Taming the robot

Better safety without higher fences

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Today's industrial robots are fairly well behaved creatures – doing only what they are programmed to do – as long as nobody gets in their way. Since robots move at astonishingly high speeds and carry loads up to 600 kg, humans must keep their distance. The two are usually separated by fences, like visitors and tigers in the zoo. However, the cost of such traditional safety equipment is high and it is slowing the advancement of robot-based automation in highly industrial-ized countries. ABB now offers a solution that cuts the cost of robot installations by replacing expensive mechanical safety equipment with dedicated electronics and software.

According to European and North American regulations for occupational health and safety, even a potential malfunction of a robot's controller hardware or software – however unlikely – is considered a risk and must be anticipated. This means that if the door to a robot cell is opened, for whatever reason, a contact must be tripped and the machine shut down immediately. To avoid even a theoretical failure of this safety device, dual channel switches and circuits are required, as are fitted in all safety circuits of ABB robot controllers. To avoid accidents caused by robot collisions, mechanical cams are used to activate position switches mounted on the robot axes, thereby limiting the robot's range of motion. These are expensive, hard automation methods that curb the efficiency of a machine that was originally intended to provide flexible and affordable autoation.

ABB's answer is not to compromise on the safety of its robotic products – but to provide customers with more cost-effective safety installations. SafeMove™ can even enhance the flexibility of ABB's robotic products.

Workers' safety – a competitive disadvantage?
The fact that accidents with robots are extremely rare suggests that adequate safety measures are already in place. Indeed, some argue that safety has been taken too far and that the strict regulations imposed on European and North American factories make them less competitive than their rivals working under less exacting safety standards. Others ask why robots should have higher safety requirements than overhead cranes. Such cranes carry substantially heavier loads than robots and their manual operation makes them subject to human error; robots perform repetitive, pre-programmed tasks and generally make no mistakes.

ABB's answer is not to compromise on the safety of its robotic products – but to provide customers with more cost-effective safety installations by making use of the latest technological advances. By replacing expensive mechanical safeguarding equipment with more efficient and re-configurable electronic motion safety for robots, the SafeMove™ concept can even enhance the flexibility of ABB's robotic products.

Next generation robot safety
SafeMove builds on the latest developments in redundant software, electronics-based safety technology and modernizations in safety regulations (ISO 10218). It allows the reliable, fault-tolerant monitoring of robot speed and position, and the detection of any unwanted or suspicious deviation from the norm. If a safety hazard is detected, SafeMove executes an emergency stop, halting the robot within fractions of a second.

SafeMove also offers new functions such as electronic position switches, programmable safe zones, safe speed limits, safe standstill positions and an automatic brake test, which allows more flexible safety setups.
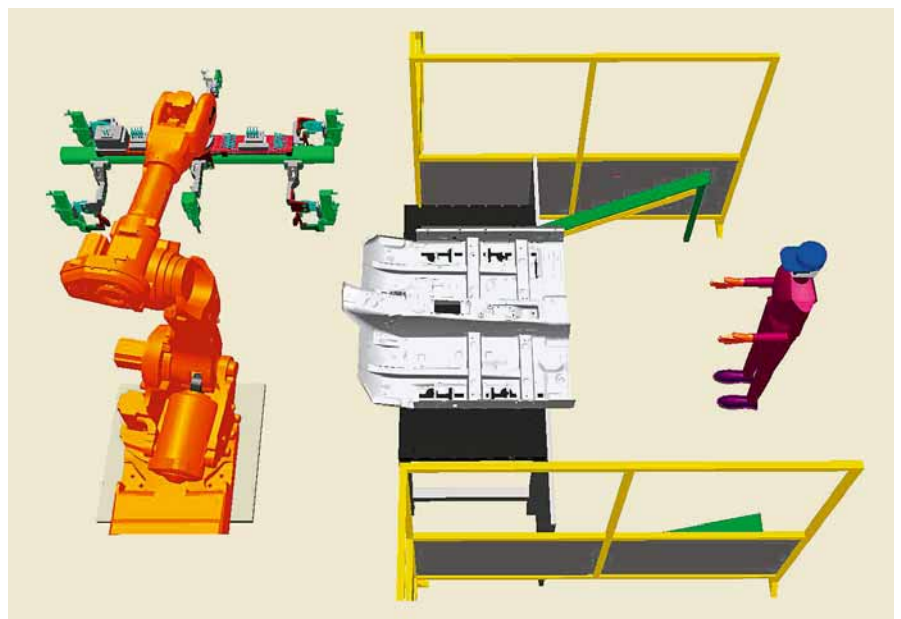
Programmable safe zones can be used to ensure that the robot stays out of protective, three-dimensional zones. These zones can have complex

shapes, adapted to specific installations. Alternatively, the robot can be confined within three-dimensional geometric spaces, allowing significant reductions in the size of robot installations. The fences can now be moved much closer to the robot, saving valuable floor space.

Of course, it is also possible to limit axis ranges by mimicking conventional electromechanical position switches using software – but this is no longer restricted to the three principal axes of the robot. Instead, all 6 axes can be safely limited. Axis limits can be combined logically, and work-piece positioners, linear tracks and other external axes can be restricted without any additional effort.

In "safe standstill" mode, robot movement is inhibited completely, yet all drives are powered and the motors are actively controlled. The purpose of this operating mode is to allow the worker to approach the robot in safety, and even to load a work piece into the gripper or carry out maintenance on the tooling without the need to shut the robot down. This not only saves cycle time when operation is resumed, it also reduces wear on the brakes and contacts needed to achieve the shut down.

In "safe speed" mode, the robot may even be allowed to move – complete-

ly or partially – at a speed that is slow enough to pose no threat to the worker, eliminating the need for a separating fence altogether. In combination with other supervision – such as confined space – workers and robots can now perform manufacturing tasks together, something that has not previously been allowed.

The safety of a robot ultimately relies on its ability to stop, or be stopped, when a hazardous situation arises. This stopping capability is determined by the function of mechanical brakes on the robot motors. SafeMove therefore contains an automatic brake test procedure, that periodically checks the mechanical brakes of the robot – something that would be very useful in a car!

Technical solution

SafeMove uses sensors that are already used for motion control to monitor the position of the motor. It then computes the robot position in a safety-rated computer that works independently from the robot controller. In addition, the sensor signals are checked for sanity. A separate model of the robot mechanics and extra reasoning about the nominal behavior of the servo control loop further enhance the safety level (patent pending). Even though SafeMove is an independent computer that sits in the cabinet of ABB's fifth-generation

industrial robot controller, the IRC5, from a user perspective, it is seamlessly integrated. Events, alarms and changes of state are logged on the robot controller's flash disk. The state of the safe inputs and outputs can be read just like normal robot I/Os and used in the robot program, even though there is no physical wiring between the I/O systems. Instead, SafeMove and IRC5 communicate over an internal network link.

SafeMove can also impose speed limits on a robot and ensure that it stays out of protective, three-dimensional zones.

Finally, synchronization between the safety computer and the robot controller must be checked after a power outage and at the beginning of each shift. This is achieved by a simple switch mounted in the cell, where it is easily accessible by the robot. The switch is visited and regularly activated by the robot – typically every 24 hours. Since this procedure can be easily combined with regular automatic tool service operations like cleaning, dressing or wire cutting, it does not normally add to the cycle time of the installation.

Process safety

Robots often handle dangerous process equipment – such as weld guns, laser heads, water jet guns, or even radioactive sources. Such equipment needs special attention in case a fault develops. It may be necessary to provide a protective enclosure around the complete robot cell that can withstand the process energy in case of a robot malfunction. Imagine, for example, the consequences if a robot were to point an ultra-high-pressure water jet horizontally rather than downwards, and the jet is accidentally turned on. This is the kind of scenario that must be considered when planning a water jet cutting cell. Use of the SafeMove function now allows safety checks to ensure that the orientation and position of the robot tool are within a defined tolerance before the tool can be activated. During operation, the robot is monitored continuously, while the tool orientation stays within the tolerance band. As soon as this tolerance is exceeded, a safe shutdown of both the robot and the process equipment is initiated. This can lead to drastic reductions in the cost of protective enclosures.

Workers and robots can now perform manufacturing tasks together, something that has not previously been allowed.

Access security

Most accidents with machine installations occur as a result of disabled safety equipment. Safety is often seen as an obstacle to productivity, and workers will sometimes take calculated risks if time can be saved. It is therefore in the best interest of both worker and employer, especially now that safety functions can be moved from hardware to software, to limit access to configuration data. This can be done by providing password-access to specially trained, authorized personnel only. Industrial practice shows, however, that it is difficult to keep passwords secret on the shop floor and this leaves the system open to abuse. ABB's scientists and engineers have therefore developed and
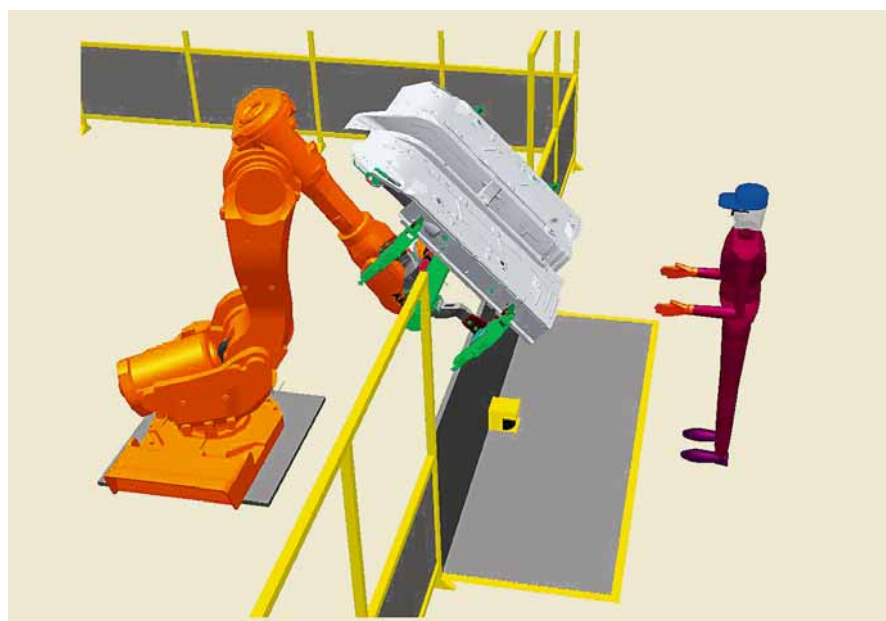
patented a mechanism that protects the safety set up of SafeMove by a combination of an access-restricted configuration tool and a public activation code. The mechanism makes the safety configuration as secure as a bank account and very convenient to use.

A separate model of the robot mechanics and extra reasoning about the nominal behavior of the servo control loop further enhances the safety level.

Safe, compact, fast and flexible
By exploiting SafeMove's features, it is possible to reduce significantly the number of safety devices employed, including light curtains, safety relays, mechanical position switches, protective barriers etc. Replacing mechanical position switches for robots and additional axes, means that there is no longer any need to maintain these devices, which are often exposed to severe environmental conditions and therefore have a limited lifetime. This allows robot cells to become more compact. Flexibility is increased as safety configurations can be reset easily using software. Replacing broken-

down robots equipped with dedicated cams and position switches used to be a lengthy procedure. Today, the time required for such repairs is significantly reduced, since the safety parameters are handled by the controller and limit switches no longer exist. This can even lead to more compact robots, since the cam rings of the past required a significant amount of space; robots without position switches provide reductions in cost.

Planning and engineering safety
ABB offers RobotStudio, an off-line programming tool that allows the visualization, programming and testing of a robot installation on an office PC, and the SafetyBuilder, a secure tool for setting the parameters of, and activating, the SafeMove controller. The combination of these powerful tools allows the engineer to design and test the safety zones in a virtual environment during the planning phase, and later use the data for engineering and commissioning. All these advantages can be fully exploited by implementing them into the initial cell concept. Of course it is also possible to retrofit IRC5 with SafeMove, so that new functions can be introduced into existing IRC5 installations.

Flexible manufacturing
In the future, SafeMove will enable completely new manufacturing con-

cepts with ABB robots. Since humans and robots are now able to work closely together, they will team up to become real colleagues. The powerful robot can lift and present heavy work pieces to the worker, and the worker can perform tasks that are harder to automate. Or the worker can load small parts from a container box directly into the robot gripper, without the need for separating turntables, receiving fixtures or roll doors, and the robot can then do the work – perhaps even in cooperation with another robot or another worker.

ABB is working to convert the technological advantages into cost savings.

ABB is working with partners and end users on new flexible manufacturing concepts to convert the technological advantages provided by applications like SafeMove into cost savings for the customers' operations. While the market is embracing these new possibilities, ABB's researchers and developers are already thinking about what will come next.

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