The future of industrial safety

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Machine safety and Industry 4.0

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Industrial machine and plant operators are faced with a challenging task: creating flexible production workflows with a high level of automation while at the same time ensuring that people, machines and plants stay protected.

With the growing interest in the concepts of Industry 4.0 and the Industrial Internet of Things (IIoT) — promoting more extensive digitalisation based on cyber-physical systems — the ability to communicate is being distributed down to individual machines and components. The goal is the creation of the 'smart factory', which uses technology to deliver greater adaptability, resource efficiency and ergonomics, as well as better information exchange among customers and business partners.

In the context of Industry 4.0, safety has yet to receive as much attention as the productivity-enhancing aspects. Understandably, any safety measures that limit the flexibility of production processes or hinder them from achieving their potential would be counterproductive in an Industry 4.0 world. The old methods of confining individual machines behind safety cages and barriers is not ideal if the aim is to have machines and production cells adapt their configurations based on individual workpieces. There needs to be the freedom to change machine behaviour and inputs dynamically.

Safety requires the right mindset

Effective industrial safety sometimes requires a mindset shift. Industry 4.0 notwithstanding, even today many organisations in Australia don't treat machine safety as seriously as perhaps they should. In a recent study[1] undertaken at the Australian National University (ANU), various flaws were found in the way Australian manufacturers understood national and international machine safety standards, and in their approach to risk assessment.

Dr Elizabeth Bluff, research fellow with the Research Centre for OHS Regulation at the Australian National University, found that many manufacturers are quick to attribute accidents to operators' failure to use their machines "properly", and slow to face up to the fundamental design and construction issues that would make those accidents less likely and less serious.

Bluff found that manufacturers should be focusing on creating a 'safe place' rather than a 'safe person' — after all, creating a safe workplace is more in their control than the activities of individuals. Machine safety systems need to cover filling, maintenance, clearance of blockages and jams, cleaning and similar activities, which present some of the most significant risks to the operators involved.

Good safety makes good business sense

Past studies have found that best-in-class manufacturers around the world make safety into a core function that delivers significant business and economic value. This includes financial returns beyond the benefits of reducing costs associated with incidents and medical expenses.

A 2012 study by the Aberdeen Group[2] found that:

"The Best-in-Class are better equipped to create a safer working environment for their employees while gaining a competitive edge in the market place. In fact, across the board, Best-in-Class manufacturers were able to effectively manage safety incidents by realising a 0.2 injury frequency rate, while at the same time performing at 90% OEE. These manufacturers were also able to achieve a 2% unscheduled downtime rate, while their peers in contrast experienced a 12% rate."

Efficient manufacturers comply with safety standards while enhancing productivity, by evaluating both the safety and operational requirements through a formalised risk management approach. This will facilitate decisions on the most appropriate technologies and control system approach taking into account the diagnostic qualities, maintenance and troubleshooting requirements.

Functional safety standards

Functional safety is a risk management approach to safety where risk is reduced in terms of the mathematical probability that a safety function will fail dangerously when called upon — a safety function being a protective function intended to reduce the likelihood of an unwanted event. The required functional safety may be achieved via different architectures or structures, providing that the overall probability of dangerous failure of the entire safety function is below the acceptable level, and that effective measures have been used to minimise systematic failures.

Achieving functional safety means applying a risk assessment and management approach in which unsafe failures are assessed and protective safety functions designed into the machine from the outset.

Various countries around the world are working towards global harmonisation of functional safety standards. Global safety standards for machinery are governed by two organisations: ISO and IEC. Regional and country standards continue to support local requirements, but in many countries there has been a move towards using the international standards produced by ISO and IEC.

In Australia and New Zealand, the Standard AS/NZS 4024.1 Series - Safety of Machinery is closely aligned to European standards from EN, IEC and ISO.

The effect of Industry 4.0

Until now, most machine safety functions have been designed to prioritise safety over productivity. An effectively designed machine safety system would shut down dangerous functions before an accident could occur — for example, if a machine guarding system is manipulated or a human enters a danger zone, sensors detect the intrusion and shut down the dangerous function.

In many cases, this can be seen as a 'sledgehammer to crack a nut' approach, and results in lowered productivity. If an operator needs to perform an 'on-the-fly' change to the machine function, or to maintain it in some benign way (such as refilling necessary materials, for example, carton blanks in a cartoning machine), then the production would need to halt to prevent injury to the operator.

One purpose of the Industry 4.0 initiative is to make production lines more efficient, more flexible and more adaptable in real time. Machine safety systems that shut down machines completely — as safe as they may be — are obviously not compatible with this requirement. The challenge is to achieve Industry 4.0 aims without compromising worker safety, and still comply with machine safety standards.

Industry 4.0 is, however, not so much a revolution as an evolution — a re-imagined use of existing technologies thanks to improved communication technologies. Today's sensors and machine control technologies are capable of more than they are currently used for.

It is already possible to adapt safety sensors accurately to the current machine process. New technologies currently in development will enable even closer coordination with processes in the future. For example, a worker approaching a machine may no longer trigger a complete shutdown, but instead cause the working speed to be reduced to a safe level, or the direction of movement modified so that the worker's safety is ensured while production continues. These capabilities are enabled by the fact that safety sensors themselves are no longer simple switching devices, but can participate in a network of sensors and safety controllers that can integrate directly with the machine automation system.

Human/robot collaboration

One of the most obvious areas where human-machine interaction is an issue is in robotic work cells. Industrial robots are inherently dangerous machines for humans to interact with and have been traditionally fenced off behind safety cages. Numerous deaths have occurred where safety mechanisms have failed and workers have entered work cells, not expecting the robot to activate.

The latest developments in robotics — collaborative robots that are inherently designed to safely work alongside human workers — are a great advancement, but are generally small robots designed for lightweight tasks. There will still be a need in many industries for large, heavy-duty industrial robots as we have today.

Current safety protection mechanisms for heavy-duty industrial robots usually involve a complete shutdown and reset. With modern safety sensor technologies, such as light curtain sensors and safety laser scanners, it is possible to 'open the cage' and define three-dimensional safety zones in the proximity of the robot, allowing the robot to 'be aware' of an approaching worker, slowing or modifying its movements, and only stopping should the worker get within its reach.

Stationary machines with safe motion control

In the same way as for robots, stationary machines pose their own safety risks for humans while they are running. By safely monitoring the speed, direction and acceleration of machine parts, it is possible to define the difference between movements that are dangerous and those that are safe.

All the signals from the safety sensors such as optoelectronic sensors, laser scanners, safety encoders and actuators can be networked with state-of-the-art safety controllers to decide whether a machine operator is in danger when they enter a hazardous area. This means that it may be possible for operators to interact with the machine while the process is running — preventing interruptions, minimising downtime and boosting the efficiency of the machine.

Example: Filling a cartoning machine

The advent of intelligent networkable sensors makes it possible for packaged safety solutions to be developed, designed and preconfigured for a specific application.

One application in which a safety system for packaging machines can be used is carton magazines that require contact protection. When it comes to the refilling of flat carton blanks, for example, packaging machines present a danger to the operator by reaching through an empty magazine and into the machine while it is still running, potentially sustaining an injury.

The flat blanks in the carton magazine of a packaging machine act as a physical guard during operation. If there is sufficient material in the magazine, then it is not possible to reach into the mechanism of the machine. However, when there is too little material left in the magazine, the packaging machine mechanism may be left exposed.

Combining a safety controller and two photoelectric sensors with special functionality, the amount of material in the packaging machine magazine can be monitored for a safe level. A sensor can monitor the stack of cartons and when the level has reached a predefined low threshold, the system can issue a warning so that it can be topped up in time to prevent the machine from stopping. The safety controller continually evaluates the sensor signals and provides a shutdown signal only if the carton blank stock is not replenished and reaches a critically low level beyond which safety may be compromised.

Rather than implementing a safety system that only stops the machine for refilling, such a system allows for the operators to safely top up the magazine while the machine is running, maintaining productivity and safety at the same time.

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1. Bluff E, 2015, Safe Design and Construction of Machinery: Regulation, Practice and Performance, Ashgate Publishing Company.

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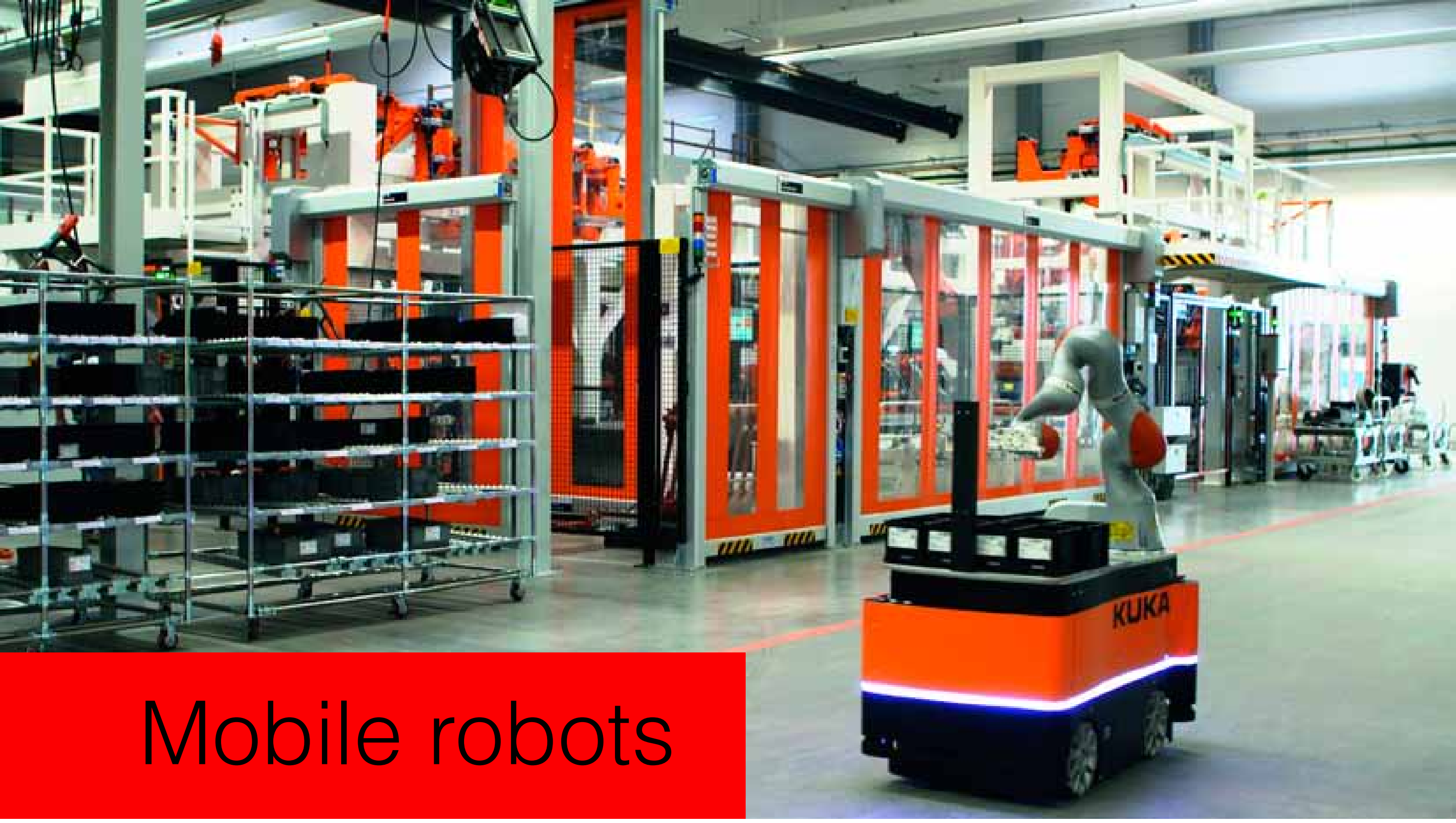

Mobile robots navigate industrial safety

Industrial production in the future will see people working with assistants that are modular, versatile and, above all, mobile.

The ability of mobile robots to move independently through factory halls and transport goods or workpieces represents the future of logistic processes in production. For robot manufacturer KUKA Roboter GmbH, the future is already here with its KMR intelligent industrial work assistant (iiwa) — a fully automated mobile system combining the lightweight robot, LBR iiwa, and the OmniMove mobile platform. Partnering with SICK, the safety of personnel working alongside and around the mobile robot is assured by the use of the company's safety laser scanners, offering a protective function as well as navigational support, thereby enabling the robot to detect the presence of obstacles or people, and stop moving on its own. Safety fencing and guarding can be dispensed with, allowing for human and robot collaboration that may previously have been off-limits.

In a logistics environment the KMR iiwa operates by picking up materials or boxes and delivering them to the production line, sharing its travelling routes and shelving areas with others, such as tugger trains and people. Embracing the principles of Industry 4.0, new materials can be ordered automatically through its ERP systems and then distributed autonomously among workstations. However, the manufacturer's focus is on more than just the production skills the robot offers in-house. According to KUKA Industrial Business Development, Mobile Robotics Peter Gmeiner, new applications are opened up, which can pave the way for greater cost-effectiveness and efficiencies.

"The KMR iiwa offers all kinds of application possibilities," said Gmeiner. "These range from fetch-and-carry services to roles in producing small quantities at multiple workstations, all the way through to complex, flexible production workflows in the automotive and electronics industries.

"Combining the sensitivity of the LBR iiwa with the mobility of the KMR iiwa also opens up the potential to add real value to quality assurance processes."

Overcoming manufacturing challenges

For some years now, KUKA has successfully been integrating SICK solutions into its OmniMove heavy-duty platform. These vehicles are able to move up to 90 tonnes and work on the basis of interaction between the SICK S3000 safety laser scanner and KUKA navigation software. When the KMR iiwa was being developed, KUKA relied on SICK to once again provide the right technology for the job. For this autonomous mobile system, SICK recommended its more compact S300 safety laser scanners, since their 270° scanning angle can ensure all-round surveillance. Multiple protective fields that offer flexible configuration options are also important in applications that use compact, mobile robots — and the 16 freely configurable protective fields offered by the laser scanners allow flexible adaptation to a range of travelling situations and environmental conditions.

Scanner data for autonomous navigation

To achieve autonomous navigation, the KMR iiwa receives control signals through its KUKA navigation software that interprets information, including data supplied by the safety laser scanner, to move to a position.

"The navigation software continually evaluates the distance measurements taken by the safety laser scanner. It then uses this information to create a kind of 'map' of the environment and determine the KMR iiwa's position within these coordinates," explained Klaus Mattuschat, who heads up the OmniMove team in Mobile Robotics at KUKA.

"Objects that are always found at the same point, like pillars in the hall or fixed parts of plants, are interpreted as established reference points. However, moving objects or objects that undergo dynamic changes are ignored, so to speak. In most cases, the KMR iiwa either moves along defined paths from one specific point to another, or it navigates freely. It's able to avoid objects that are in its way by itself."

Mobile systems: a cornerstone of the intelligent factory

For Thales Alenia Space, developer of satellites and components for civilian and military space technology, the KMR iiwa ensures much shorter assembly times and effective use of personnel labour. In 2015, the company planned to utilise the mobile robots for an automated workstation. In this project two robots would assemble components from different storage containers as part of a kitting application — the painstaking job of assembling every component needed to carry out a given production task — into a kit in preparation for the next step. A robot then would move the kit to the workstation to be mounted on a satellite. The company also used a KMP omniMove transport platform to easily transport the delicate satellites from one station to another within the production room.

According to SICK, the intelligent factory concept envisages individual production elements being networked with one another during production. This requires data that is captured, evaluated and transmitted by sensors to be reliable. Maintaining transparency at all stages of the production and logistics chain is crucial for this data. It is not just data networking that is important, however. Mobile systems like the KMR iiwa provide a link between individual stages of work, especially in automated and networked production environments. They represent a new form of mobility — one that also relies on innovative solutions to protect humans and materials.

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Industry 4.0 would not be possible without intelligent sensors

The possibilities of today's sensor intelligence

The Information Age for industry is just getting off the ground. The limitless exchange of manufacturing, product and logistics data means it is now possible to make better decisions and experience complete transparency across all levels of the value chain. At the start of the process chain, this world of greater resource efficiency depends largely on the equipment that supplies this data: the intelligent sensors. It is absolutely essential for sensor technology to be intelligent, rugged and reliable when it comes to dealing with challenges such as the safe interaction between people and machines, high levels of variance and controlling fluctuations in demand at short notice.

Sensors provide the senses for machines. The feedback they provide is what makes intelligent machines possible in the first place. Sensor intelligence focuses on one aspect of sensor technology: equipping machines with the ability to see, recognise and communicate intelligently. Intelligent sensors contribute the ability to classify and interpret information. This is characterised by intelligent signal processing, which derives the truly relevant information from large quantities of data and makes it available to various levels. This is why — in addition to the primary control system for machines and systems — information is provided for monitoring production systems and making it possible to detect faults. Transparency of the processes and material flows produces additional potential for optimisation. Processes are becoming more efficient and cost-effective and are increasing competitiveness.

Examining the four challenges throughout the production levels — 'quality control' at the sensor and drive level, 'flexible automation' at the machine level, 'safety' at the production level and 'track and trace' at the corporate level — makes it clear that we as a driver of technology in Industry 4.0 are already capable of presenting and implementing solutions.

Flexible automation requires variable basic conditions. Manufacturing plants have to be flexible and adapt to what the individual customer wants. Due to high product diversity, even as the part batch sizes continue to decrease, intelligent components (smart sensors) have to be capable of adjusting and controlling themselves.

The essential driver for the area of safety is the interaction of people and machines, while taking into account workplace ergonomics and safety. The central questions here are what role people are to play in production of the future, and how can sensors support and keep them safe in that role?

Vertical integration — that is the keyword for track and trace. Traceability of products during complex manufacturing and logistics processes is a priority for this integration. Logistics for production and transport merge until delivery is made to the customer, requiring the flow of goods to be transparent so that decisions can be made more quickly.

Increasing quality requirements and the desire for resource efficiency necessitate autonomous fault detection through comprehensive product and production data. In the area of quality control, goods in the production process and supply chain must be reliably and uniquely identified so that they can support efficient automated control.

Flexible automation: customising goods in the packaging process

Using a packaging machine as an example shows how an automatic batch change without manual intervention — by using intelligent components with automated control — generates higher product diversity with a general increase in productivity. Maximum productivity with product variation down to a batch size of 1 is a central goal of the Industry 4.0 concept.

As an example: final packaging of prepackaged batches with bottle sizes of 0.5 L and 1.5 L capable of being packaged on one system by means of detection from smart sensors with automatic format changeover. The sensors detect the product changeover and tell the control system that the system has to readjust, so that the right box can be set up, the bottles can be fed in and the box can be labelled and transported away. The changeover steps are listed on a monitor while the machine adjusts. The system keeps running automatically and does not have to be put back into operation manually. If the sensors detect an incorrect placement when measuring the length of the product, they notify the control system. The product is sorted out without the system coming to a stop. In addition, the sensors provide data for proactive maintenance, such as monitoring the system for fine particles to automatically implement measures that safeguard the packaging process.

Intelligent, communicative sensors are what make Industry 4.0 possible in the first place. Smart sensor solutions — the use of state-of-the-art sensor technologies in combination with complete integration into the control level — focuses heavily on decentralising certain automation functions to the sensor. This takes some of the load off the control system and increases the productivity of machines.

Safety: robot protection using laser scanners

Sensor intelligence is a prerequisite for safe interaction between people and machines in the era of Industry 4.0. Safe laser scanners reliably monitor the hazardous area of stationary or mobile machines and systems, such as welding robots or automated guided systems. Protection of people is the top priority here. If a person enters the area, the dangerous movement must be stopped safely. On established systems people are protected but production is stopped.

In the future, smart sensors in the context of Industry 4.0 will be used not only to ensure the safety of people, but also to implement ever-increasing production specifications.

The digitally switching protective fields currently in use are being replaced with flexible ones, which are automatically calculated during highly dynamic movements and adjusted corresponding to the hazardous areas of the robot. The compact systems use an integrated swivel mirror as an optical radar to scan their surroundings in two dimensions and measure distances according to the time-of-flight measurement principle. This results in freely definable safety zones.

Quality control: reliable data acquisition and tracking

The future holds continued increases in the speed that packages are transported. The distances between the packages are becoming smaller. This means checking the quality of products is even more important. To accomplish this, the package data is scanned on the conveyor belt and read into the software. The packages are identified and compared. Is the package damaged? Is the code complete? Are the weight and volume the same? Is there a pile-up of packages, or is a package possibly even missing? Automatic fault detection is made possible by comprehensive product and production data. The data is completely synchronised in seconds. Defects can be tracked by all centres, and it is possible to trace where the weak point is. In addition, quality defects can be identified and resolved in the process. Since the speeds on the conveyor belts are further increased, maximum productivity is ensured — not just within a location, but also globally.

The example of an intralogistics process shows how increasing quality requirements and the desire for resource efficiency can be implemented in the context of Industry 4.0. The sensors detect changes to the object and enable seamless data acquisition. The software solution analyses the process data and implements actions. The combination of a variety of data and the analysis software is an important prerequisite for Industry 4.0 and the issue of sustainability. Goods in the production process and the supply chain must be reliably and uniquely identified so that these can support efficient automated control. From an individual package on a conveyor belt to a complete overview of millions of packages transported every day — there must be a convenient way to call up and analyse the status of all acquired data.

Smart sensors acquire and communicate this data. However, users do not experience true added value until this data can be used as a basis for improving business processes. This data offers extensive opportunities but also presents the significant challenge of preparing it in a way that allows companies to make the right decisions. This is the cornerstone of Industry 4.0: the seamless flow of data and information from the sensor to the control system and back.

From sensor to sensor intelligence

The increasing speed in the computing power of state-of-the-art chips enables remote processing of substantially larger amounts of data and capabilities like the associated use of complex mathematical methods. This is resulting in completely new dimensions for the scope, accuracy and ruggedness of measurements. Sensor solutions measuring in multiple dimensions, such as camera systems and laser scanners, would also be impossible without this development due to their high data volume.

The computing power enables even more intelligent sensors, but they do not turn into sensor intelligence until equipped with the right software and application knowledge. The intelligent linking of application knowledge with the flexibility of state-of-the-art software architectures enables the next development stage for sensors. This is characterised by the possibility of sensors that can perform more extensive analysis, automatically adapt to changes, communicate in the network and remotely solve complex tasks within a larger manufacturing network. In other words, the sensor links to the machine, system, factory and the entire value-creation chain, and provides for transparency in production. As a result, it provides the entry point into the world of Industry 4.0. For all virtual worlds, however, sensor intelligence remains one thing above all — part of a sensor. Even the cloud and apps need to have a physical basis in the real industrial environment, namely, a rugged and reliable piece of hardware.

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SICK is one of the world's leading manufacturers of sensors, safety systems and automatic identification products for factory automation, logistics automation and process automation. As a technology and market leader, SICK provides sensors and application solutions that create the perfect basis for controlling processes securely and efficiently, protecting individuals from accidents, and preventing damage to the environment.

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