Safety and control in collaborative robotics

Robotics technology is moving at the speed of light, and the standards process is struggling to keep up. New types of collaborative robots can be safely implemented: Do a risk assessment, work with experienced suppliers, and get involved with standards development.

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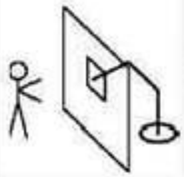
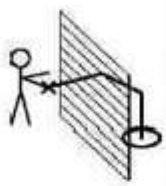
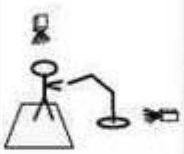
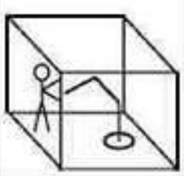
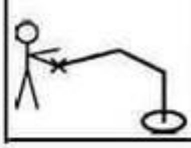
Human collaborative robots are expanding automation possibilities and shedding old barriers. Liberated from their enclosures, these cage-free robots are easier to implement and easier to use. They are making automation more accessible to small and midsized businesses, and allowing manufacturers of all sizes to have more flexibility in automating diverse tasks. With these advantages come new concerns. At the top of the list is the safety of their human coworkers.

New safety standard raises more questions

In May, the Robotic Industries Association (RIA) announced the updated robot safety standard approved by the American National Standards Institute (ANSI). The new ANSI/RIA R15.06-2012 standard is an update to the 1999 edition and is now harmonized with the international ISO 10218:2011 robot safety standard. One of the key updates to the globally harmonized standards addresses human and robot collaboration.

Conceptual applications of collaborative robots

NOTE For requirements see 5.11

Type of application		Description	Safeguards	Objectives
	Hand-over window	– autonomous automatic operation within safeguarded space – robot moves into window – no interruption of automatic operation during access	– fixed or sensitive guards around the workspace – reduced speed and reduced workspace near the window – no robot workspace outside the window – when lower edge of the window less than 1000 mm safeguards according to 5.10.3	– loading, Unloading – testing, benching, Cleaning – service
	Interface window	– autonomous automatic operation within safeguarded space – robot stops at an interface window and can then be moved then manually outside the interface.	– fixed or sensitive guards around the workspace – reduced speed and reduced workspace outside and near the window – hold-to-run control for guided movement	– automatic stacking/ de-stacking – guided assembling – guided filling/ un-filling – testing, benching, cleaning – service
	Collaborative workspace	– autonomous automatic operation within a common (collaborative) workspace – robot reduces speed and/or stops when a person enters the common (collaborative) workspace	– person detection system using one or more sensors – reduced speed according to the distance (5.11.5.4) – robot stops safely when prohibited space accessed and possible automatic restart after clearance if properly safeguarded	– common assembling – common handling – testing benching, cleaning – service
	Inspection	– autonomous automatic operation within safeguarded space. – a person enters the collaborative workspace while robot continues operation with reduced speed and reduced travel	– fixed or sensitive guards around the workspace – person detection system or enabling device – reduced speed and reduced workspace after entering the workspace – measures against misuse	– inspection and tuning of processes, e.g. welding application
	Hand-guided robot	– application specific workspace – moving by hand guiding – moving hand guided along a path	– reduced speed – hold-to-run control – collaborative workspace depending on hazards of the application	– hand-guided assembling, painting, etc.

The standard identifies four requirements for collaborative robot operation, which allow humans to be in the vicinity of an operating robot without safety enclosures. Robots in a collaborative scenario must satisfy at least one criterion to meet the standard:

- Safety-rated monitored stop
- Hand guiding
- Speed and separation monitoring
- Power and force limiting.

An international committee has drafted ISO Technical Specification (TS) 15066 to provide guidance on using the new standard for collaborative operation. The subject matter is still under technical development, and an industry consensus needs to be achieved before it can be recognized as an amendment to the ISO 10218 safety standard.

“The international group is working on determining what sort of finite limits we may be able to put into the standard to help provide guidance for both robot manufacturers and end users,” said RIA’s director of standards development, Pat Davison. “Right now, the standard says that power and force limits need to be enacted, but it doesn’t designate what is allowable power and what is allowable force.”

ISO TS 15066 will also provide guidance on speed and separation monitoring, including determining the minimum separation distance and establishing maximum safe speed. Adoption of the specification is expected in 2014.

In the meantime, how are users of these new collaborative technologies supposed to ensure safe implementation without specific guidelines? And where does OSHA stand on human and robot collaboration?

“Robot safety falls within OSHA’s general duty clause which says that the employer has to provide a safe work environment,” said Davison. “OSHA does not specifically address human and robot collaboration. Instead, OSHA references industry standards such as the RIA standard.”

Risk assessment helps safeguard the collaborative workspace

Davison notes the importance of identifying and thoroughly analyzing the risks involved with implementing any new robot application.

“The standard mandates that a risk assessment be performed for each new robot application. Risk assessment looks at all the tasks that are going to be associated with that application over its lifecycle. It evaluates all the potential hazards associated with those tasks and determines ways to mitigate those hazards, either by reconfiguring the system so the hazard is eliminated, or adding safeguarding or other mechanisms that reduce hazard exposure.”

Gil Dominguez, PE, CMSE, is a safety consultant with Pilz Automation Safety L.P. in Canton, Mich. He is on the R15.06 Subcommittee for Industrial Robot Safety with Davison and is also involved in the international committee working on TS 15066.

Dominguez said that robot manufacturers are using TS 15066, even in its preliminary state, as a guideline for initial collaborative robot designs, and that end users are implementing systems following the recommendations in the draft specification. He has performed risk assessments on collaborative robotic systems and stresses the importance of thoroughly assessing the potential hazards in these scenarios.

“Because you’re using robots in a totally different way than we’ve always done in the past, it becomes even more crucial to perform a detailed risk assessment on the hazards and exposures of the person working adjacent to a live robot,” said Dominguez. “And given the complexity of the human body, the interactions and exposures that can occur have to be analyzed more precisely.”

Dominguez and Davison acknowledge that the technology is ahead of the standard and that much work still needs to be done to provide specific guidelines to robot manufacturers, integrators, and end users. Ultimately, the onus for providing a safe work environment lies with the end user.

It helps to understand the different modes of collaborative operation and the robotics technologies that are leading the way.

The technology within

Each of the four modes of collaborative operation protects users in different ways,” said Dominguez. “In safety-rated monitored stop, you’re protecting people by keeping the robot from moving when a human is in the collaborative workspace. In hand guiding, you’re protecting people by allowing the robot to move only when the robot’s motion is under an operator’s control.”

“In speed and separation, you’re protecting people by monitoring where the person is in relationship to the robot, and slowing down and eventually stopping the robot if the person gets too close, and eventually even altering the robot’s path,” explained Dominguez. “The biggest challenge we have in collaborative robotics is coming up with control systems that can monitor people and robots in real time to ensure, at a high integrity level, that a collision which could cause injury cannot occur.”

“In power and force limiting, you have to make sure that the forces exerted on someone’s body if they do come in contact with the robot are low enough that any injury which may occur would be considered minor. But different parts of a person’s body are more sensitive than others.”

Herein lies the dilemma for the standards writers. Exactly how much power and force is too much? Some robot manufacturers aren't waiting around for the answers.

Baxter's series elastic actuators

Rethink Robotics' Baxter received a lot of attention after it hit the U.S. market in September 2012. An all-purpose shop floor tasker, Baxter is designed to use common sense and work safely alongside human coworkers without the need for costly programming. Baxter is touted as "inherently safe."

The patented technology that gives Baxter its safety prowess was born in the lab at the Massachusetts Institute of Technology. "I was doing my master's at MIT with Professor Gill Pratt," said Matthew Williamson, director of technology development at Boston-based Rethink. "Between the two of us, we invented the series elastic actuator (SEA)."

Williamson said he eventually did his doctoral work under the supervision of Rethink's founder and CTO, Rodney Brooks, who was an MIT professor at the time. "Rod used the SEAs in his research robot arms, including the ones I used in my thesis."

"It's the series elastic actuators that make Baxter inherently safe," said Williamson. "They make the robot compliant as opposed to stiff. It's the difference between being hit by a spring and being hit by something rigid."

The SEA consists of a motor, a gearbox, and a spring. Williamson described how the mechanism senses and limits force. “The way the SEA works is that you measure the twist of the spring to control the force output, and that measurement of the twist of the spring gives you a force sensor.”

“Electric motors, which are the predominant actuator technology, are very good at position control, but they’re not very good at force control,” Williamson explained. “A spring is a good way of converting a position to a force, because of Hooke’s Law, force = kx. Force control is an enabling feature that is good for working in unstructured environments, which has been our goal with Baxter.”

“And then it takes a fair amount of engineering to get that right, in terms of the spring design and the choices of the motors and gearboxes, and so on,” added Williamson. “In Rethink’s case, the challenge has been making it at an affordable price point.” As of late July, Baxter starts at $22,000, including built-in sonar and camera sensors to detect humans when they enter the robot’s space, and integrated vision for object detection.

“We have a robot that is lightweight (75 kg) and low power, so the energy in the system is reduced,” said Williamson. “But on top of that, the force sensing allows us to do force and position control, which allows us to control the robot’s speed to make sure that it won’t damage anyone. We also have systems for detecting and responding to collisions and making sure the robot doesn’t clamp, compress, or crush a person.”

The SEAs in Baxter’s flexible, back-drivable joints allow him to achieve power and force limiting collaborative operation under the new safety standard.

Universal’s torque sensors, sophisticated software


Universal Robots' UR series sport a lightweight design, as low as 18 kg, and patented sensor technology that contribute to its power and force limiting operation.

"We monitor the current of the motors as well as the position of the encoders, so we've got redundant encoders in every joint. By looking at current and looking at position, we're able to derive force," said Edward Mullen, national sales manager at Universal Robots USA Inc. in Stony Brook, N.Y. "It also keeps our price point lower ($34,000), because we don't have expensive sensors in every single joint."

"The robot knows the required amounts of force to pick up a load and move it. When it recognizes an increase in torque or force required for movement, such as in a collision, the robot arm safely stops without causing harm," said Mullen. The UR's control system is redundant so that any dangerous failure forces the robot to fail in a safe condition.

Whereas Universal's UR series and Rethink's Baxter achieve collaborative operation through power and force limiting, traditional robot manufacturers achieve it by satisfying other criteria.

Source:

http://www.controleng.com/single-article/safety-and-control-in-collaborative-robotics/6fec60e21f303fa660c81bb2584236f8.html