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Safety as a Key Issue for Deployment of Automated and Robotized Systems

Marek Vagaš*, Vladimír Baláž, Peter Marcinko

Department of Robotics, Faculty of mechanical engineering, Technical University of Košice, Slovakia
*Corresponding author: marek.vagas@tuke.sk

Abstract Automated and robotized systems are widely used in industry with deployment to perform unsafe, hazardous, highly repetitive and unpleasant tasks for human. Furthermore, industrial robot, unlike human, can perform complex or mundane tasks without tiring, and they can work in hazardous conditions that would pose risks to humans. For example, robots are increasingly being used in industry to perform such tasks as material handling and welding, and there are around one million robots in use worldwide. However, robots can pose hazardous risks to humans if sufficient precautions are not provided. To avoid injury, it is necessary to find a mutual link between the behavior of the robot and possible personal injury. It is usually necessary to ensure that the robot has not exceeded the maximum safe zone, and thus it has not come into contact with man. Safe planning is an important component of the safety strategy. Safety planning and the a priori identification of potentially hazardous situations as a means of reducing potential robot-safety hazards have received less attention than control-based (reactive) techniques. So, it is necessary to manage of risk for humans working near robots involves in general very broad considerations, ranging from potential electrical and pressurized fluid hazards, pinching hands, dropping parts, etc.

Keywords: *safety, industrial robot, assessment of risk, standards, safety equipment*

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1. Introduction

Safety is a key factor in industrial and service robot applications, making robotics safety an important subject for engineers. For instance, around 12-17% of accidents in industries using automated and robotized systems have been reported to be related to automated production equipment, including robots. The first fatal robot-related accident in the United States occurred in 1984. On July 21 of that year, a die cast operator was working with an automated die cast system that utilized a UNIMATE Robot.

The robot was programmed to extract the casting from the die-cast machine, dip it into a quench tank and then insert it into an automatic trim press. A neigh boring employee discovered the victim pinned between the right rear of the robot and a safety pole in a slumped but upright position. The victim died five days later in the hospital [1].

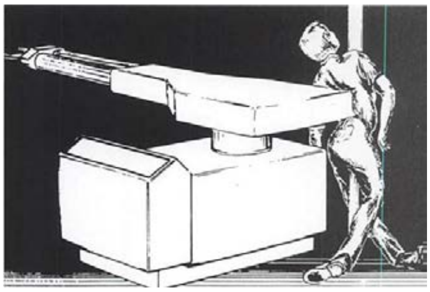


Figure 1. The first fatal robot-related accident

Robot safety may be interpreted in various ways, including preventing the robot from damaging its environment, particularly the human element of that environment, and simply preventing damage to the robot itself. Without proper precautions, a robot experiencing a fault or failure can cause serious injuries to people and damage equipment in or around a work cell.

A robotic safety incident typically occur when a robotic arm or controlled tool causes an accident and/or places an individual in a risk circumstance, an accessory of the robot's mechanical parts fails, or the power supplies to the robot are uncontrolled [2]. Robotic incidents can be grouped into four categories:

- Impact or collision accidents: Unpredicted movements, component malfunctions or unpredicted program changes related to the robot's arm or peripheral equipment can result in contact accidents.
- Crushing and trapping accidents: A worker's limb or other body part can be trapped between a robot's arm and other peripheral equipment, or the individual may be physically driven into and crushed by other peripheral equipment.
- Mechanical part accidents: A breakdown of the robot's drive components, tooling or end-effector, peripheral equipment, or power source can lead to a mechanical accident. The release of parts, failure of gripper mechanism, or the failure of end-effector power tools (e.g., grinding wheels, buffing wheels, deburring tools, power screwdrivers and nut runners) are a few types of mechanical failures.

- Other accidents: Other accidents can result from working with robots. Equipment that supplies robot power and control represents potential electrical and pressurized fluid hazards. Ruptured hydraulic lines can create dangerous high-pressure cutting streams or whipping hose hazards. Environmental accidents from arc ash, metal spatter, dust, and electromagnetic or radio-frequency interference can also occur. In addition, equipment and power cables on the floor present tripping hazards.

2. Directive and Standards

Directives and standards are of great importance for manufacturers of automated and robotizes systems and safety components. To ensure safety in these workplaces, much effort has been expended, especially in the United States and Europe, to codify the safety requirements for humans working around industrial robots [3]. In the U.S., the Robotic Industries Association (RIA) developed the R15.06 robot safety standard through the American National Standards Institute (ANSI).

In Europe, ISO brought forth the first edition of ISO 10218 in 1992, which was subsequently adopted by the European Committee for Standardization (CEN) as EN 775. The American documents provide more detailed information for the integration and use of the robots, while the ISO documents place more emphasis on requirements for robot manufacturers. Safety requirements also evolved over time with the issuance of ANSI/RIA R15.06-1992 and the ISO10218:1992 (EN 775). ISO 10218 (parts 1 and 2) is intended as a harmonized standard in the European Union, and has been officially recognized in other countries as their national standards.

Work is ongoing in the US and Canada to produce an integrally combined document, as ANSI/RIA R15.06 or CAN/CSA Z434 respectively, which also contains the ISO 10218 series of standards. An overview of the present status of robot safety standards is given in Table 1.

Table 1. Present status of safety standards for robots in Europe and North America

Type of safety standards	Europe	North America
Robot safety standard	ISO 10218-1:2011 (robot) ISO 10218-2:2011 (robot systems and integration)	ANSI/RIA R15.06 / ANSI/RIA/ISO 10218 / RIA TR R15.206 CAN/CSA-Z434-03 (R2013) (robots and robot systems)
Machinery safety standard	ISO 12100:2010 (risk assessment) ISO 13849-1:2006 (functional safety) IEC 62061:2005 (functional safety)	CSA-Z432-04 (R2009) ANSI B11.0-2011

3. Practical Application at Specific Robotized Workplace

Safety of specific robotized workplace is resolved by an external device, i.e. security 2D laser scanner from the company SICK. Robotized workplace is based on human-robot cooperation at assembly task [8]. It consists from industrial dual arm robot SDA 10F, 2D laser scanner, human operator and two work desks with necessary equipment. Location of 2D laser scanner on the work desk of robot within cooperative workplace can be seen at Figure 2.

Figure 2. Specific robotized workplace and 2D laser scanner

Using dimensionally small 2D laser scanner S300 mini, it can be tracked the three safety zones (one is protective and two are warning) that are programmable via software CDS by connecting to a computer [8].

There is an advantage of the various parameters setting, such as the shape of zone, the range of scanning zones, the response, and many others [9]. Figure 3 represents the design and drawing of 2D laser scanner safety zones to ensure cooperative workplace using CDS Software.

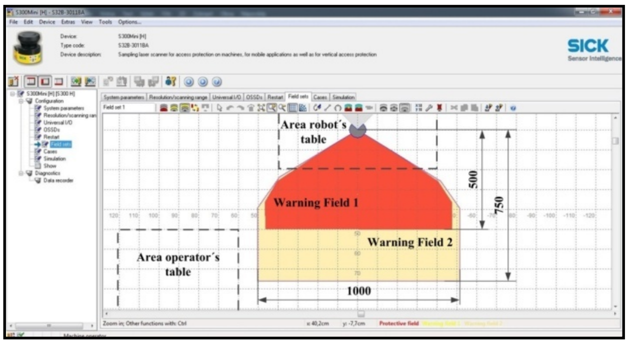


Figure 3. Drawing of the proposed 2D laser scanner security zones

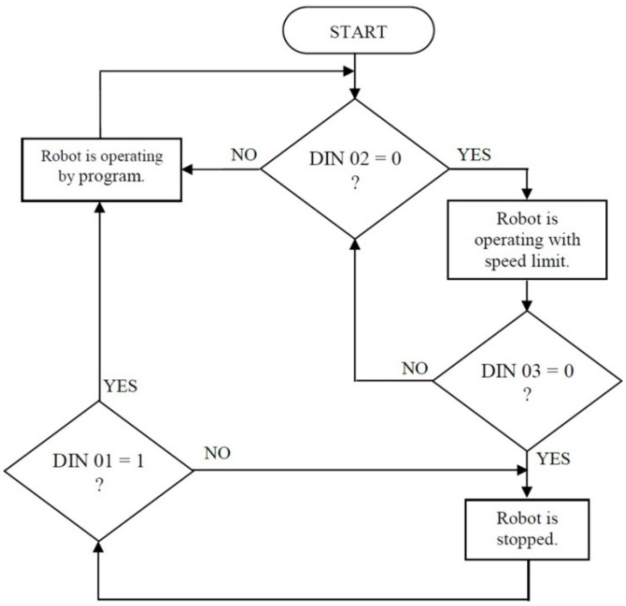
Workplace safety is based on the support and usage of the functions of the robot control system Speed Limit - speed restriction robot, which is represented by warning field 2. The safety is also ensured by the function Hold - suspension of the robot what represents the warning field 1.

The outputs of each zone of the laser scanner are connected to the digital external inputs of the robot (Figure 4) according to the available documentation and schemes of producer [10]. Determined conditions for ensuring correct functioning of cooperative workplace are as follows:

- Servo motors and button Start are ON
- Robot is in mode "Remote"

In the case that these conditions are met, the robot control system controls the external digital input DIN 02, which is responsible for the activation of speed limit at a constant speed of 250 mm / s. In the case of logic zero, robot slows down to the specified speed. On the contrary, robot performs the specified assembly task in collaboration with a man according to the predetermined program and procedures. Digital external input DIN 03 is activated when a person or unknown object exceeds the relevant zone of the scanner [11].

At that moment industrial robot MOTOMAN SDA10F stops. After man or object leaving the zone of scanner, the reactivation of the robot to the motion is needed what is conditional by a digital external input 01. This is responsible for starting, respectively continuation of the robot´s program using an external device, in our case the 2D laser scanner.



Notes: DIN 01 = Ext. start, DIN 02 = Speed limit, DIN 03 = Ext. hold

Figure 4. Flowchart safety robotized workplace through the use of functions of the robot control system

The experiments have been executed in a laboratory of robotic systems, cathedra of robotics, TUKE, Slovakia. Two approaches were mainly taken into account: the safety with regards to the entering persons into shared workspace during working and assembly time, represented by overall assembly time until to packaging of assembly object into the prepared box.

Practical experience based on the software CDS showed that safety laser scanner scans the visible surrounding contour several times [12]. From data obtained the CDS suggests the contour and size of the warning field with human access into the protection zone see Figure 5.

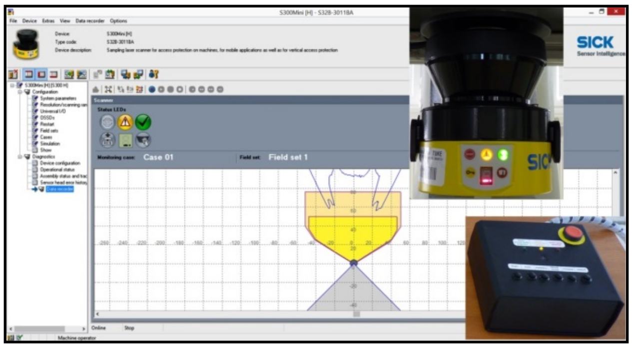


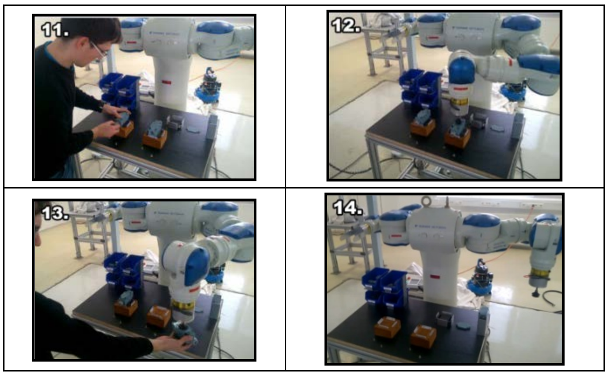
Figure 5. Experiment for reading of warning field in case of human access into protection zone

Demonstration and implementation of proposed solution was realized at workplace illustrated at Table 2. It is split into sub sequences (frames) that determine basic assembly processes at robotized workplace. Assembly sequence starts at home position of dual-arm robot (Nr.1) that waits for instructions from a human operator of the initiation of the assembly process [13].

The operator stands in front of the dual-arm robot work desk and works on the assembly of a product. Man enters instructions via the control panel buttons and he controls the running and accuracy of assembly. The final step (No. 14) of assembly sequence is the return to start position (No.1).

Table 2. Cooperative assembly sequence of limit switch



4. Conclusion

Building a protection system that works in practice and provides sufficient safety requires expertise in several areas. The design of the safety functions in the protection system in order to ensure they provide sufficient reliability is a key ingredient. An important feature of a safety control system is that the required safety function should be guaranteed as much as possible to work whenever any faults arise.

Industrial robots should be almost instantaneously directed by such safety devices from a hazardous state to a safe state. If there is a danger to the operator, maintenance personnel or other personnel from robotic motion within the restricted or operating space, this area must be safeguarded.

Area safety scanners and light curtains are often used in these areas, as the scanner coverage area is wider and more flexibly programmed than with other devices.

These safeguarding devices must be located at a distance that provides adequate stopping time of the system and accounts for the speed of approach from the personnel in the area as well as a depth penetration factor.

Acknowledgements

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