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COLLABORATIVE ROBOTICS

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Abstract

A collaborative robot (cobot) is essentially an industrial robot that can safely operate alongside humans in a shared workspace. Unlike a typical industrial robot, which is usually confined to safety cages, a collaborative robot is designed to work safely in close proximity to human operators. Cobots are cost-effective, safe, and flexible to deploy. They make automation easier, even for small and mid-sized companies around the world. This paper introduces collaborative robots and their applications.

Keywords: robots, robotics, collaborative robotics.

INTRODUCTION

Artificial intelligence, machine learning, and robotics are hot topics in many industries right now. Robots touch every corner of modern life. They have imparted education, business, engineering, communications, transportation, agriculture, medicine, and national defense. Traditional industrial robots are designed to achieve positioning accuracy with high repeatability, high speed, and stiffness. Robot industry is developing a new generation of industrial robots that are designed to work in collaborative environments and in close proximity to humans [1]. These newly developed machines are known as collaborative robots.

Collaborative robots have been an important new development in the robotics industry. A collaborative robot is a robot intended for direct human-robot interaction. It is different from the traditional industrial robot which is usually fenced and isolated from human contact. An traditional industrial robot requires a fence, as typically shown in Figure 1 [2]. Collaborative robots are able to work safely alongside humans without the need for fencing and gates. Their three main characteristics are: safe, easy to use, and affordable. Service robots may also be regarded as cobots since they are intended to work alongside humans.

WHAT ARE ROBOTS?

The word "robot" was coined by Czechriter Karel Čapek in his play in 1920. Isaac Asimov coined the term "robotics" in 1942 and came up with three rules to guide the behavior of robots [3]:

(1) Robots must never harm human beings,

(2) Robots must follow instructions from humans without violating rule 1,

(3) Robots must protect themselves without violating the other rules.

Robotics has advanced and taken many forms including fixed robots, collaborative robots, mobile robots, industrial robots, medical robots, police robots, military robots, officer robots, service robots, space robots, social robots, personal robots, and rehabilitation robots [4,5]. Robots are becoming increasingly prevalent in almost every industry, from healthcare to manufacturing. Figure 2 indicates that robotics is one of the branches of artificial intelligence.

Special forms of robots in common use include drones and chatbots. Drones are flying robots, a type of robots, that are poised to proliferate in certain commercial sectors. Drones can help utility crews after a storm by quickly and safely identifying areas in need of repair. Drones can also help with maintenance tasks, such as surveying solar panels for damage.

Chatbots have empowered the banks and other financial institutions by simplifying the complex processes. We interact with Facebook Messenger bots all the time. Messenger bots are revolutionizing the small business world. Messenger bots can answer customers' questions, collect user's info, organize meetings, reduce overhead costs, and engage in other business tasks. Big companies like Walmart, Alibaba, and Amazon have been benefitting the help of bots.

COLLABIRATIVE ROBOTICS

A collaborative robot (cobot) is a form of robotic automation built to work safely alongside human workers in a shared, collaborative workspace. It is designed to assist humans in a specific task or allow humans and robots to work simultaneously in the same workspace. A task is shared between the cobot and the human worker, the reason for the term "collaborative." With cobots, both machine output and human efforts go side by side. For example, in an assembly line, the human workers load up the mechanical robots with the necessary parts and robots do the rest of the job.

Cobots are equipped with software-controlled sensors that help them detect objects, people, and potential collisions. They promise a marked improvement compared to legacy industrial robotics in worker safety and human complementarity. The software monitors every movement of the cobot and immediately shuts it down if it detects something unexpected. Although cobots have built-in safety features, a risk assessment is necessary to ensure that the robots and humans interact safely. A typical cobot is shown in Figure 3 [6].

The International Federation of Robotics (IFR), a global industry association of robot manufacturers and national robot associations, defines four levels of collaboration between industrial robots and human workers [7]:

- *Coexistence:* Human and robot work alongside each other without a fence, but with no shared workspace.
- *Sequential Collaboration*: Human and robot are active in shared workspace but their motions are sequential; they do not work on a part at the same time.
- *Cooperation:* Robot and human work on the same part at the same time, with both in motion.
- *Responsive Collaboration:* The robot responds in real-time to movement of the human worker.

Cobots are designed to be more responsive than regular industrial robot. They have many uses, from service robots, logistics robots that transport materials within a building, to industrial robots that help automate unergonomic tasks. Companies are using them because they can be placed alongside humans in small assembly lines, because they are affordable and easily trainable, and because they are flexible to handle repetitive, boring, and ergonomically challenging tasks.

TYPES OF COLLABIRATIVE ROBOTS

Collaborative robots come in a variety of shapes, sizes. and functions. The different types of Cobot are defined by their safety and programming features. According to ISO 10218, from the International Organization for Standardization, the four types of collaborative robots are defined as follows [8]:

1. *Safety Monitored Stop:* Collaborative robots defined as safety monitored stop are intended for

applications that have minimal interaction between the robot and human workers.

2. *Speed and Separation:* These collaborative robots use more advanced vision systems to slow operations down when a human worker approaches and stop operation altogether when a worker is too close to the robot.
3. *Power and Force Limiting:* These collaborative robots are built with rounded corners and a series of intelligent collision sensors to quickly detect contact with a human worker and stop operation.
4. *Hand Guiding:* These collaborative robots are equipped with a hand-guided device by which an operator directly controls the motion of the robot during automatic mode.

The four major types of collaborative robots are not all built for constant collaboration, but each features a number of safety capabilities to prevent serious injury. Collaborative robots also come in mobile varieties. In Japan, a fleet of mobile robots collaborates with humans.

APPLICATIONS

A cobot is a robotic device which manipulates objects in collaboration with a human operator. Cobots are used in numerous applications and sectors worldwide. The automotive and electronics industries are expected to be the largest users of collaborative robots. The flexibility of collaborative robots, as well as their financial accessibility, make them an ideal solution in a wide range of industries and applications. Some of the most common areas of application of collaborative robots are:

- *Manufacturing:* Manufacturers are implementing cobots into their production to address labor challenges, increase productivity, and improve quality. Cobots frequently carry out manufacturing-related tasks, including assembly, packaging automation, material handling, machine tending and product quality control.A typical use of cobot in manufacturing is displayed in Figure 4 [9].
- *Welding:* Welding is an essential part of manufacturing. Welding work is carried out with greater precision and avoids the risks derived from this task such as burns or cuts. Cobots are a good option for smaller welding companies looking to automate their production. A cobot for welding is shown in Figure 5 [10].
- *Human-robot Interaction:* Collaborative robots enable engineers to quickly and easily deploy automation in assembly applications where high levels of human-robot interaction are required. Their interaction with humans is more natural. All human-robot collaboration applications require engineers to perform a thorough risk assessment.
- *Medicine:* Robots are being increasingly utilized in the medical field. A new breed of sensitive and collaborative robots is poised to shape the future of robotics in medicine.
- *Pick and Place:* A pick and place task is one in which the robot is required to pick up a workpiece and place into another location and/or orientation. Tasks such as machine tending and packaging/palletizing could also be regarded as pick and place. Incorporating a cobot into a pick and place application can be done with minimal cost and disruption to production [11].
- Other application areas include [12]:

- ✓ Automotive
- ✓ Electronics
- ✓ Metal fabrication
- ✓ Packaging and co-packing
- ✓ Plastics
- ✓ Food and agriculture
- ✓ Plastics
- ✓ Furniture and equipment

- ✓ Scientific research
- ✓ Furniture and equipment
- ✓ Pharmaceutical and chemical

ADVANTAGES

Cobots continue to expand throughout the industry because of the many benefits they offer. Cobots have been most popular among small and medium-sized businesses. They can be deployed in a wide range of environments and bring many different benefits when compared to traditional industrial robots. In most cases, a collaborative robot is responsible for repetitive, menial tasks while a human worker completes more complex and thought-intensive tasks. Due to shortages of qualified workers and increasing labor costs, the market for cobots continues to grow. Other advantages of collaborative robots include following [8,13]:

- *Automation:* Automation is fundamentally more consistent and reliable than human hands for most repeatable tasks. Collaborative robots allow automating tasks without making major changes in production lines. A cobot is a fully automated system that performs a designated task, set by a customized program, with the utmost precision and repeatability. It takes instruction sets from programmers and automate processes; simple or repeative tasks.
- *Improved Safety:* Collaborative robots are designed to minimize the risk of accidents and injuries in the workplace. Once the cobot program is set to the user's desired quality level, the robot will perform its function the exactly and precisely the same way. By eliminating human error, users can expect far less safety hazards. The robots have built-in capability to detect any unexpected outside force and will stop on contact. This allows the robots to work safely around humans. The robots move at a safe speed to maintain a safe work environment.
- *High Efficiency:* Robotic work stations require a minimal amount of operator involvement after they have been installed and programmed. One trained worker can program multiple machines, eliminating the cost of advanced training for each operating station.
- *Versatility:* Virtually no job is too large or too small. Cobots are capable of a wide variety of applications. They can be moved and repurposed within a production environment as required; increasing end user utility.
- *Flexibility:* Collaborative robots can be easily programmed. This allows for collaborative robots to automate several different tasks with quick changeover times. This flexibility lowers the initial cost of automation and directly contributes to ROI and productivity.
- *Low Cost Deployment:* Collaborative robots come equipped with safety features and do not require fences. This lowers costs while reducing integration time. The low cost of deploying a collaborative robot makes them far more accessible to a wider customer base.
- *Fast ROI:* Collaborative robots often cost less than traditional robots.

They have proven their ability to deliver faster return on investment (ROI) than their industrial counterparts. This is primarily due to the fact that upfront costs are significantly lower, more tasks can be automated per robot, and collaborative robots contribute to high productivity.

- *Accuracy:* Cobots consistently operate with the same amount of force and in the same manner. This guarantees that parts are of identical quality, accurate, and positioned correctly.
- *Increased Productivity:* Increased productivity is another advantage of cobots. Cobots operate continuously without any interruption. Since boring, dangerous, and repetitive jobs are usually assigned to cobots, they can be completed quickly, which increases productivity.
- *Quality:* Quality control errors lead to malfunctioning or unacceptable products. Robots achieve high quality due to their precise and programmable nature.

DISADVANTAGES

As robotic technology continues to advance, the possibilities seem boundless. But such rapid, relentless change also presents many challenges. At first, some people thought that cobots were introduced to replace people's jobs. In reality, cobots are designed to work as assistants for tasks that are too dull, dirty or dangerous for people to perform. Other disadvantages of cobot include the following [14]:

- *Human Dependency:* A cobot can theoretically operate around the clock but it still needs human supervision or assistance at times. Industrial robots, on the other hand, can operate to capacity without the need for human intervention.
- *Limited Speed:* One of the main arguments against collaborative robots is the fact that the robots trade off speed for safety. Cobot operate at lower speeds than other types of robots. To limit force and momentum, cobots simply must operate at lower speeds than other types of robots. Since a cobot's primary goal is safety, speed is secondary, especially when additional safety precautions are adopted. As a result, cobots often are not suggested for applications that require speed.
- *Safety Clearances:* Getting a safety clearance for a cobot can be challenging. Along with meeting safety regulations, relocating a cobot and changing its tasks or its tool set often requires additional safety accreditations.
- *Lower Payloads:* Most cobots support payloads up to 10kg, which may be unsuitable for some applications.

CONCLUSION

Collaborative robotics is an umbrella term that refers to the general idea of proximity between machines and humans for some useful tasks in a shared space. The relatively new robotic technology allows robots and human operators to work together in ways that were previously impossible. Cobots have unique features that make them a good choice for many applications.

Collaborative robotics is the fastest growing segment for new robotics deployments. Collaborative robots are revolutionizing the manufacturing assembly process.The robotics revolution has begun, and there is no turning back. Year after year, the collaborative robot market is expected to experience significant growth, with no slowing down in sight. Currently, the collaborative robots market is dominated by a few major manufacturers. For more information about collaborative robotics, one should consult the books in [15-25] and the following related journals devoted to robotics:

- ✓ *Robotica*
- ✓ *Robitics and Autonomous*
- ✓ *Robotics and Computer-Integrated Manufacturing,*
- ✓ *Advanced Robotics*
- ✓ *Autonomous Robots*
- ✓ *Journal of Robotics*
- ✓ *Journal of Robotic Systems*
- ✓ *Journal of Robotic Surgery*
- ✓ *Journal of Robotics and Mechatronics*
- ✓ *Journal of Intelligent & Robotic Systems*
- ✓ *Journal of Mechanisms and Robotics-Transactions of the ASME*
- ✓ *Journal of Automation, Mobile Robotics and Intelligent Systems*
- ✓ *Journal of Future Robot Life*
- ✓ *IEEE Robotics and Automation Letters*

- ✓ *IEEE Transactions on Robotics*
- ✓ *International Journal of Medical Robotics and Computer Assisted Surgery*
- ✓ *International Journal of Robotics Research*
- ✓ *International Journal of Social Robotics*
- ✓ *International Journal of Humanoid Robotics*
- ✓ *International Journal of Advanced Robotic Systems*

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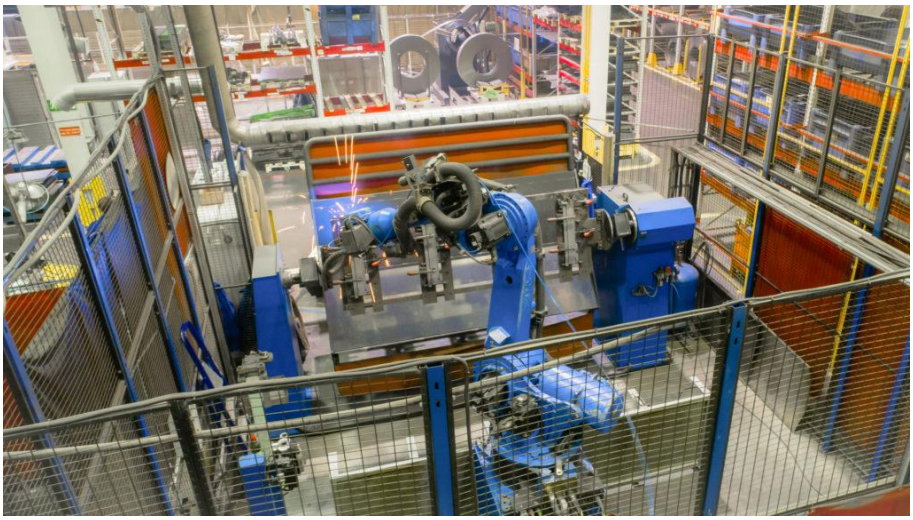

Figure 1. An traditional industrial robot requires a fence [2].

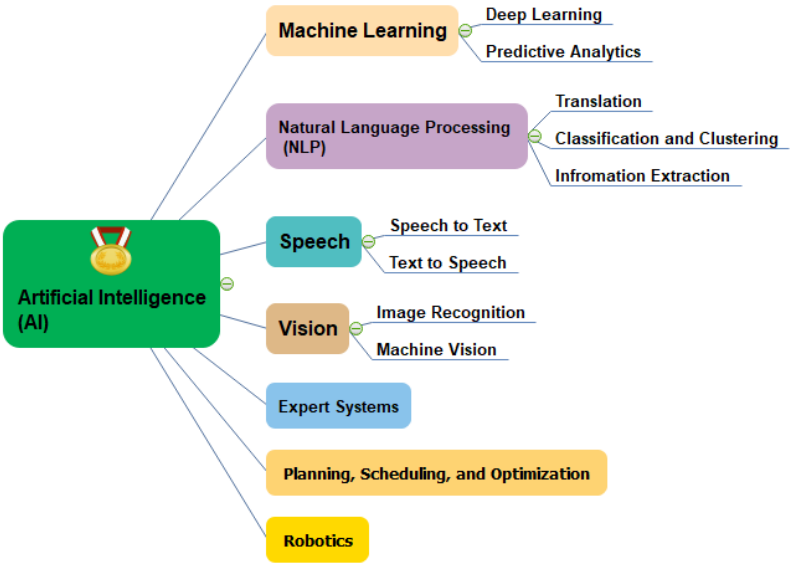

Figure 2. Robotics is one of the branches of artificial intelligence.

Figure 3. A typical cobot [6].

Figure 4. A typical use of cobot in manufacturing [9].

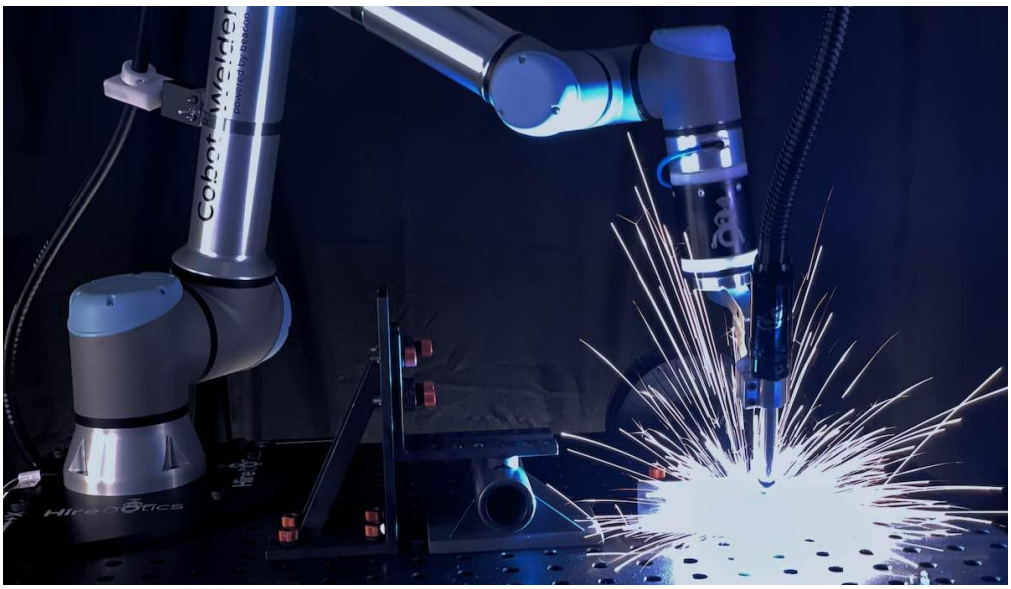

Figure 5. The use of cobot in welding [10].