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Development of retrofittable collision avoiding sensor for industrial robots

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Abstract

Many robots were installed in the manufacturing industry in the last decade. This shows the importance and value of the robot system in production. But many robots are not collaborative with humans. Collision detection is a fundamental issue for the safety of a robotic cell. All existing collision detection sensors are worked by opposing force (contact between robot and human) and it is injurious to humans due to the high collision force response of the robot at maximum speed. This research work demonstrates the use of the capacitive sensor for collision detection and the experiment shows the collision avoiding by non – contact manner. The sensors are mounted on the links of the robot. If the robot comes closer to humans, the capacitive sensor will detect the human presence and send the signal to the robot controller before the robot touches the human. The controller will turn off or hold the robot in position immediately based on the sensor signal. So this technique will ensure human safety more and more when compared to the current robot system. This sensor can be installed on a new robot and retrofitted to the old robot.

Keywords: Robot collision, Capacitance sensor, Non – Contact Sensor, Human safety.

1. Introduction

Collision detection and avoidance are fundamental issues for the safety of a robotic cell in industrial environment. Errors in programming, as well as unexpected events or objects in the robot workspace may lead to collisions [2]. So using an advanced collision detection procedure, collisions can be quickly detected. The matter has been widely investigated in the most recent years with

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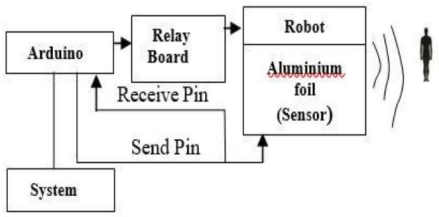

Figure 1: Block diagram of collision detection sensor

particular application to the case of Human- Machine Interaction (HMI), which is effectively and safely achieved through the adoption of particular strategies and technological solutions.
Several methods can be found in the literature to detect collisions for industrial robots, but some of them are based on the usage of sensors that are not included in the standard equipment of manipulators [4, 6, 8, 5]. For example, some techniques use vision sensors to detect the presence of unmodeled objects in the cell, or exploit algorithmic approaches, typical of methods using proprioceptive sensors only, but making use also of extra sensors (e.g., torque sensors), to improve the performance of the procedure. These collision detection approaches are need a higher-level knowledge of robotic arm model and its kinematics, mathematical calculation and many experimental analyses [3, 10, 9, 1, 7]. Therefore, these approaches are fully contact based, between human and robots and it's need an input of collision detection which is derived from external force. So this case will suitable when the robot working in minimum speed and human will not injure at this case. However, when the robot is working at maximum speed it causes severe injury to the human. Because robot will not stop until detect the collision input range. In order to overcome this issue a non – contact collision avoiding sensor is the alternative methodology to ensure the human safety.

2. The Proposed Collision Detection Sensor

The proposed collision detection sensor is a fully non – contact based between robots and human to detect the collision. The working of this sensor is based on electro- magnetic induction and capacitance principal. In 1831 Michael Faraday discovered electro-magnetic induction. It is state that there are two conductors when the current flows in conductor 1, simultaneously electromagnetic field is created. In addition to that, electromagnetic induction will be produced when conductor 2 is induced in electromagnetic field of conductor 1. Due to this reason, the voltage gain will be in conductor 2 and this process act as capacitor with respect to presence of die electric medium between two conductors. So non – contact collision avoiding sensor using these principals to detect the nearness of conductive materials without actually meeting them.

3. Experimental Setup

The proposed non-contact collision detection sensor was attached with TAL robot. The block diagram of the collision detection sensor arrangement is shown in figure 1. This can be retrofittable to any existing industrial robot or a new robot without much modification. The components used for developing non-contact collision detection arrangement is discussed below.

3.1. Controller

An Arduino is an open-source controller based on easy-to-use hardware and software. The Fig. 2 shows a controller intended for senses the environment by receiving inputs from many sensors, to controlling lights, motors, and other actuators.

Figure 2: Arduino Board

Figure 3: Aluminium foil

3.2. Sensor

Aluminium foil is a current conducting material shown Fig. 3. In this setup, aluminium foil with plastic sheet covered the robot arm and act as good capacitance sensor. Using different insulating material such as plastic, or another insulating material to get a different set of values.

3.3. Robot

The sensor is tested with a TAL robot, which is a 5 axis articulated robot having 1000 mm/sec as maximum speed. Fig. 4 shows the experimental setup of the robot with the sensor. The aluminium foil is wrapped on the robot arm and the send pin is connected to the foil from arduino board. The high value ($100k\Omega - 50M\Omega$) resistor is connected between send pin and receive (sensor) pin. The receive pin is the sensor terminal which is in the arduino board. The small capacitor (100 pF) or connect sensor pin to ground improves stability and repeatability of sensor values. Additionally, 5 V relay board is connected to the arduino for giving the input to the robot controller to stop the robot or to hold the robot.

Now arduino board is giving 5 V supply to the sensor pin and get back same voltage through the receive pin. If any human interaction occurs while running time of the robot, it forms the capacitor based on electromagnetic induction and capacitor principal. So the actual voltage will drop at receive pin due to capacitance property. The output will change at receive pin depends on distance between human and sensor. Fig. 5 shows Process of collision detection sensor. Threshold value can set by the user based on detection distance. If threshold value reached, the input signal sent to the robot from the arduino to stop or hold the robot based on user need.

4. Result and Discussions

The experimental analyses report that the sensor output signal, stop the robot at 3 mm distance from the human while running time of the TAL robot at speed of 500 mm/sec.

Figure 4: Experimental setup with TAL robot

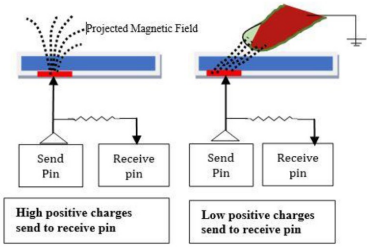

Figure 5: Process of collision detection sensor

Table 1: Sensor output values for different distance

S. No	Distance betweenhuman and robot (mm)	Sensor output value	Collisionsignal
1.	No humaninteraction	< 150	Signal canbe set by the user with respect to sensor output value.
2.	50	(85 -97)	
3.	40	(63-70)	
4.	30	(48-55)	
5.	10	(30-40)	
6.	5	(15-23)	
7.	3	(8-11)	
8.	0	(0-2)	

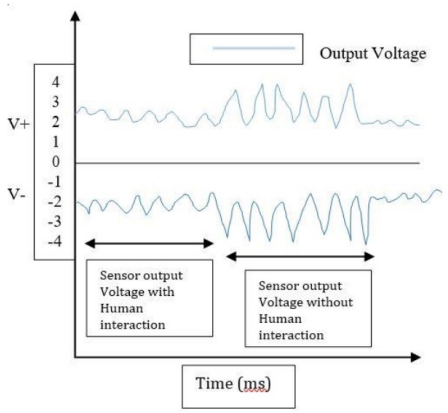

Figure 6: Sensor output waveform

The sensor was tested with in varies distance and got different set of values with respect to distance between human and robot. The values are shown in table 1. The primary deficiency of these sensors, however, is that they only detect metal conductors and different metal types can affect the detection range. The sensor output value can calculate from the variation of output voltage which is shown in fig. 6.

5. Conclusion

The proposed work demonstrated the ability of the capacitive sensor to detect the collision on robot. This will improve the human safety in the robotic work cell. This sensor will be a better replacement for the robots having collision detection sensor working in a collaborative environment. In future, research to be eliminating the grounding issues, because it affects the stabilising of sensor output value and also measure the external force at the time of impact from the variation of output voltage of the sensor with respect to distance of the objects and robot.

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