Human-Robot Interaction.
Safety problems

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Abstract: *The question of human safety becomes increasingly important as future robots will be required to share their working area with human operator. The following issues have to be considered: What are the requirements on the hardware and on the software? What are the possible dangers for the human? How can we recognize and prevent the danger? What safeguarding systems should be implemented? In this paper were suggested some solutions on assigned questions.*

Keywords: *Human-Robot interaction, Safety*

I INTRODUCTION

Recently, the main aim of automation was the construction of systems excluding the involvement of humans. In fact, to guarantee the safety of humans within the working area of a robot, additional sensors and equipment are required, which would increase the cost of an automatic system. Therefore many efforts have been made to separate the working area of robot systems from man. But today the demands for high flexible robotic systems, which must have the capabilities of adapting themselves to an uncertain environment, are rapidly increasing. The main idea is to combine the complementary capabilities of robots and humans where robots are considered as intelligent autonomous assistant of humans. The most significant fact that must be considered is safety.

State of the Art

Until now, the state of the art was such that industrial robots could only be operated in safeguarded workspaces, without the possibility of humans entering this area with the robot in Automatic mode. The robots executed predefined motion and application programs. In now days, with successfully implemented Safe Robot technology which based on a dual-channel monitoring system with built-in redundancy and cyclical testing of the brakes and the robot mastering, jointed-arm robots can collaborate directly with human operators in a wide range of tasks.

The robot controller is now directly responsible for safety-relevant control tasks which, until now, have been the responsibility of an external safety PLC in the robotic cell. This means that in many applications light barriers, scanners or safety mats can be wired directly, and reaction time and robot braking distances is reduced. This technology can be used to combine the superior sensory capabilities of the human operator with the work output and enormous load-bearing capacity of the robot. [1] Another area of researches is sensory protect systems. Researchers at Virginia University [2] have investigated a combination of light curtains, pressure mats, and ultrasonics. Wikman [3] have reported an approach to robot collision avoidance using low level reflex control. In Japan [4] have used fault tree analysis techniques to assess robot hazards. Zurada and Graham [5] have investigated the integration of sensory information in robot safety systems using a neural network approach. Jozef Zurada, Andrew L. have used integrated sensing architecture for monitoring the robot workspace, and a new detection and decision logic for regulating the safe operation of the robot.[6] KUKA group made a safety integrated robot KR3 SI for medical application. It includes proximity sensors to reduce robot speed and collision prevention devices: safe switches to stop robot in case of contact and protective foam covering the arm to absorb kinetic energy.

II REQUIREMENTS

In developing a robot safety system it is necessary to consider the area over which safety should be provided, and to specify the appropriate safety response within these regions. The three safety regions identified by the NIST [7]. Level 1 safety region is the area outside the reachable work area of the robot. Safety achieves by use of a physical barrier (woven wire fence, light curtain). Level 2 is reachable workspace volume of the robot, excluding a small volume immediately surrounding the robot itself. Intruder is within reach of the robot, but not in imminent danger of being struck.

Level 3 safety region is defined to be the volume immediately around the robot. In a simple model this might be a fixed distance, 12 cm. In a more sophisticated model, this region could vary with the velocity of the robot. This level almost always requires an immediate emergency stop of the robot system.

Addition requirenments:

Sources of energy must be isolated, the design of robots shall minimize electromagnetic, radio interference, the robot cannot be placed in automatic using the pendant, Automatic mode may only resume when the person leaves the restricted area, failure of the presence-sensing device shall stop robot operation. Whilst the robot is collaborating with a human the robot control shall operate in a safe reduced speed (not exceeding 250mm/second) using hand-guiding actuators that include an enabling device (pendant controller) with an emergency stop located in the area of the end-effector. Maximum power and force are to be determined by risk assessment and shall not exceed 80 watts and 150N. A robot is equipped with a separate circuit breaker that can be locked only in the off position. All devices designed in compliance with ergonomics demands.

III SOURCES OF HAZARDS[8]

Robotic incidents can be grouped into four categories: a robotic arm or controlled tool causes the accident, places an individual in a risk circumstance, an accessory of the robot's mechanical parts fails, or the power supplies.

1 Impact or collision accidents. Unpredicted movements, component malfunctions, program changes;
2 Crushing and trapping accidents. A worker's body part can be trapped between a robot's arm and other peripheral equipment;
3 Mechanical part accidents. Breakdown of drive components, tooling or end-effector, peripheral equipment, or its power source.
4 Other Accidents.

Hazards happenning because of:

1 Human errors;
2 Control errors;
3 Unauthorized Access;
4 Mechanical failures;
5 Environmental sources;
6 Power systems.
7 Improper Installation.

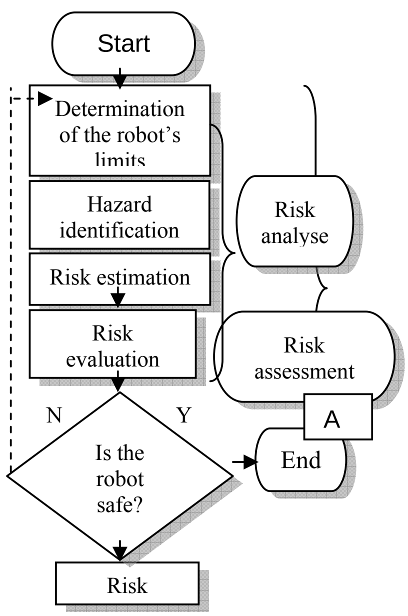


Figure 1
Algorithm of hazard analysis

The proper selection of an effective robotics safety system must be based on hazard analysis of the operation involving a particular robot. (Fig. 1)

Here we should cosiderate lifecycles, limits application area, training level, human factors, reliability of the safety function, possibility of defeat, hazard removing, appropriate protective measure, etc.

IV SAFEGUARDING SYSTEMS

The proper selection of an effective robotic safeguarding system should be based upon a hazard analysis of the robot system's use, programming, and maintenance operations. Among the factors to be considered are the tasks, start-up and programming, environmental conditions, location and installation requirements, possible human errors, scheduled and unscheduled maintenance, possible robot and system malfunctions, normal mode of operation, and all personnel functions and duties.

1 Awareness Devices

Personnel should be safeguarded from hazards associated with the restricted envelope using one or more safeguarding devices: non/mechanical limiting devices; presence-sensing safeguarding devices; fixed barriers; interlocked barrier guards; chain or rope barriers with supporting stanchions or flashing lights, signs, whistles, and horns. They are usually used in conjunction with other safeguarding devices (ultrasonics, microwave, infrared, capacitance devices) controlled through software.

2 Safeguarding of the Operator

When a person is permitted to be in or near the robots restricted envelope to evaluate or check the robots motion or other operations, all continuous operation safeguards must be in force, the robot should be at slow speed (of 250 mm/c) with teaching mode controlling.

3 Maintenance

While maintenance and repair is being performed, the robot should be placed in the manual or teach mode, personnel work within the safeguarded area and within the robots restricted envelope.

V SAFETY SENSORS

Three primary functions of the safety controller are sensing, integrating sensory information to create a hazard map, and producing a safety decision which regulates robot system activity. Typical sensor groups would include ultrasound ranging devices, passive and active infrared sensors, capacitive and pressure sensing sensory units [9]. Robot grippers may have simple limit switches or photo-electric transducers, force and pressure sensing devices, fixed stops for robot's movement limitation, that prevent motions beyond the physical limitations of the robot into unexpected regions.

Next currently available sensory technologies can be evaluated as advantages for robot safety applications: vision (monitoring and inspectation:camera or solid-state device), sonar (20 kHz frequency, detection ranges ..10m), capacitance(detection ranges 40–50 cm) and infrared sensors(radiation range 8–18 μm. a set of detection zones, referred to as pair of fingers. Typical infrared units have ten to 12 finger pair, range of detection may be up to 12 m).

Robot's sensory devices collect recieved information (visual, tactile, auditory, electromagnetic radiation), microprocessor and control system process initiate robot's actions based upon the preprogrammed sequences.

VI NON/SENSING DEVICES

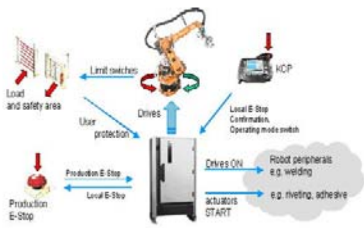
The presence detectors that are most commonly used in robotics safety are pressure mats and light curtains. They can be used to detect a person stepping into a hazardous area near a robot and stop all motion of the robot, because of interlocking with it's controller. An awareness barrier must be placed close to the mats to prevent activation of the sensors.

Safety light curtains and grids are non-contact protective system using sender and receiver interlocking with the robot controller. Also protect person from high intensity light and radiation, activate when the light beam is cut off. (resolution 14mm, 30mm, 2-4 beams for finrer, hand and body protection). Laser scanners. (used for non-contact monitoring of a freely programmable area)

Non-sensor safety devices.

Interlocked, fixed barrier guard. This is a physical barrier around a robot work envelope incorporating gates equipped with interlocks. All automatic operations of the robot and associated machinery will stop when any gate is opened. Shouldn't be located closer than 2ft to the robot and end effector envelope. Safety fencing must have a mesh size as specified in DIN EN 294 and be high enough to prevent anybody from reaching over them. The number of gates must be kept to a minimum and connected to the safety devices incorporated in the linear unit and to the overall emergency stop system.

Hand control and foot switches. (switch to start and stop).



VII ROBOT SAFETY SYSTEM[10]

1 Emergency Robot Braking
Dangerous robot movement is arrested by dynamic braking systems rather than simple power cut-off.

2 Working Space Limitation
The working space is limited by adjustable software limit switches for all axes, backed up by mechanical limit stops.

3 Load Limitation
All axes are safeguarded by overload protection devices, which automatically switch off the linear unit if the permissible power input is exceeded

4 Motor Monitoring
Protection against overload by temperature sensors.

5 Voltage Monitoring
The servo power module is switched off if the voltage is too low or too high.

7 Temperature Monitoring

8 Jog Mode (deadman function)
Test modes at reduced velocity.

Emergency Stops
Provided in case the robot needs to be stopped immediately (handles, bars, push buttons). ES override all controls, remove drive power, stop all mowing parts, include additional emergency stop circuit. In a dangerous situation, emergency stop control devices are operated manually, triggering a signal to halt a potentially hazardous movement.

VIII SAFE CONTROL TECHNOLOGY

Configurable safety controller or programmable safety PLC can be directly hardwired or distributed via safety-related fieldbus. This incorporates basic functions such as robot status, local and remote, emergency stop, drive status, operating mode, robot reset, status of guarding equipment.[11]

<u>Robotic safety control devices</u>:

1 Safety Relays are centralized in a control cabinet close to the robot. Use for monitoring E-S, safety gates, light curtains/barriers, hand control, sensing mats, muting functions.

2 Modular Configurable Safety Controller or Modular Safety PLC. Have Graphical User Interface (GUI) configuration for logic and input/outputs. Support fieldbus communication of diagnostics to a host system or HMI. Programming using certified software blocks for the relay logic. Online diagnostics and communicated to programmable logic controllers and HMI over conventional fieldbus. Continuous monitoring and self-testing.

3 Safety PLC with remote I/O using SafetyBUS p. SafetyBUS p provides three core cabling to the control cabinet and direct interfacing to limit switches and the Electronic Safety Circuit (ESC) via two I/O units.

4 Safety PLC with direct SafetyBUS p interface to the robot ESC. Sensors and actuators are connected to the

SafetyBUS p system via decentralized I/O modules.
5 ESC Electronic Safety Circuit is a microcontroller-based safety bus. This dual-channel system permanently monitors all connected safety-relevant components. Consists of 3 modules: KCP (teach pendant); KPS (power supply unit); MFC. The nodes are modules connected to each other via power supply and communication lines. In the event of a fault or interruption in the safety circuit or failure of the power supply, each module sets its outputs to a safe state. The ESC system switches off the power supply to the drive units, causing the axis kinematic system to stop.

Conclusion

In this paper I tried to give a review of the most important factors that should be considered during interaction between human and robot and the summery of existing safety devices which make our system more secure and safer.

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