Human-Robot Interaction: Challenges and Opportunities for Collaboration

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Abstract- A review of the most significant research concerns that are now facing the human factors area is offered, coupled with a description of the current state of human–robot interaction (HRI). Collaborative robots are growing more in demand in a wide variety of industrial settings due to the versatility of these robots as well as their comparatively inexpensive costs. As a direct consequence of this, there is now a rise in the quantity of collaborative solutions being created for use in industrial applications. It is not easy to carry out scenarios in which robots operate autonomously while simultaneously synchronising their operations in a safe industrial setting with workers on the shopfloor. However, this is something that needs to be done. This publication provides research that is based on five recognised difficulties and that gathers the key crucial variables to keep in mind when creating applications for them in order to bridge the vacuum that presently exists in the safe implementation of industrial collaboration scenarios. The paper is called "This publication offers a study based on five identified issues that gathers the key critical factors to keep in mind while building applications for them." This review was conducted with the intention of bridging the knowledge gap that now exists in the field of the secure implementation of industrial collaboration scenarios. As a consequence of this, a classification scheme with four distinct tiers is provided. This system gathers both the issues that have been identified in the field of human-robot interaction as well as the achievements that have been achieved in that sector. It has been found that there are a range of interaction tactics between humans and robots, and in-depth discussions have taken place on the topic of both one-way and two-way collaboration between humans and robots. This has been done by doing a comprehensive analysis of a significant number of recent papers that are important to research. The challenges that come with putting human and robot cooperation into practise for various manufacturing processes, as well as the challenges that come with one-way and two-way collaboration between humans and robots, are uncovered and discussed in this article. Additionally, the article discusses the problems that come with putting human and robot cooperation into practise for various manufacturing processes.

Indexed Terms- Robot Interaction, Human Challenges

I. INTRODUCTION

The introduction of Industry 4.0 has caused significant changes to be made in the procedures that are used during the production process. One of its key objectives is to reduce the quantity of human labour required for manufacturing by teaching industrial robots to perform tasks that are considered to be of the lowest cognitive demand.[1,2] It is necessary to swiftly reconfigure the systems in order to fulfil the demand for high output in a short amount of time for a number of product variants. According to experts working in the manufacturing sector, the reorganisation of a production system in order to create new goods or product variants requires a big financial investment and is a very challenging process to go through. According to Landes (1969), human–robot cooperation (HRC) has the potential to provide a wealth of prospects by addressing the challenges inherent in the sphere of active research interest and making it feasible to transfer both information and activity. In other words, HRC has the ability to make it possible to transmit both knowledge and activity. Because it permits the effective utilisation of previously acquired resources in conjunction with the use of newly produced technology, HRC is an important strategy that can be implemented to a wide range of industrial enterprises. This is because HRC can be applied to a wide variety of industrial businesses. Figure 1 illustrates the multiple processes that take place in businesses where robots are used as a component of a system to achieve precision and repeatability. These operations are shown to take place across a variety of different sectors. [3]

Assembly, welding, quality control inspections, painting, palletizing, and material handling are all included in these processes. Intelligence and adaptability are two fundamental features of the human condition that, when combined, make it possible for humans to quickly perceive risks and incorporate such assessments into their decision-making processes. This ability to quickly recognise risks and incorporate them into their decision-making processes is what distinguishes humans from other animals. The incorporation of these characteristics into the robot has the potential to result in the production of a system that is efficient and cooperative, which would lead to a considerable improvement in flexibility. At this point in time, the expansive benefits offered by HRC are constrained because of the communication barrier that exists between people and robots.[4] There is a high probability of risks and a potential risk related with this barrier. Despite the fact that HRC provides them, this is the situation that exists. Bidirectional intent detection, work role identification during task execution with human colleagues, estimation at trade-off to achieve optimality, and evaluation by itself during live collaboration are the primary challenges that need to be conquered in order to successfully expand HRC, as shown in Figure 2. These obstacles must be overcome before HRC can be successfully expanded. It wasn't until the middle of the 20th century that people started thinking about the possibility of humans and robots working together. During that time period, researchers introduced this notion by means of work sharing and time sharing tasks. These are the types of activities in which the actions are carried out in a sequential manner, one after another, independently.[6]Even though it ensures that people are safe, it still requires a significant amount of time to pass during which one of the available resources must be left idle. After a period of time had elapsed, the researchers started working together with the robots through the use of voice control while concurrently participating in communication that was just one-way. Figure 3 depicts the evaluation of HRC technologies to assess whether or not they are compliant with the requirements that have been set over a specific amount of time. The development of advanced sensor-based control, voice control, and gesture control are some examples of the one-way communication techniques that have been created in order to achieve this objective.[7] Later on, augmented reality (AR) paired with improved vision sensors made it simpler to establish two-way communication. This aided in increasing productivity and making better use of the resources that were readily available. Because of this, individuals were able to steer clear of any possible hazards.

Figure 1 The function of industrial robots within the context of the manufacturing industry [5]

Figure 2 Key obstacles for collaboration between humans and robots [10]

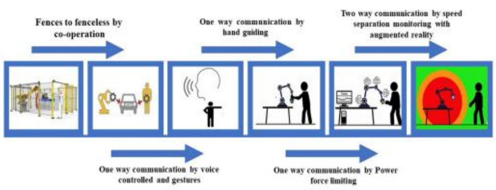


Figure 3 The Development of HRC-Related Technologies [11]

The Internet of Things (IoT) enabled cyber physical system and upgraded communication devices each played a role in the creation of, a novel category of hand-guiding collaborative robots in a manner that followed the other.[8,9] These robots work in tandem with humans and take their cues for movement and action from the people around them. This article's objective is to offer an overview of the current state of the art technologies that are implemented in HRC. More specifically, the study will focus on the challenges that were encountered when employing these technologies as well as the opportunities for further development.

- Necessity of human–robot collaboration

The IR was the spark that initiated the transformation of technology to make it easier for people to carry out work in an effective manner with the least amount of effort, as well as to carry out sophisticated activities that humans are unable to accomplish because of the limitations of their capabilities. This transition has made it possible for people to carry out duties in an effective manner with the least amount of effort. As a consequence of the improved capacity of machines and equipment to carry out a wide array of industrial operations, human employees started to be replaced.[11,12] The human race is capable of doing tasks that are considered to be among the most challenging, and they also have the cognitive capacity to make decisions under conditions that might result in harm. Two elements that have the potential to impact the significance of the role that ergonomic considerations play in the process of assigning jobs are the weight of the object and the posture of the person performing the work.[13,14] However, the ability to achieve repeatability, precision, and the lifting of high weights while performing job duties is limited. The human anatomy is the most significant constraint that exists, and a physical incapability may cause an ergonomic imbalance through poor posture and continuous stretching. On the other hand, the robot has been specially created and developed so that it can carry out repetitive tasks with better precision and without growing weary. This was done in order to maximise the robot's potential. Robots are able to work in hazardous environments and can carry higher weights than human employees can.[15,16] Robots can also function in confined spaces. Intelligent behaviour may be programmed into robots by the use of complex controls, with the support of sensors similar to those found in automation seen in stationary applications. The level of intellect is only adequate for doing tasks in an environment that has been previously comprehended, and it is unable to make rapid decisions even when they are required. According to the findings of a number of studies, the robot grippers and the kinematic arrangement both provide unique challenges when it comes to the manipulation of things that are both flexible and extremely small. Expensive sensors are fitted in the robots at in order to fulfil the requirements laid out in the specifications.[17]]

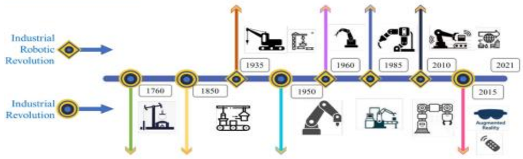


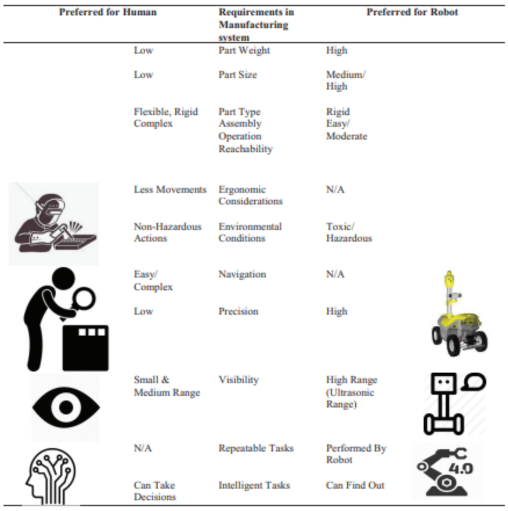
Figure 4 Industrial robots are driving a revolution in their respective industries .[18]

a few examples of the simpler occupations, which people are also capable of doing in certain circumstances. When it comes to job assignment, one of the most important factors to consider is often the amount of dexterity that the robot possesses. It is possible to make productive use of the synergy that exists between people and robots in order to accomplish a variety of jobs while also limiting the amount of time and money that is necessary for manufacturing. This is something that is both practical and possible to do. This is an idea that is not completely out of the question.[19,20] The re-configurability of production layouts in manufacturing companies is made possible by the combination of human traits such as intelligence and flexibility with the precise and repetitive actions of robots. This, in turn, enables manufacturing companies to produce a wide variety of goods. In order to construct a production system that is more cost-effective, it is vital to have suitable job sharing and allocation; the parameters that drive task allocation are represented in figure 5.[21]

- Communication between human beings and artificially intelligent machines

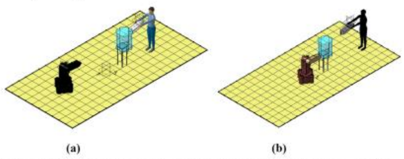
It is risky to perform work in the same production cell as a preprogrammed robot that works in that setting because a robot operates in a specific environment to fulfil a specific task that has been assigned to it without understanding the environment in which it functions. Because of this, it is risky to perform work in the same production cell as a robot.[22] It is important to build a separate cell for the robot that has a fencing boundary that reaches as far as the robot's end effector can reach in order to avoid any type of collisions from occurring while the operation is being performed.[23] This is required in order to keep the robot safe. In this scenario, the installation of many robots might result in a substantial consumption of space and the use of time-consuming material movement systems. In the many sorts of work cells that are available, people and robots can take turns working in these cells one after the other to perform their respective tasks.[24] This is due to the fact that the existence of one resource does not have a negative impact on the efficiency of the operation of the other resource. While a robot is working on the product, the human is not contributing in any manner and is keeping their distance from it; after the robot has finished the task, the robot will be kept in an off condition (inactive), and the person will work on the task.[25,26] The typical setup for the distribution of labour is depicted in figure 6, which may be found here. Time-sharing is somewhat comparable to work-sharing in the sense that both the robot and the human are required to work independently based on the amount of time that is allotted to them for their separate tasks. This is the case with both time-sharing and work-sharing. This is done so that the amount of downtime that each resource endures may be cut down to a minimum. According to Michalos et al. (2016), the phrase "parallel work sharing" refers to a scenario in which a person and a robot work concurrently on the same piece of work without cooperating. In this scenario, the person and the robot do not share the work. Figure 7 depicts a differentiated partition that allows people and robots to perform their work in distinct regions of the same workplace.[27,28] This is possible as a consequence of the partition's ability to keep the two groups physically apart. It needs to have the ability to comprehend the situation in order for humans and robots to be able to interact with one another in an efficient manner. This would ensure that people are safeguarded from any harm that may be caused by robots. [29]

The communication in one direction, whether it be through words or gestures, is uncomplicated and effective due to the fact that it is concentrated on the need of human beings. The instructions that the robot receives through these communications allow it to carry out tasks in the workspace in accordance with those instructions.[30] Following that, the information is transferred to the robot in the manner depicted in Figure 8, which is an example of the one-way communication method. A speech sensor will detect the user's voice in order to facilitate voice-based communication, and then it will convert that recognition into an operational command for the controller. These findings appeared in three different investigations that were all published independently. The system that is controlled by gestures provides a higher level of engagement since it is not dependent on the language that the user speaks. Even the most fundamental hand movements may be understood by a computer.



Preferred for Human	Requirements in Manufacturing system	Preferred for Robot
Low	Part Weight	High
Low	Part Size	Medium/ High
Flexible, Rigid Complex	Part Type Assembly Operation Reachability	Rigid Easy/ Moderate
Less Movements	Ergonomic Considerations	N/A
Non-Hazardous Actions	Environmental Conditions	Toxic/ Hazardous
Easy/ Complex	Navigation	N/A
Low	Precision	High
Small & Medium Range	Visibility	High Range (Ultrasonic Range)
N/A	Repeatable Tasks	Performed By Robot
Can Take Decisions	Intelligent Tasks	Can Find Out

Figure 5 The selection of resources based on the properties of the production system[31]



Notes: (a) Work by human, robot – inactive; (b) work by robot, human – inactive

Figure 6 "Work splitting between humans and robots under a single source active state [32]

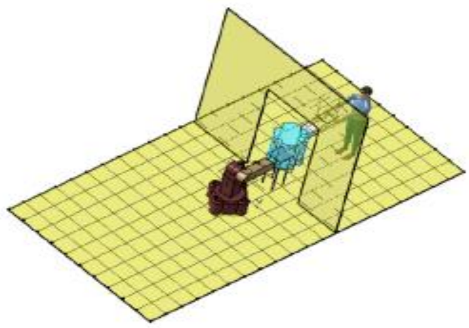


Figure 7 Sharing of human and robotic labour in parallel"[33]

A gesture sensor and the processing necessary to translate it into an actionable command. In addition, the instructions that are received from the controller are what will be used to function the robot. The human maintains some distance away from the robot in order to control it either by speech or gestures, as described in the previous two techniques.[34] The Human Resource Centre (HRC) makes use of a number of useful methods, including tele-operation.

It allows a one-way connection between the operator and the robot using a variety of interface technologies such as teach pendent and joy stick, and it does so without the need of any intermediate software. Despite the fact that this kind of one-way communication technique is highly beneficial for giving orders from human to robot, in the event that they are executed incorrectly .[35]

- Challenges and opportunities

A human–robot co-operation system provides a fantastic opportunity to combine the unique capabilities possessed by people with those possessed by industrial robots that are already in existence. This technology makes it possible for humans and robots to interact with one another through time-sharing and work-sharing obligations while maintaining a better degree of safety. While the elimination or reduction of idle time for a robot is a big concern, this technology makes it conceivable for humans and robots to connect with one another.[36,37]

The use of voice control technology to run collaborative robots with people is proven to be a very beneficial approach for managing robots to carry out a wide variety of specialised industrial operations.[38} This is due to the fact that humans are better able to understand human speech than robots are. [39] However, a dysfunctional function might be the consequence of irresponsible action on the part of people, as well as overlapping or intermixing with other forms of noise. [40] In this mode, one of the most difficult tasks will be to devise a method for filtering out annoying sounds while at the same time offering an interface that is capable of supporting several languages. [41,42] The use of gestures to cooperate between people and robots has been shown to be one of the most effective and versatile kinds of communication that may take place between humans and robots. This is in comparison to voice control, which is the traditional method of interaction between the two. [43,44] During this stage of the process, human and robot contact is made by photographing a human gesture using a suitable communicative device that is worn by the human participant. This step is necessary for the method to proceed. Nevertheless, the potential for a form disruption in the production process exists whenever there is an interaction between a human operator and another individual, regardless of whether or not that other individual acts in a reckless or irresponsible manner.[45,46] Visibility may be adversely affected by a number of factors, including illumination and several other components of the surroundings, which can eventually lead to misconceptions. [47] One technique to make power force restriction approaches useful for human cooperation with low payload robotics is to incorporate a range of sensors on the joints and linkages of the robot. This will allow the robot to better understand its environment.[48] However, these methods are not appropriate for human collaboration with high-speed or heavy-payload robots because of their lack of adaptability. Adaptable connections that have a high payload capacity could be the solution to this challenge.[49] The partnership of people and robots in the product inspection system raises a number of important questions, one of the most important of which is the method for evaluating humans' and robots' respective performances in comparison to one another. [50] A lack of such an evaluation may cause several interruptions in the production line as a whole; as a consequence, it is essential to develop a system that can find and repair these defects in an effective manner in order to avoid more issues from occurring.[51] It has come to our attention that the majority of HRC technologies allow it conceivable to reorganise computer systems in order to execute mass customization. However, in order to create such a high-end connection, the most powerful adaptive systems that are now accessible are required.[52]

CONCLUSION

IR 4.0 ought to be outfitted with an autonomous system so that it can fulfil the current demand for mass manufacturing that can be tailored to individual specifications. Existing sensor-equipped autonomous robots are capable of doing a situation analysis; nevertheless, these robots have a great amount of difficulty carrying out automated decision-making in a range of scenarios within the industrial sector. Researchers have pushed for human–robot collaboration as a method of sharing work and knowledge based on the capabilities of both humans and robots, in addition to the limitations of each. The industrial applications of the HRC, such as welding, assembling, and inspection, are taken into consideration for the purpose of conducting research on them, and this consideration is based on the research literature that is currently accessible. Shared workspace, shared work piece, work sharing, time work sharing, collaboration methods of hand guided, power force limitation, manual guiding, and speed separation monitoring approaches are some of the criteria that are being investigated in HRC applications. The following observations and findings have been arrived at, and it has been determined that a significant amount of research was necessary in this area in order to achieve the objectives set forth by HRC. It has been observed that the existing fence that was used to create the work sharing environment requires more space so that welding operations may be done out utilising HRC. This is necessary in order for the work sharing environment to function properly. The use of solutions for three-level collaboration can reduce the amount of space that is needed while at the same time providing a greater number of lockouts, switches at low levels, hardware at medium levels, and interfaces with high levels of collaboration .

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