MAE 4300 – Professional Practice in Mechanical Engineering

Applications and Ethics of Collaborative Robots

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1 Introduction

Robots are becoming increasingly common throughout the world and especially in the manufacturing space. Most, current industrial robots are designed with safety cages or other safety measures as they can cause significant harm to humans. These safety systems have often limited the tasks these robots could preform, but new technologies have broadened possibilities. Many of these new applications of robotics rely on the robot collaborating with humans. Human robot collaboration (HRC) combines the relentless efficiency of robots with the adaptability of human workers to increase performance and enable new use cases for robotic automation. These collaborative robots, called cobots, use a variety of methods to ensure worker safety without traditional measures such as fences. As with any new technology one must consider the ethical implications of implementing these cobots. International and national standards organizations have published safety and risk evaluation standards for industrial robots in general and cobots in particular. This has allowed cobots to enter the workforce effectively and safely. However, there is need for additional standards as cobots are increasingly seeing use in non-industrial applications (Wang *et al.* 2020). These new applications also bring with them new ethical questions for the technology, both safety concerns and other new concerns. Cobots as a technology are extremely versatile and as that technology improves they will continuously be employed in new applications in manufacturing, medicine, and most other industries. Engineers, companies, industry organizations, and regulators must be proactive in assessing new safety issues as well as a range of broader impacts of ethical concern.

2 Context

Cobots are still in the early stages of their implementation throughout society. While one can envision ways to utilize cobots for many applications this report presents two specific examples: manufacturing and the medical industry. Manufacturing is the primary industry where cobots are currently in general use and as such offers practical examples of this technology and its benefits as well as the downsides. The medical industry, specifically the application of robot assisted surgery, is an example of a field where cobots will likely see use in the future. It is also a field where the potential for harm is extreme and so this technology must be rigorously assessed before use.

2.1 Manufacturing

Industrial robots have been crucial to manufacturing for many years and have allowed for tremendous improvements in efficiency. Most of these industrial robots can pose significant harm to workers if safety measures are not in place. These safety measures prevent workers from interacting with the robot during its operation. This keeps the worker safe, but also limits the applications where these robots can be used and requires much more infrastructure around the robot. Cobots were developed with the aim of keeping workers safe without blocking their access to the robot.

First, this allows cobots to be much more adaptable. With standard industrial robots the safety fences and other precautions make it very inefficient to move the robots throughout the factory or to change the operation they preform. The flexibility of the cobot also allows for lower upfront investment. In addition to not having to purchase the safety equipment, the work cell often needs less infrastructure like conveyors, or more robots, and cobot work cells take up less manufacturing floor space. They need less infrastructure because of both the lack of physical safety systems, and the ability of humans to collaborate with cobot operations. Cobots also leverage their collaboration to allow for unique applications which are too difficult or expensive to develop a fully automated method. Collaboration enables actions to be carried out with more variability and including unusual motions that fully robotic systems cannot accomplish (Javaid *et al.* 2022).

Throughout various industries cobots are employed in material handling, assembly, product testing, machine tending, and many other tasks. However, cobots are still a small part of the industrial robot workforce. A 2019 European Union survey found that only 3.5% of the interviewed businesses had implemented human robot interaction (HRI) (Wischniewski *et al.* 2022).

2.2 Medical Industry

Robots have seen significant adoption to preform minimally invasive surgeries, growing from a small volume in 2000 to about 800,000 surgeries in the United States in 2018. Cobots have yet to see much implementation in these procedures. The current robotic surgeries usually consist of a doctor manually controlling a robot and not sharing space (Alemzadeh *et al.* 2015). As cobot technology improves it will expand the range of procedures as well as the effectiveness of robotic methods. In Buess et al the authors examine how cobots could be incorporated into surgical procedures. Using maxillofacial surgery as a test case they determined which the parts of the procedure could be automated. Then they used motion capture technology along with other observations gathered while observing the procedure to program the cobot. Then the procedure was conducted on a dummy by the surgeon along with robot assistance. They found they were successfully able to replace the human assistant with a cobot and preform the procedure effectively (Beuss *et al.* 2021). Technology like this will see use alongside greater and greater use of manually controlled surgical robots as well as automated surgical robots.

Cobots are currently seeing use in other less safety intensive areas of the medical field. Copenhagen University hospital uses UR5 cobots to automate part of their blood sample testing. Other cobots have been used for sanitising, patient monitoring, and even basic patient interaction (Holland *et al.* 2021). These platforms will see increasing capability and associated use as the AI and sensing systems for human interaction are improved. The offer massive potential to provide augmentation to the extremely strained medical system in many countries. Furthermore, in augmenting the medical staff they allow for less expensive medical staff which reduces the overall cost of healthcare.

2.3 Other Industries

Outside of the first two industry examples, applications in sectors like food service and education have also been proposed. A Korean team developed a cobot barista platform which could operate autonomously to prepare drinks and interact with customers and workers (Lee *et al.* 2021). Additionally advances in human interaction AI as well as text processing AI like GPT3 have given birth to proposals for cobot use in education. Robots could interact directly with students to assist in learning, and provide supervision and monitoring (Timms 2016). However this technology needs significant improvement and refinement before this is possible.

3 Ethical Issues

As cobots are implemented more throughout society the ethical implications of this technology should be closely reviewed. Safety and worker health have been the primary focus of cobot ethics but as the technology expands to new use cases additional issues must be addressed. Cobots working in autonomous service and human interaction roles should be carefully designed to provide a pleasant and bias free experience for human collaborators. In addition to these concerns, as with any automation intervention we must consider the effects these cobots have on whatever or whoever they replace. To break down this issue the various stakeholders involved can be grouped into three main groups: the companies/engineers implementing cobots, the workers in all industries who are working alongside cobots, and the customers interacting with cobots in service sectors like the medical industry.

3.1 Companies

The companies implementing these systems as well as the engineers they employ to do so largely benefit from this technology. Companies implementing cobots do so to increase productivity, improve worker safety, increase adaptability, and for many other benefits to their operation. They can also allow expansion into new business domains like robotic surgery. As companies continue implementation they have an important ethical role to do so safely and fairly. Furthermore, the engineers designing cobots as well as the engineers implementing the cobots have important roles to play in ensuring their ethical use. As systems increasingly automate, more decisions are made by engineers and the machines they create. These engineers must understand this responsibility and carefully take into account knowledge from the experts they are replacing (ASME 1976). This is especially critical in the medical industry because there is a large body of specialized knowledge that robotics engineers do not have which is critically important to cobot operation and customer safety.

3.2 Workers

Workers are an important stakeholder as they are the stakeholder currently most involved with cobots and they have both a negative and a positive relationship with cobots. For one, the workers are put in an competitive relationship with the cobots as this technology largely replaces human labor. Automation and the loss of manufacturing jobs in most circumstances can be very detrimental to workers and communities through economic decline and diseases of despair (O'Brien *et al.* 2022). However, the ethical discussion of whether or not automation should happen in general is a discipline and society spanning question which is out of the scope of this report.

In addition to this slight competitive relationship, cobots also can help improve the lives of workers they work alongside. For example, a study was done of Ohio small businesses and the improvements to worker health and safety from implementing robots and automation. This study found in almost all cases studied that the automation reduced risk factors (Lowe *et al.* 2022). Although this study examined automation in general, cobots are particularly useful in taking over strenuous or repetitive activities such as bolt tightening, and lifting components into place in tasks which otherwise would have to be fully human operations. In these situations the implementation of the cobot improves worker health by reducing the amount of harmful movements required in addition to the general productivity benefits. A 2022 study of institutional data from United States found that greater exposure to robots reduced work-related injury rates by about 1.2% . The same study also found increased robot use to be associated with a 4% reduction in physical job intensity as well as a 5% decline in disability in data from Germany (Gihleb *et al.* 2022). However, this data is generalized to industrial robots as such the specific effects of cobots are not clear.

One must also consider that cobots naturally introduce an additional risk to the work environment by their lack of safety containment systems. Organizations like the ISO and ANSI have been proactive at implementing standards to address this question. The ANSI/RIA R15.06 (1999) and the ISO 10218-1 (2006) established general standards for industrial robot safety, and the ISO 15066 (2016) established a more specific standard for collaborative robots (ISO 2006) (RIA 1999). This last standard is especially useful as it includes guidelines on protective measures, power and force limits, and other safety measures specific to cobots (ISO 2016). Modern cobots are generally considered very safe but ultimately they do pose risks to workers that could be avoided with significant investment into automated systems. The exact level of danger posed by cobots is hard to determine as there is little data available. This means when implementing cobots companies must carefully consider risk of injury or other consequences to ensure their workers are safe. As automation dominates these facilities companies must consider the mental effects of isolation and other negative mental health effects from working alongside robots. Currently there is little to no data showing negative mental effects to the workers working with the cobots. However, this issue is may increase if the workers become more isolated or the workers develop more of and adversarial relationship with the cobots (Gihleb *et al.* 2022). Overall the pace of development in this field means regulators and industry organizations must continue diligently updating and expanding the standards regularly to keep pace with technological possibilities. Worker mental health will become increasingly important to measure as well as the larger effects of automation.

3.3 Customers

The fields where customer integration with cobots will play a large role are still limited in their actual use. As this use grows the standards mentioned previously will be an essential first step for protecting consumers. However these standards may need to adapt as they are largely based around cobots in industrial environments. Many of the same safety issues that workers face are also faced by the consumers, but there will be new issues come that with the variety of applications where cobots will be employed. The medical industry is an example where the consumer (patient) is in an extremely vulnerable position in relation to the robot. Current surgical robots, operated by doctors, have seen some incidences of patient injury and death during procedures. A study of FDA data from 2004 to 2013 found an annual average number of incidents to be 83.4 per 100,000 procedures (Alemzadeh *et al.* 2015). Although this incidence is not unreasonable and has likely improved in the decade since this data was collected, significant improvements are needed for expanding the use of robots in surgery on a large scale or in more automated applications.

Since automated collaborative systems are being developed for applications across society new challenges will continue to arise. One major concern is when automated systems interact with customers one cannot assume they have a basic level of competence of knowledge about the device whereas a manufacturing employee would have some special knowledge. For example, emergency stop procedure must often be automated entirely or must be made extremely obvious to allow novice customers to interact safely (Vasic and Billard 2013). This greatly increases the responsibility of the engineer and programmer to build a system robust enough to be safe in every scenario.

One must also more carefully consider the data collected by cobots when they are interacting with customers. Whether they are dynamically interacting with customers or just preforming an action like making coffee, the robot will be collecting a large amount of data. Regulators will need to consider what information and under what terms should cobot manufacturers and operators be able to collect data.

4 Conclusion

Cobots have massive potential in a variety of industries and have demonstrated the ability to be used safely and with positive effects on all stakeholders. Customers, workers, and companies each interact differently with cobots and benefit from them in unique ways. The ethical issues facing this technology are mainly focused on the safe interaction of cobots and stakeholders. Although many safety measures have been developed the technology is rapidly evolving so the safety frameworks and associated international standards must evolve rapidly with the technology. These standards and frameworks will need significant additional breadth and depth as the application expands from manufacturing to common use in more diverse fields like surgery, food service, and education. Also, although regulators have yet to be involved largely in this technology, as it becomes more ubiquitous there may be need for measures more significant than industry standards such as government regulation.

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