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Design of Safety System in Cell Production Line with Dual-Arm Robots: A Feasibility Study

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***Abstract*— This paper proposed the design of safety system in cell production system for cellular phones using dual-arm robots. To detect an interruption of human workers during a robot operation, a safe camera system for 3D zone monitoring is introduced. A signal for an interruption is sent to PLC control system of cell production line and an alarm signal is given to robot systems to stop or slow down a motion of each robot. Also, power down of motor of robot joint through the channel of EMO switch can be conducted to prevent any safety accident quickly.**

***Keywords*—cell production, human-robot collaboration, robot, safe camera, safety system**

I. Introduction

Mass production systems such as the existing auto industry involve simple repetitive tasks, and hence, automated processes using high-speed and high-precision robots are applied and implemented. However, in cellular phone and tablet computer industry, the requirement for automation of the cell production is desperate because of rapid changes in processes, handling of numerous parts, and coping with the needs of a mixed-model production system. Although attempts have been made to introduce automating equipment in some processes, practical automation is difficult due to the decrease of flexibility in incorporating changes in the product. Therefore, most production operations are, currently, carried out manually by human workers. The most appropriate automation method for cell production process for IT products is to use robots because they can help realize flexible production [1-5].

However, introduction of robots in production line requires several additional systems like safety fence due to the safety problem and it divides the workspace into that of robots and that of human workers. For solving this problem, removing safety fence and installing another safety method is important to make human-robot collaboration possible and to make workspace share between robot and human.

In the viewpoint of robot safety, two perspectives can be considered. One is a safety function of robot and the other is a safety alarm by monitoring the surroundings of robots. First one is required when a human worker is in the proximity of a robot during teaching process. Next one is required when a robot is normally operating in high speed and it can do a human an injury in contact. In this paper, we focus on second case using a safe camera system.

This paper is organized as follows. In section II, the cell production system for cellular phones with two dual-arm robots is introduced. In section III, the design of safety system for our production system is proposed. In section IV, some implementation results are described and the conclusions are made in section V.

II. Cell Production System With Dual-Arm Robots

In a conventional cell production line, several human workers stand in order in front of a conveyor and conduct the charged jobs. Then, final products come out after final worker finished his jobs.

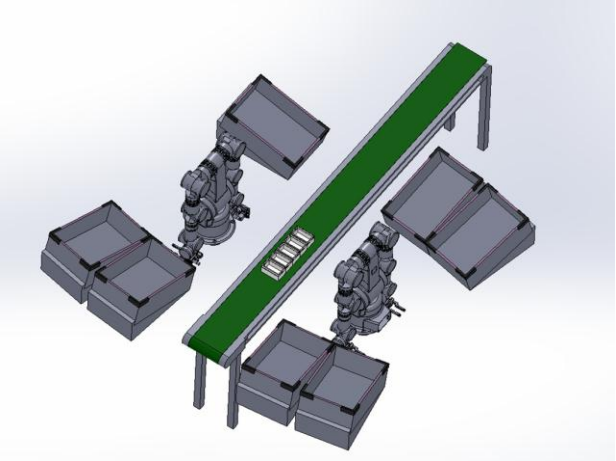

Figure 1 Design of cell configuration

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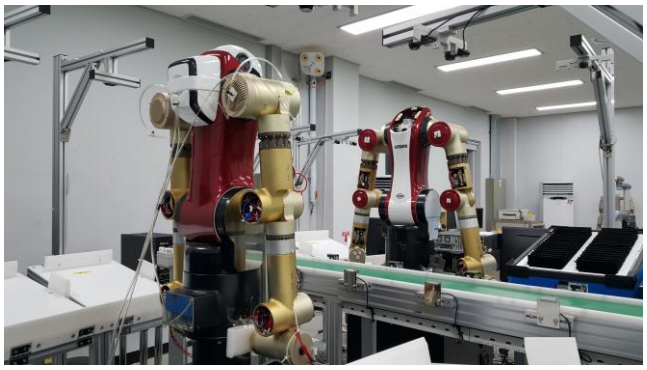

FIGURE 2 CELL PRODUCTION LINE WITH TWO DUAL-ARM ROBOTS

FIGURE 3 SAFETY CAMERA

However, this configuration is not efficient for robots because collisions can be made between neighboring robots and the length of lines may be longer with considering the workspace of robots. So we designed the cell configuration like figure 1.

Each dual-arm robot is placed in opposite side and trays of accessories are placed in the surroundings of each robot. The packing can be achieved in the sequence: a cradle, a travel adapter (T/A), two batteries, a USB cable, a set of earphones, a manual, and a middle cover. Since a dual-arm robot operates using two arms at the same time, packing task should be conducted by two robots turn by turn. Figure 2 shows the implementation of the robotic cell. Vision systems are placed above each tray to recognize the pose of target objects [6, 7].

III. SAFETY SYSTEM

As previously mentioned, we focus on a safety system to make an alarm by monitoring the abrupt appearance of a human worker in the vicinity of a robot during operation. Using the alarm signal from safety system, a robot controller can make a proper action like reducing speed or stop and thus prevent an injury of a human by collision with a robot. To monitor the interruption of a human worker within the workspace of a robot, a safe camera system is introduced

A. Safe Camera System

SafetyEYE system from PILZ is adopted for 3D zone monitoring. It can detect and report objects that encroach into warning and detection zones, which can be freely defined [8]. Detection zone can be easily defined and combined into groups to avoid occlusion from peripheral equipment. Figure 3 shows the safety camera and figure 4 shows the view of safety camera and detection zones which defined by user. .

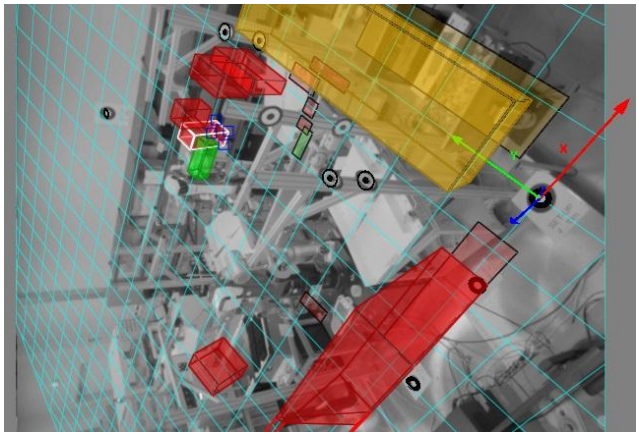

FIGURE 4 VIEW OF SAFETY CAMERA AND DEFINED DETECTION ZONES

B. Control Logic

Detection signal from SafetyEYE system can be handled in two ways. First one is to cut the power of motor off when the safe camera system detects unexpected object and thus a robot will stop and cannot move unless motor power is provided again, which will be conducted manually. The other one is to send a detection signal to PLC controller of cell production line. Then PLC controller sets alarm for that and a robot controller recognizes alarm signal and takes a proper action; reducing speed of a robot or stopping a robot. To prevent abrupt cut-off of actuating power of a robot, bypass switch is added. If bypass switch is on, the function of cut the power of motor off is disabled and thus the response for detection signal is decided by a robot controller. This function can be effectively used in setting-up or debugging phase because a human worker should access a robot.

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Since a power of motor is always enabled in that case, a robot controller should take proper action to secure the safety of a human worker in the vicinity of a robot.

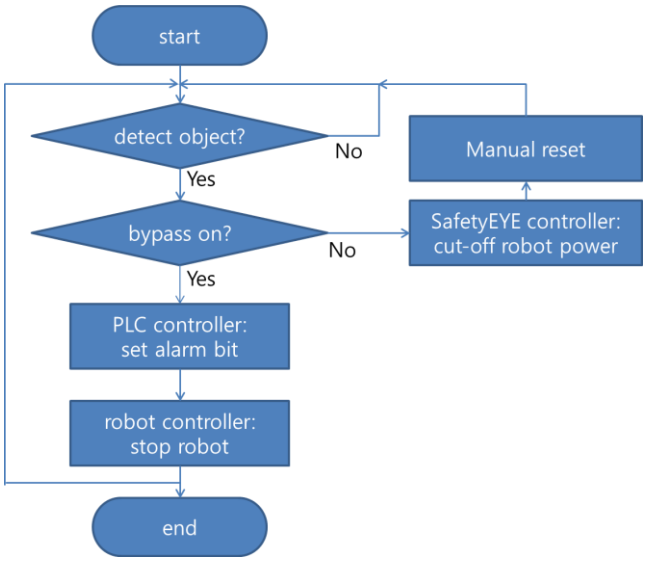

FIGURE 5 FLOW OF SAFETY CONTROL LOGIC

Figure 5 shows the flow of safety control logic in the proposed safety system.

IV. IMPLEMENTATION

The proposed system is applied to our demo line for cell production of cellular phones using two dual-arm robots to study the feasibility. To monitor the wide range of working area of robots, a safety camera should be installed at high position as possible. However, the height of ceiling of our lab is about 3.3m, so it is difficult to secure the monitoring zone as needed.

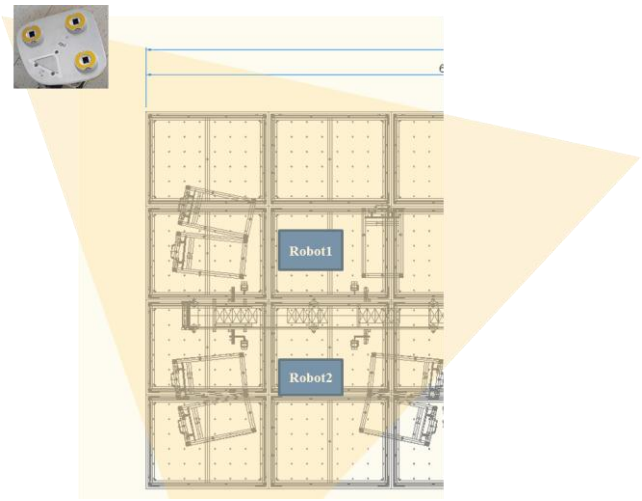

FIGURE 6 POSITION OF SAFETY CAMERA IN DEMO LINE

Thus we should find the proper installing position and angle of camera to get appropriate view for monitoring and camera was installed in the corner of demo line like figure 6 and you can also find a camera in figure 2. Since a detection zone is limited by the position of safety camera, we should make a detection zone in detail not to miss a motion in dangerous area. Also, if we make a detection zone within the workspace of a robot, the motion of a robot will be recognized as unexpected interruption, so the dangerous zone (red zone) is set up mostly in the back side of robots and warning zone (yellow zone) is set up in side of robots. Figure 4 shows the defined red zone and yellow zone. Green zone means exceptional area of red zone to adjust a shape of detection zone minutely. In addition, occlusion should be considered. In our configuration, there are several columns to hold the camera for localizing the picking object and those columns can make occlusion between safety camera and detection zone. To solve this problem, red zone block is divided into several small blocks and make dangerous zone by combining those red zone blocks. In figure 4, you can see the several red zone blocks especially in the vicinity of robot2.

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Overall system configuration is shown in figure 7. Safety camera is connected to safety controller through optical cable. Vision information is transferred to controller and decision of appearance of unexpected object is conducted by safety controller. Safety controller and PLC control system for cell line is connected and interlock signal and bypass signal is sent from safety controller to PLC system. Also safety controller can disable the power of robot system through the channel of EMO switch when bypass switch is off. The power can be recovered manually by a human operator after confirming the safety situation. PLC control system is connected to robot controller by optical cable through MELSECNET protocol. If an interlock signal, which means there is any object in red zone or yellow zone, is received by robot controller when bypass switch is on, control command to stop a motion or reduce a speed of motion is sent to a robot.

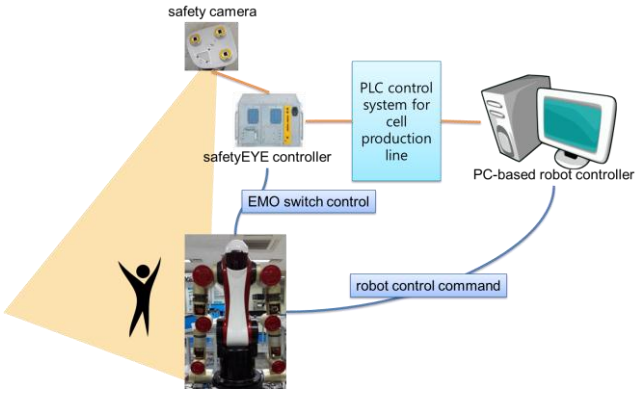

FIGURE 7 OVERALL SYSTEM CONFIGURATION

V. CONCLUSION

This paper prosed safety system for cell manufacturing system with dual-arm robots using safety camera for 3D zone monitoring. The proposed system is applied to demo line using two dual-arm robots for cellular phone packing task in our laboratory to study the feasibility.

Safety camera, safety controller were installed and connected to PLC control system and robot controller. Monitoring zone was defined to minimize the occlusion by configuration and the interference among dangerous zones.

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