. For example, autonomously working robots are used in the process of spraying and is shown in the figure below.

Fig 5. Agricultural Robot Sprayer. [11]

III. Rehabilitation and Medical:

For people with disabilities, working out with robots turns out to be a very effective method order to exercise and stretch various joints and muscles. Cobots can provide opportunities for interaction and therapy which are not possible with other forms of technology. Intelligent wheelchair is of the example of this technology which are used for path planning and to avoid collisions for a person with physical and mental challenges. [12]

Coronavirus pandemic was the period where the nasopharyngeal swabs of patients were collected for the detection of coronavirus genetic material with the help of autonomous robots. Cobots can also be used for the processes of cleaning in order to minimize the spread of viruses.

IV. Other applications:

Some of the other applications of collaborative robots and human robot interaction are the fields of military, mining, education, space exploration, etc. Keeping safety into consideration, humanoid robots and wearable robots such as exoskeletal systems can be a great asset in today's world. With increasing demand of products and safety of human lives, these technologies with continues to grow in the coming decade.

7. Challenges

Along with advantages, cobots and HRI have their fair share of challenges as well. The reason behind developing cobotic systems is to exploit the expertise of both robots and human. This gives rise to various complexities in its design and performance. The challenges which still needs to be addressed are discussed in this section.

The unstructured nature of environment ends up into being the reason behind majority of its challenges. Space exploration is one such challenge. Due to the factors like radiation, dust, temperature and presence of vacuum in the space, the existence of robotic systems gets hampered. The facility of communication can be very limited due to lack of power and time delay. Military is another area where the environment is unstructured.

Unlike space exploration and military, assistive robotics does not get affected by unstructured environment. The close proximity between robots and humans is behind this particular problem. This interaction can evolve into unanticipated patterns. Humanoid robotics is a challenge area when a human form is taken by a robot. Social and emotional aspects of interaction become more important than anything else with this type of form. Due to the requirement of language understanding and sophisticated speech recognition, natural language interaction has come up as another problem in this technology.

There has been endless debate on robots providing jobs versus taking them away. This issue is related to human values and fear of dominance by robots. There is no doubt that robots act as useful assistants to humans but it also diminishes the human sense of self-worth. [13]

8. Future Trends

There is an abundance of future potential for cobots and HRI because they offer various benefits for achieving industrial standards. Along with many challenges and problems, it has potential of producing solutions having positive social impact. The flexibility and productivity of this technology will make it possible for its expansion in wide range of industries in the upcoming years. According to previous research, it is expected that the market of collaborative robot all over the world will grow at a Compound Annual Growth Rate (CAGR) of 30.37 %. While its market value will grow from 674.9 million to 2305.2 million USD by the year of 2025. [14]

Ability to perform unrestricted moments and extensive interactive features are two of the future capabilities of collaborative robot which may come into existence. Retrofitting of industrial robots, that is converting traditional robots into cobots, plays a very important role to achieve greater automation in industries. The future of these technologies looks very bright as robots get integrated into more and more applications all over the globe.

8. Conclusion

Cobots and HRI have emerged as immensely valuable tools in wide range of industries. Market value of these technologies has experienced substantial growth with increasing demand of factors like flexibility, safety, productivity and accuracy. Focusing on the safety of workers present in the proximity area will lead towards the adaptation of cobotics in industries. Along with various challenges and research gaps, space exploration and defense are the fields where cobotics can be a great asset given that enough amount of research and development is carried out in coming future. The need of both of these technologies will continues to rise as more and more industries are willing to adopt autonomous and efficient production techniques.

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BIOGRAPHY

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