DEVELOPMENT OF ROBOTIC ARM FOR MOVING OBJECTS IN THE INDUSTRIAL CONTROL TRAINER

Aryuanto Soetedjo[1], Irmalia Suryani Faradisa[2], A.S.M Mukter -Uz-Zaman[3], Ainur Rofik[4]
[1,2,4] Department of Electrical Engineering, National Institute of Technology (ITN) Malang, Indonesia
[3] Faculty of Engineering, Multimedia University (MMU), Malaysia
[1] aryuanto@gmail.com

ABSTRACT: This paper presents the development of robotic arm as a complimentary tool in the industrial control trainer. The robotic arm is employed to automatically move the object from the storage box to the conveyor system for further sorting process. The developed robotic arm has four degree of freedom (DOF) that consists of the shoulder part, the elbow part, the wrist part, and the gripper part. The robotic arm is developed using the low cost acrylic material and electronic components. The servo motor is employed to drive the robot arm, while the ATMega8 microcontroller is used as the main controller. The photodiode sensor is used to detect the presence of the plastic object or the metal object in the storage box. The experimental results show that the proposed system is able to achieve the goal properly and suitable to be implemented in the industrial control trainer module.

Keywords: Robotic arm, conveyor system, industrial control trainer, sorting object

1. Introduction

A robotic arm is a widely used robot in the industrial automation systems. It is used for several tasks, such as an automated sorting system (Bdiwi, Suchy, 2012; Pereira, Fernandes, Sequeira, 2014; Sumardi, Febriramadhan, Triwiyatno, 2016; Szabo, Lie, 2012), moving object in the hazardous environments (Ansari, Amir, Hoque, 2014), pick-and place of objects (Cai, Xiong, Yin, 2012; Zhang, Chen, Liu, Sun, 2010).

Due to the importantly of the robotic arm in the industries, they are included in the academic courses or in the laboratory experiments (Braae, 1996; Qassem, Abuhadrous, Elaydi, 2010; Rai, 2014). The study of the linear control theory of robot was proposed in (Braae, 1996). The visual software was developed by (Qassem, Abuhadrous, Elaydi, 2010) to model and simulate the robot arm. The computer vision was employed to demonstrate the ability of robot for grasping the objects.

In this work, we develop a robotic arm to pick and move an object in the conveyor system. The work is the extension of our previous work in (Soetedjo, Ashari, Ardiles, 2017). The robotic arm is employed to pick the object from the storage to the conveyor system. To simplify the system, the photo detectors are used to detect the presence of objects in the storage. Based on the information of the sensors, the robot pick-up the object and move to the defined location the conveyor system. The system could be utilized for a fully automatic industrial control trainer to study the conveyor system for handling and sorting the objects.

2. Material and Method

Figure 1 illustrates the configuration of robotic arm in the industrial control trainer. As shown in the figure, it consists of the Industrial Control Trainer (ICT), the robotic arm, the storage box for metal object and the storage box for plastic object. The ICT is a conveyor system equipped with the sensors and actuators for sorting the objects, i.e. the plastic and the metal objects. In this system, a robotic arm is used to move the object from the storage box to the conveyor. Since there are two storage boxes, the object is identified by the sensor installed on the storage box. For instance, when the sensor on the metal storage box is active, then the robotic arm will move to the metal storage box to pick up the object and move it to the convesyor.

.

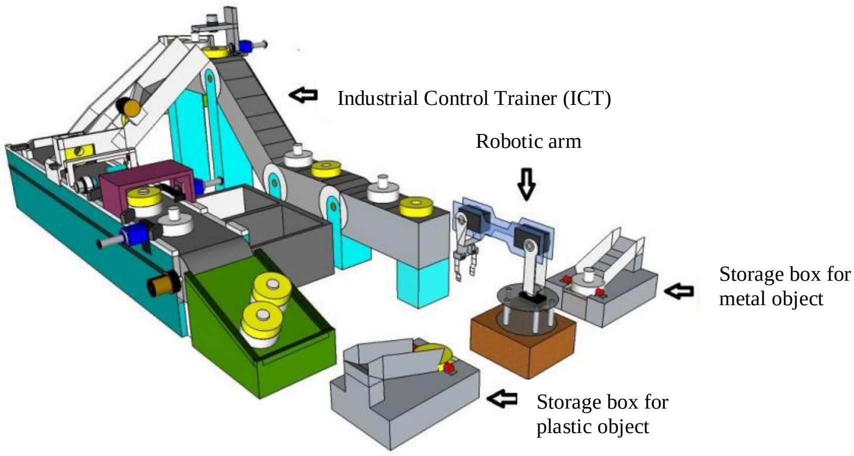


Figure 1 Configuration of robotic arm in the industrial control trainer

2.1 Hardware Configuration

The hardware configuration is illustrated in Figure 2. As shown in the figure, the ATMega8 microcontroller is used as the controller to read the photodiode sensor and to control the robotic arm. The photodiode sensor is placed in the storage box to detect the presence of the object, i.e. the metal object or the plastic object.

The robotic arm consists of four servo motors to drive the shoulder, the elbow, the wrist and the gripper. The movement of robotic arm is controlled by the microcontroller in according to the status of photodiode. There are four basic movements of the robot, i.e. a) move the arm to the storage box location; b) move the arm to pick up the object; c) move the arm to the conveyor location; d) move the arm to place the object down to the conveyor.

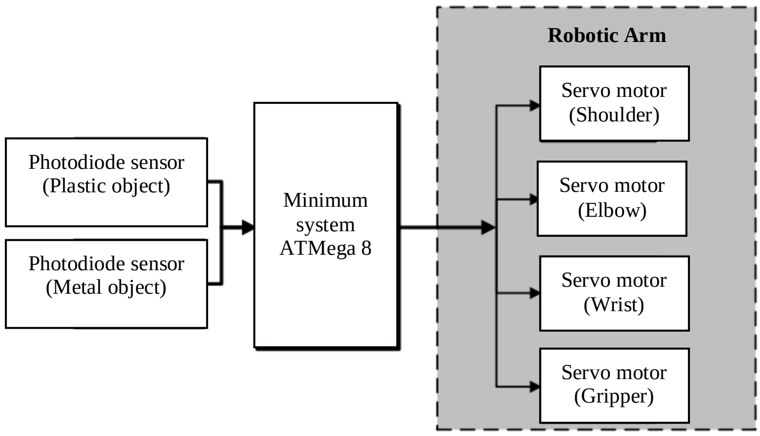


Figure 2 Hardware configuration.

2.2 Mechanical Design

As described previously, the mechanical design of robotic arm consists of four parts, i.e. the shoulder part, the elbow part, the wrist part and the gripper part. The shoulder part is designed to move in the horizontal direction, i.e. move to the left and right. The mechanical designs of 2D drawing and 3D drawing are illustrated in Figure 3 and Figure 4 respectively. As shown in the figure, the shoulder forms a cylinder which is made from the acryclic material. The shoulder part is also used as the base of the robot.

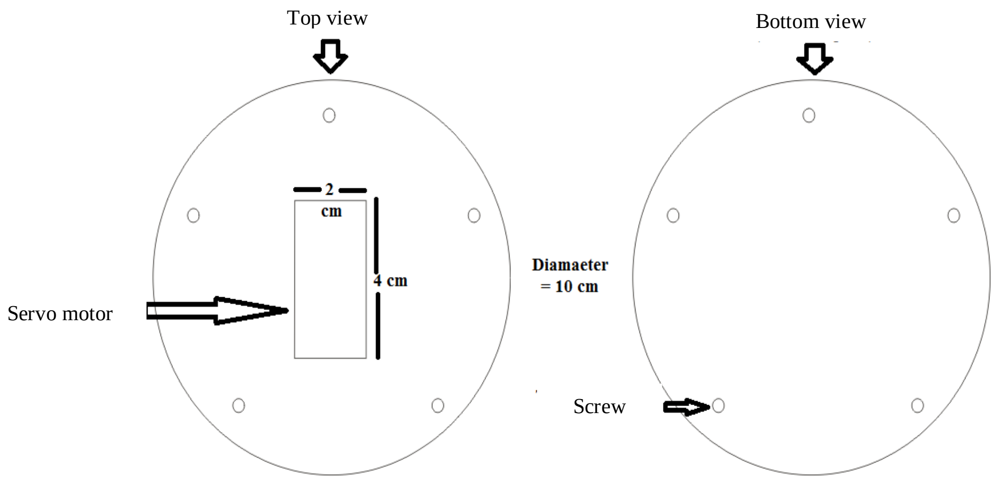


Figure 3 Mechanical design of shoulder part (2D drawing)

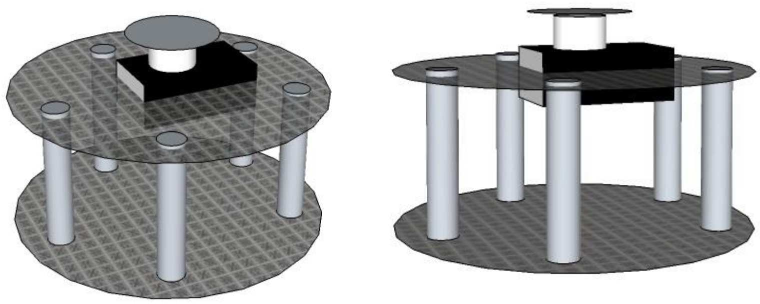
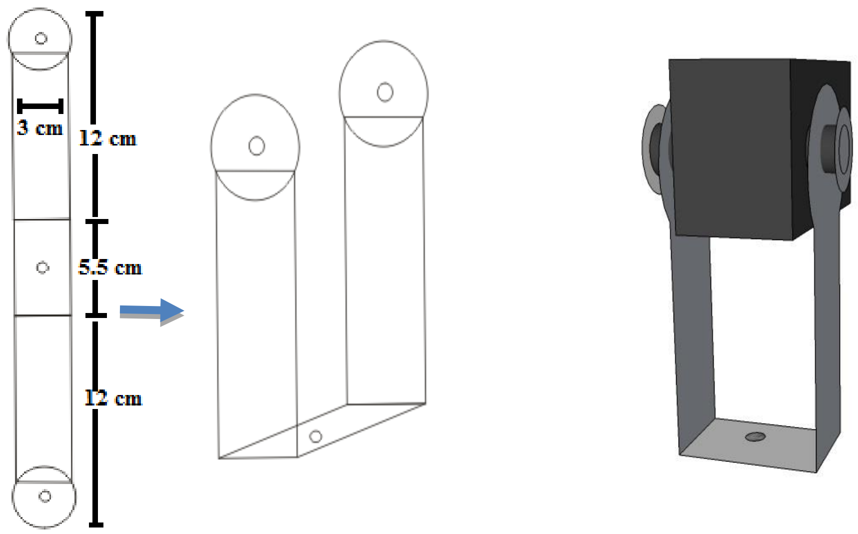


Figure 4 Mechanical design of shoulder part (3D drawing)

The elbow part is designed to mimic the human elbow. The elbow is used to move up and down. The mechanical design of the elbow part that is linked to the shoulder is illustrated in Figure 5. While Figure 6 illustrates the mechanical design of the elbow part that is linked to the wrist.

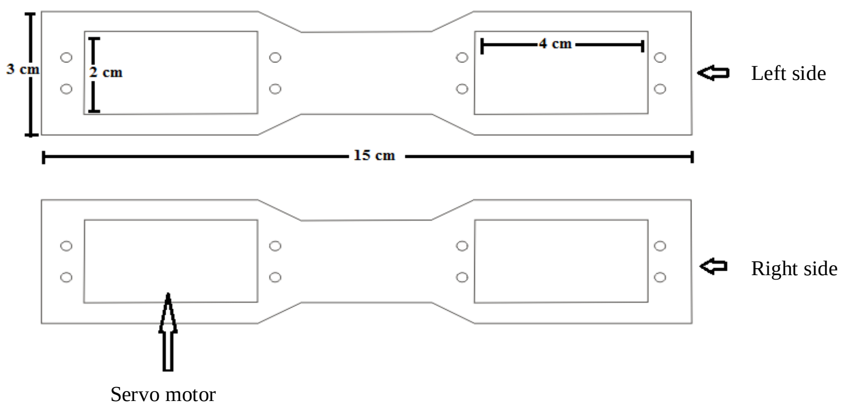
The wrist part is designed to connect the elbow and the gripper as illustrated in Figure 7. The wrist moves up and down, which is driven by the servo motor placed in the link of the elbow as shown in Figure 6.

The gripper is designed to grip the object as illustrated in Figure 8. The gripper is driven by a servo motor in one side only. While the other side is fixed.

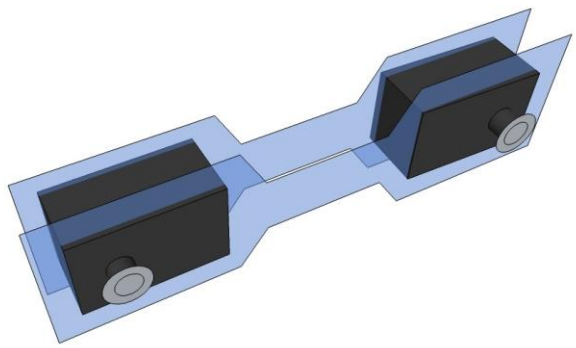


(a) (b)

Figure 5 Mechanical design of elbow part: (a) Link to the shoulder (2D drawing); (b) Link to the shoulder (3D drawing).



(a)



(b)

Figure 6 Mechanical design of elbow part: (a) Link to the wrist (2D drawing); (b) Link to the wrist (3D drawing).

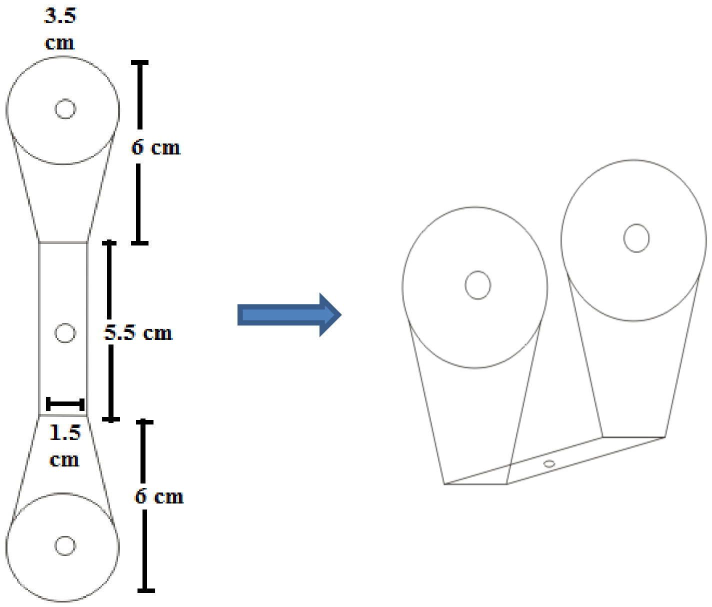


Figure 7 Mechanical design of wrist part (2D drawing).

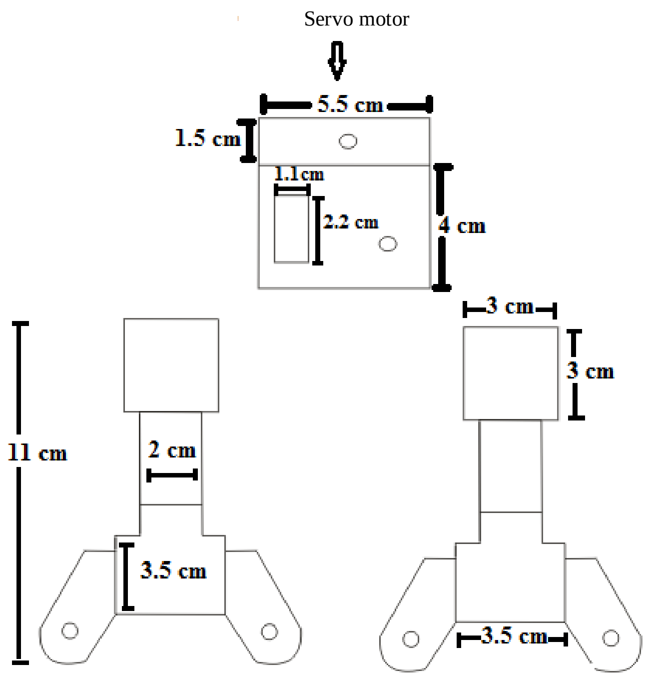


Figure 8 Mechanical design of gripper (2D drawing)

2.3 Electronic Design

The ATMega8 microcontroller system is illustrated in Figure 9. In the figure, the Port-C (PC0 and PC1) are used as the analog input to read the analog signal from the photodiode, where PC0 is used to detect the plastic object and PC1 is used to detect the metal object.

The Port-B (PB2 to PB5) are used to detect the user inputs from the Push Buttons, where PB2, PB3, PB4, and PB5 are connected to the Push Button-0, the Push Button-1, the Push Button-2, the Push Button-3, and the Push Button-4 respectively. The Push Button-1 is used as the manual control to move the robot to the plastic storage box. The Push Button-2 is used as the manual control to move the robot to the metal storage box. The Push Button-3 is used as the manual control to pick up or place the object. The Push Button-4 is used as the manual control to move the robot to the home position.

The Port-D (PD0 to PD3) are used to control the servo motor, where PD0, PD1, PD2, and PD3 control the Servo Motor-1, Servo Motor-2, Servo Motor-3, and Servo Motor-4 respectively. The Servo Motor-1 is used to drive the shoulder. The Servo Motor-2 is used to drive the elbow. The Servo Motor-3 is used to drive the wrist. The Servo Motor-4 is used to drive the gripper.

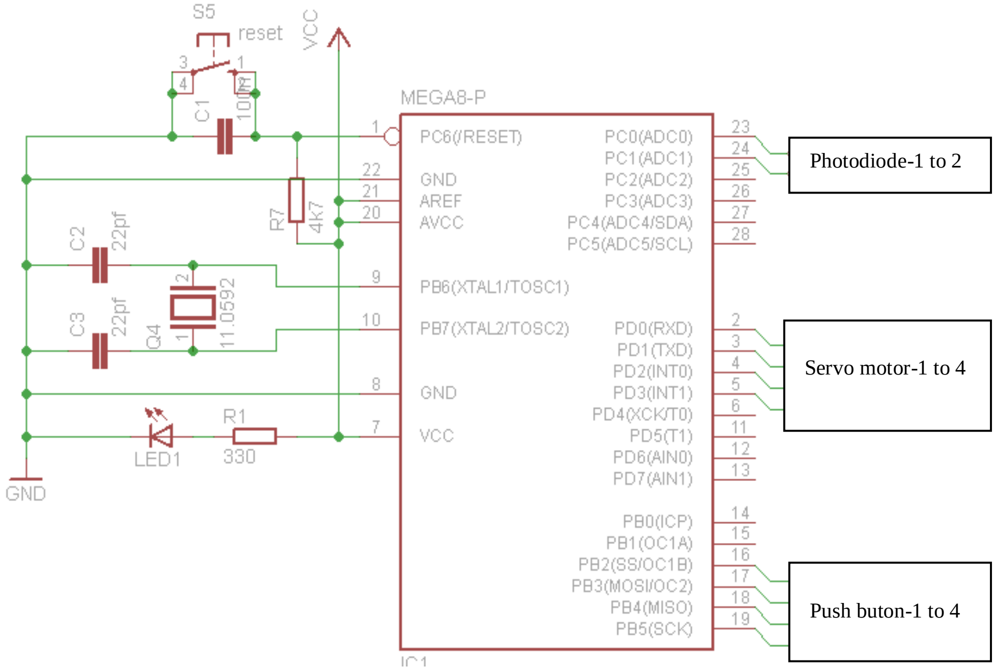


Figure 9 Microcontroller system.

3. Experimental Results

Several experiments are carried out to verify our proposed system as described in the following. The home position is defined as the position of robotic arm at the rest as illustrated in Figure 10. The robotic arm parameters such as the pulse width of the servo motor control, the servo motor angle and the direction of motor movement are given in Table 1. In the table the clockwise (counter clockwise) direction means that the angle is measured in the clockwise (counter clockwise) direction from the normal position of the servo motor (0^0).

Figure 11 illustrates the position of robotic arm when it moves to the plastic storage box position. The robotic arm parameters are given in Table 2. From the table, it is obtained the angle of servo motor – shoulder is 90^0 in the counter clockwise direction. It means that the shoulder moves 90^0 to the left from the home position.

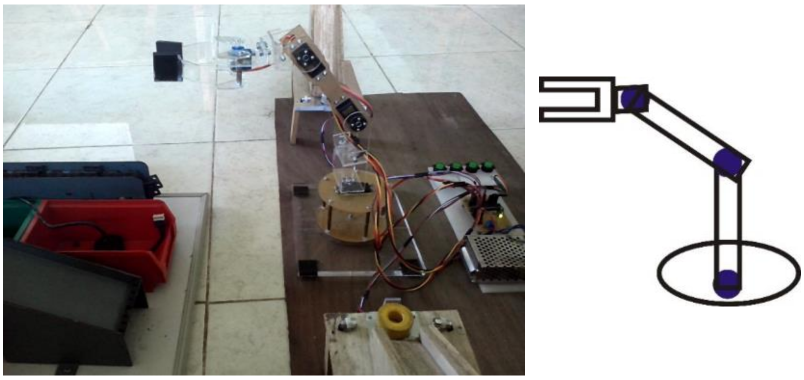


Figure 10 The robotic arm in the home position

Table 1 The robotic arm parameters in the home position

No	Servo motor	Pulse width of servo driver (µs)	Servo motor angle (°)	Movement direction
1	Servo motor - shoulder	1500	0	Normal
2	Servo motor - elbow	1950	45	Clockwise
3	Servo motor - wrist	1050	45	Counter clockwise
4	Servo motor - gripper	1500	0	Normal

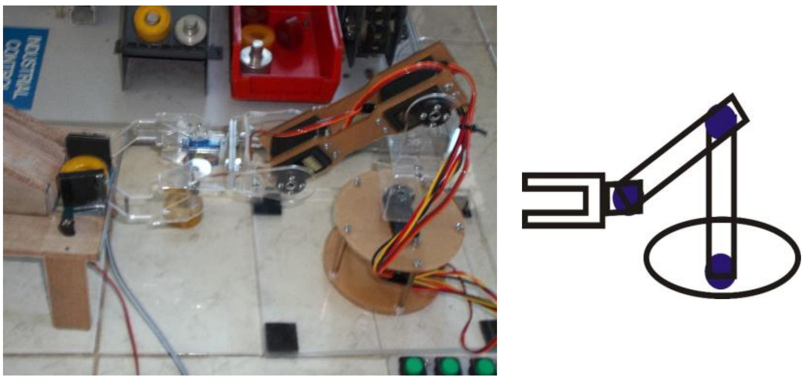


Figure 11 The robotic arm in the plastic storage box position.

Table 2 The robotic arm parameters in the plastic storage box position

No	Servo motor	Pulse width of servo driver (µs)	Servo motor angle (°)	Movement direction
1	Servo motor - shoulder	600	90	Counter clockwise
2	Servo motor - elbow	1050	45	Counter clockwise
3	Servo motor - wrist	1950	45	Clockwise
4	Servo motor - gripper	1212.5	22.5	Counter clockwise

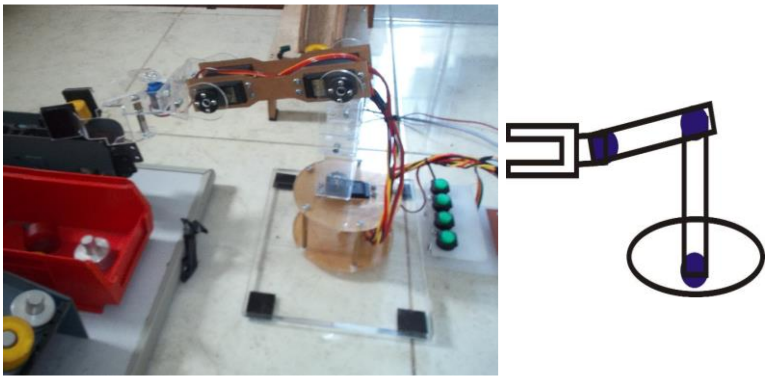


Figure 12 The robotic arm in the conveyor position

Table 3 The robotic arm parameters in the conveyor position

No	Servo motor	Pulse width of servo driver (μs)	Servo motor angle (^{o})	Movement direction
1	Servo motor - shoulder	1500	0	Normal
2	Servo motor - elbow	1050	45	Counter clockwise
3	Servo motor - wrist	1950	45	Clockwise
4	Servo motor - gripper	1500	0	Normal

Figure 12 illustrates the position of robotic arm when it moves from the plastic storage box the conveyor position. The robotic arm parameters are given in Table 3. From the table, it is obtained that servo motor angle is back to 0^0 which means that the shoulder position is the same with the home position.

The results of robotic arm movements on the response of the object detection are given in Table 4. The results show that the robotic arm move to the appropriate direction when the object is detected in the storage box. It is noted here that the objects in both storage box cannot present simultaneously.

Table 4 The robotic arm movement on the response of object detection

No	Location	Object type	Robotic arm angle (shoulder) (^{o})	Movement direction
1	Plastic storage box	Plastic	90	Counter clockwise
		No object	0	Normal
2	Metal storage box	Metal	90	Clockwise
		No object	0	Normal

Table 5 shows the results of the firmness of the gripper under the different types and conditions of the objects. As shown in the table, the gripper works properly, i.e. grip the object strongly when the weight of object is below than 40 g and the object surface is not very slippery.

Table 5 The robotic arm movement in the response of object detection

No	Object material	Object diameter (cm)	Object weight (g)	Object thickness (cm)	Object surface	Remarks
1	Plastic	3.3	10	1.5	Rather slippery	Object is gripped strongly
2	Metal	3.3	40	1.5	Slippery	Object is gripped rather strongly
3	Plastic & Metal	3.3	50	3	Very slippery	Object is gripped weakly

4. Conclusion

The robotic arm is developed to automatically move the plastic or the metal objects from the storage box to the conveyor system in the industrial control trainer. The movement of robotic arm is triggered by the photodiode that senses the presence of the object. The functionality of developed robotic arm has been tested and yields a good result. The gripper of the robotic arm is able to grip the object strongly when the object weight is below than 40 gr and the surface is not very slippery.

In future, the robotic arm will be improved both in the mechanical parts and the electronic parts. Further integration with the advance machine vision techniques will be conducted.

References

Ansari, M. J., Amir, A. and Hoque, M.A. 2014. Microcontroller based robotic arm: Operational to gesture and automated mode. Proceedings of 2014 International Conference on Electrical Engineering and Information & Communication Technology, Dhaka, 2014, pp. 1-5.

Bdiwi, M. and Suchy, J. 2012. Robot control system with integrated vision/force feedback for automated sorting system. Proceedings of 2012 IEEE International Conference on Technologies for Practical Robot Applications (TePRA), Woburn, MA, pp. 31-36.

Braae, M. 1996. A robot arm for a first course in control engineering. IEEE Transactions on Education, Vol. 39, No. 1, pp. 40-45.

Cai, W., Xiong, T. and Yin, Z. 2012. Vision-based kinematic calibration of a 4-DOF pick-and-place robot. Proceedings of 2012 IEEE International Conference on Mechatronics and Automation, Chengdu, pp. 87-91.

Pereira, V., Fernandes, V. A. and Sequeira, J. 2014. Low cost object sorting robotic arm using Raspberry Pi. Proceedings of 2014 IEEE Global Humanitarian Technology Conference - South Asia Satellite (GHTC-SAS), Trivandrum, pp. 1-6.

Qassem, M.A., Abuhadrous, I. and Elaydi, H. 2010. Modeling and Simulation of 5 DOF educational robot arm. Proceedings of 2010 2nd International Conference on Advanced Computer Control, Shenyang, pp. 569-574.

Rai, N., Rai, B. and Rai, P. 2014. Computer vision approach for controlling educational robotic arm based on object properties. Proceedings of 2014 2nd International Conference on Emerging Technology Trends in Electronics, Communication and Networking, Surat, pp. 1-9.

Soetedjo, A., Ashari, M.I. and Ardiles, C. 2017. Development of Industrial Control Training Module using Distance and Color Sensors for Detecting Objects. International Journal of Engineering and Managemen, Vol. 1, No. 1.

Sumardi, Febriramadhan, L. and Triwiyatno, A. 2016. Design of color based object sorting through arm manipulator with inverse kinematics method. Proceedings of 2016 3rd International Conference on Information Technology, Computer, and Electrical Engineering (ICITACEE), Semarang, pp. 117-122.

Szabo, R. and Lie, I. 2012. Automated colored object sorting application for robotic arms. Proceedings of 2012 10th International Symposium on Electronics and Telecommunications, Timisoara, pp. 95-98.

Zhang, Y, Chen, B.K., Liu, X. and Sun, Y. 2010. Autonomous Robotic Pick-and-Place of Microobjects. IEEE Transactions on Robotics, Vol. 26, No. 1, pp. 200-207.