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COLLABORATIVE ROBOTICS

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Abstract

Industrial automation and robotics are nothing new within manufacturing. However, a new paradigm is emerging which blends manual and robotic activities. Where traditional automation solutions have been isolated from human workforce for safety reasons, new sensorised and aware robotic systems – or collaborative robotic systems (Cobotics) - are now becoming common place, allowing these systems to be integrated into the human workforce.

Now, for the first time, it is possible to combine the human and robot capabilities, expanding the reach of both. The flexibility offered by these Cobotics enables the robotic system to be repurposed quickly for various tasks according to the needs of the plant floor, changing the way we see automation.

This, however, brings an additional complexity to automation design, requiring the consideration of the needs and behaviour of the operator, implying among other considerations a human-centric design aspect in automation.

Introduction

The latest generation of Industrial robots have opened a debate in the last few years, as their design principles call into question concepts which have here-to-fore been considered sacrosanct within Robotics. New features of these advanced robots include “teachability”, asking the question, what is it to be a robot programmer and “inherent safety”, bringing into question the need for safeguarded space. The former of these leads to the possibility of flexible and easily re-purposed robotic systems, while the latter when brought to its natural conclusion implies the new possibility of human-robot interaction and collaboration, leading to these robots being referred to as Collaborative Robots.

A Collaborative Robot is one that has features which make it appropriate for Collaborative Applications (applications in which a human and robot operate collaboratively on a job) or Coexistent Applications (ones in which the human and robot share a space but don’t necessarily directly interact), these can include capabilities like Force/Torque sensing. The industrial robot, however, includes only the manipulator (robot arm) and the controller (often a teach pendant), but does not include the end effector or any additional components needed to perform its tasks. These can include machinery, equipment, devices, external auxiliary axes or sensors and often involve end-of-arm tooling, such as gripper, polishing head, welding torch, and extra sensors such as vision system, force torque sensor, safety sensor. In order for an application to be Collaborative it must first be safe, the implication therefore is that a Collaborative Application demands consideration well beyond the simple use of a Collaborative Robot. The robot, combined with the end effectors and the supporting sensors and equipment, are designated as the robot system and this must be rendered safe before collaboration can happen.

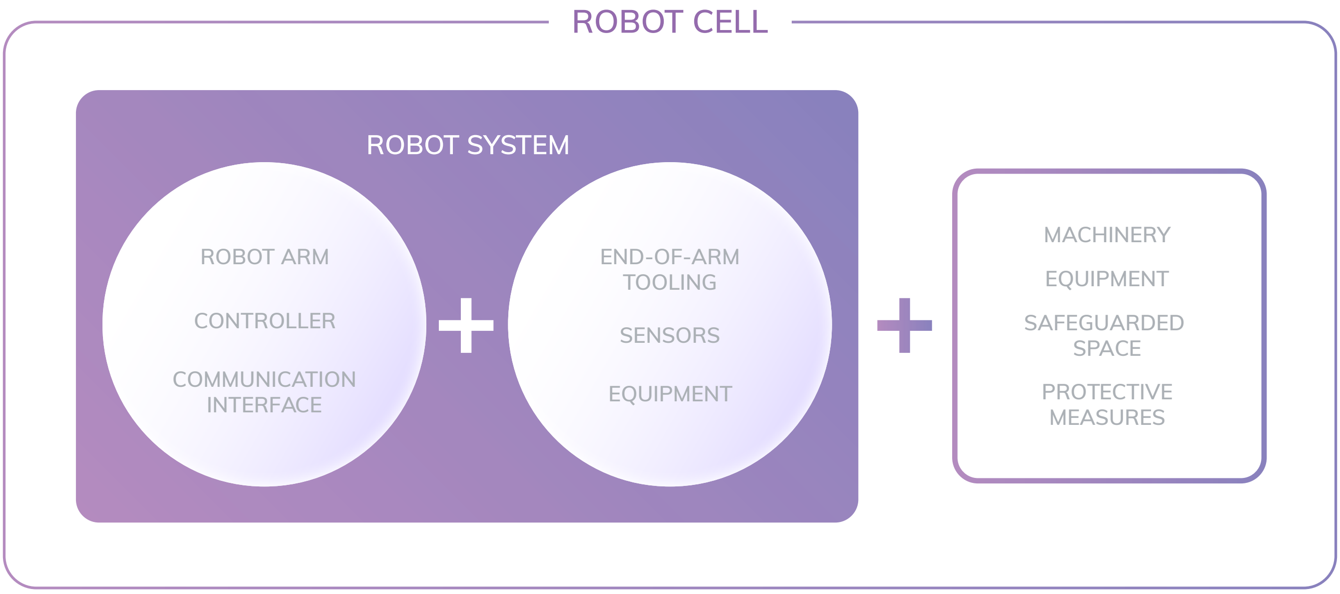

Figure 1 - Definition of terms according to ISO 8373:2012

What Is different

Hazard Removal vs. Risk Mitigation

Historically, industrial robotic applications have restricted operator access to the operations area while the industrial robot system is active in order to achieve safety i.e. the hazard is removed. This limits the industrial robotic application to operations where absolutely no human intervention is needed.

However, a new paradigm has emerged that allows human and robot to collaborate on the same application, combining the human reaction and cognition skills with the repetitive performance of robots, extending the reach of both. What allows the collaboration with the human is the implementation of the appropriate safety measures and mechanisms. ISO/TS 15066:2016 provides four methods which can be included in an operation to reach the required safety level. These includes the Safety-rated monitored stop, Hand Guiding, Speed and separation monitoring, and Power and Force limiting.

1. In the Safety-rated monitored stop robot feature, the robot motion is stopped before an operator enters the collaborative workspace to interact with the robot system and complete a task and resumes after the operator has exited without any additional intervention.

2. In the Hand-guiding operation method, the operator uses a hand-operated device to transmit motion commands to the robot system.

3. In the Speed and separation monitoring operation method, the risk reduction is achieved by maintaining at least the protective separation distance between operator and robot at all times.

4. The Power and Force limiting operation method requires specifically designed robot systems. Through inherently safe design or safety-related control system, the hazards associated with the robot system are kept below the threshold limit values that are determined during the risk assessment. Such robot systems consist of what are being called a “Collaborative Robot” and allows physical contact, either intentionally or unintentionally, between the robot system (including the workpiece) and the operator. Such robots are designed to dissipate forces in case of impact and are programmed to stop when abnormal forces are detected.

In this new paradigm, the approach is that of risk mitigation and therefore. An important distinction to make here is that technically, almost any robot can be used for Collaborative Applications with the appropriate safety mechanisms in place. ISO/TS 15066:2016 proposes four operation methods in order to reduce the risk level, only 1 requires a “Collaborative Robot”. The collaborative nature of an application therefore comes down to the implementation of risk-reducing safety measures as opposed to the selection of specific robots.

Job sharing / Reallocation of tasks

With the move from hazard removal to risk reduction, comes the opportunity for human and machine to share tasks, this allows increased productivity and better workforce support.

Due to their complexity or their throughput size, some operations are not appropriate for traditional automation technology and have to be performed manually by operators. This means the allocation of human resources to tasks that either do not maximize their value-add potential

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or expose them to health and safety risks like repetitive strain injuries.

By allowing a robot to take on a sub-set of tasks within a process, however, such operations can be optimised. Tasks that are tedious, repetitive or requiring high repeatability can be easily allocated to a robot and tasks requiring cognitive, reaction and fine motor skills can be allocated to human operators.

Currently, highly manual processes often involve health and safety challenges, which can lead to reduction in productivity from chronic conditions. For example, according to OSHA, 57% of European workers say that their work involves repetitive hand or arm movements, which expose them to ergonomic injuries. Similarly, Cobotic applications include supporting an ageing workforce to extend their capabilities, delaying the departure of highly experienced operators.

Human-Machine Interaction: Design

The new human-robot dynamic brings an additional complexity to robotic design, requiring the consideration of the needs and behaviour of the operator. Mechatronics skills are not sufficient in robotic design anymore, an important part of human-centric design has now become critical in terms of safety and ease-of-use. As an example, in the case of force-limited robots, contact between human and machine is allowed, this means that the design must consider the possibility of this impact and provide new communication channels to enable more intuitive, less intimidating and safer interaction.

Some emerging design trends in this new category of robot therefore include rounder shapes and hidden joints, allowing the force of impact to be spread over a bigger surface and thus reducing the pressure applied on the object of contact. Some robot designs also include a soft external skin or even a sensitive skin composed of tactile sensors. Sensors and smart technologies are often added to make the robotic system more “people-aware”, as well as location/context-aware. These new sources of data can be linked through IIoT systems to part management systems or optimisation algorithms, which leads ultimately to smarter robotic systems.

Flexibility

The high flexibility of the Collaborative robots enabled by their ease of programming and small footprint, provides a key opportunity in automation of processes. This flexibility means that a robot system is not limited to one task and can be repurposed quickly for various tasks according to the needs of the plant floor. The fact that this new generation of robot can guided through a sequence of operations without the need for traditional robotic programming the setup for some activities directly in the hands of the process experts -the operators, greatly reducing the time-to-value. This also reduces the risks associated with purchasing as, if the system does not prove fit for purpose, it can be moved to deliver value elsewhere.

Addressing the Roadblocks: IMR & Cobotics

As with any new technological capability, there are questions to be answered, for Cobotics, these questions tend to revolve around: Where can value be extracted? Will my employees be safe? Will my employees work alongside a robot? IMR as an organisation is seeking to address each of these questions and others through direct collaborative relationships with manufacturers, system integrators, standards organisations and academic institutions in additional to chairing the Cobotics National Steering Committee.

Where can value be extracted?

As an Innovation focused organisation, this is one of IMR's first considerations. We work with many manufacturers to understand their needs & motivations and seek to align and test appropriate technology in an iterative way. We use both widely accepted processes like Design Thinking and internally developed tools which draw on - among other things - Lean principles, in order to align our activities and the resultant solutions to the value being sought.

Often, a research project, which can usually be a co-funded initiative, is necessary to investigate the particulars of a process. However, in order to help guiding the reader, some broadly applicable limitations of current Collaborative Robots (usually imposed to achieve the badge) can be enunciated as follows.

Broadly speaking, if the application in question involves high speed operation, lifting of heavy payloads (greater than roughly 10 kg), or long reaches (greater than roughly 1.3 m), this category of robot will not be applicable. A collaborative application can of course be implemented using any robot if mated with the appropriate sensorisation and protocols, however the investments in these supplementary technologies will quickly erode the Return on Investment (ROI) on these systems.

Understanding the limitations of Collaborative Robotics

Due to their design, force-limited robots are limited in:

- Payload – Majority ranges between 2 and 10kg *(FANUC 35kg, COMAU 110kg)*
- Reach – Majority ranges between 500 and 1,300mm *(FANUC 1813mm, COMAU 2210mm)*
- Speed – Limited by the risk assessment of the application.

Moreover, at the time of the paper, end-of-arm tooling for Collaborative application still lacks flexibility (needs of increased dexterity, flexible gripping mechanisms, additional integrated features and sensors).

The Collaborative robotic applications still need to fully adapt to:

- The human
- Unexpected events
- Evolution of the environment

Will my employees be safe?

Health and Safety is predominant in any robotic applications as the operators' safety will always be the primary factor for achieving an acceptance (at all levels of the organisation). As mentioned previously in the paper, the safety of the application is implemented not by hazard removal, but by risk mitigation. This involves special care being taken with the risk assessment performance and the design of the required safety preventive measures. This is an area in which most organisations will, in time, require up-skilling. Moreover, the time and cost required to bring the Collaborative robotic application to an acceptable risk level has to be taken into account in the Return On Investment (ROI) and Ramp-Up Time of the application. IMR and our partners, however, can support organisations as they explore where this new capability can drive value within their organisation.

Current risk assessments and safety considerations are based on ISO TS 15066. Among other work in this space, IMR are participant members of the ISO TC299 technical committee, which is in the process of drafting the next iteration of safety standards for Industrial Robotics.

Will my employees work alongside a Robot?

The engagement of operators is far more important in this mode of automation than in any previous incarnation, as the operator needs to work with and trust the robot. There are therefore a number of new considerations that IMR seek to address in the design of solutions, for example:

- The move for hazard removal to risk reduction (especially through technological means) result in the safety controls becoming invisible on the factory floor. This is a major benefit of this technology but can cause some cultural unease for early adopters as perceived danger and actual danger temporarily diverge.

- The introduction of industrial robots of any sort brings with it the potential for job security concerns, how these robots are introduced is critical to their success.

Therefore, one of the biggest concerns in the introduction of a Cobot in a working environment become its usability and safety, and even more important, user's needs and motivations in using it.

IMR is addressing this challenge by developing and exploiting a vast range of skills, from cognitive psychology and sensorisation, to user interface development and robotic programming, which can be used to remove any operator's fear and rejection for this new powerful and innovative technology.

Conclusion

Collaborative Robotics seeks to change the way we see automation, allowing extraction of value from the joint capabilities of human and robot working in collaboration with no safeguarded space. Their ease-of-use places Cobotic systems as valuable flexible assistants, where highly manual processes are still source of many chronic conditions.

However, challenges such as the lack of fully-developed authoritative information and standards, leading to a lack of understanding of risk management are driving hesitation when it comes to Cobotics implementation.

IMR have been developing critical skills, tools, and partnerships required to tackle these challenges and to enable businesses to implement the technology with confidence and with maximum value delivery. These include skills such as human and process understanding, human/machine interface and communication, and collaborative robotics programming, strong involvement in the National Steering Committee, international standards groups and the development of a National Cobotics Laboratory.

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