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APPLICATIONS OF THE SCARA ROBOT ARM USING VISION SYSTEM

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Abstract. *The article implements the object classification according to various colors using the vision system, and controls the Selective Compliance Assembly Robot Arm (SCARA) robot arm to catch the assigned object moving to the plastic basket with the same color. The control device of the SCARA robot arm uses Programmable Logical Controller (PLC) based control system. The control system (ASDA-SM) is all in one device to be produced by the DELTA Company. The four-joint based SCARA robot arm contains four AC servomotors, four driver devices, a gripper and a vision system. The PLC-based controller also programs motion commands of the gripper to catch the assigned objects using five methods. That is, Ladder Diagram (LG), Function Block Diagram (FBD), Sequential Function Chart (SFC), Instruction List (IL) and Structure Test (ST). The Human Machine Interface (HMI) of the PLC based control system is DOP-HO7 to be a touch panel. In the image recognition, we use Hough transform algorithm and Otsu algorithm to decide color and shape of the assigned object. Users can control the motion path of any joint, and control the gripper to catch each object of the working space moving to the plastic basket with the same color.*
Keywords: SCARA robot arm, PLC-based control system, AC servomotors, Hough transform algorithm, Otsu algorithm

1. **Introduction.** How to find a fast and effective way to program the motion trajectory of the robot arm becomes an important problem. A robot arm is a mechanical device that is driven by some electronic motors or pneumatic actuators. A well-trained robot arm can be instead of human to complete assigned tasks automatically. The purpose of the paper is to design and implement a four-degree-of-freedom SCARA robot arm, and helps the human to finish the classification tasks with the vision system.

There are some researches regarding the robot arm in the past. For example, Su and Su designed a seven-joint robot arm using PC-based controller. The robot arm can catch the pencil to write the assigned words on the platform, plot the house outlook, and build a church using some wooden blocks [1]. Homayounzade and Keshmiri developed an observer-based impedance controller for a robot arm during a constrained motion. The proposed method required the measurements of link position and interaction force [2]. Sim et al. presented a binocular stereo vision to decide the desired location of the SCARA robot arm [3]. Kenmochi et al. proposed a motion control method based on environmental mode for a dual arm robot. The robot arm can analyze distinctive complex motion by controlling mode information and particular features [4].

In the image recognition applications, the robot arm catches the assigned object using the feedback signal of the image system. Karthikeyan et al. presented a simple active tracking system, using a laser diode, a steering gear box setup and a photo-resistor, which is capable of acquiring two dimensional coordinate in real time without the need of any image processing technique [5]. Cao et al. designed a 5-DOF SCARA robot arm for welding, and built the model and the kinematic equations using D-H method [6]. The paper is organized as follows. Section 2 describes the system architecture of the SCARA robot arm, and explains the functions of the controller (ASDA-SM). Section 3 explains the hardware structure of the SCARA robot arm. Section 4 presents the experimental results for the robot arm to finish assigned tasks with the vision system. Section 5 presents brief concluding remarks.

2. **System Architecture.** The system architecture of the SCARA robot arm system is shown in Figure 1. The system contains a PC-based computer, a PLC-based controller (ASDA-SM), a vision system (Open CV), four AC servomotors, a solenoid and a gripper and a Human Machine Interface (HMI). Using the controller (ASDA-SM), four AC servomotors, a solenoid and a gripper integrates the SCARA robot arm. The solenoid drives the gripper to catch the assigned object. The core of the program language is DRAS. The DRAS is developed by the DELTA Company to match with the national standard communication protocol (IEC61131-3). The functions of the DRAS can integrate the PLC control system, and set parameter of each servo-controller (ASDA-SM), and program the driver software of the HMI, and communicate with the PC system via Modbus interface, and process the vision signals through Emgu system using Visual Studio C # language.

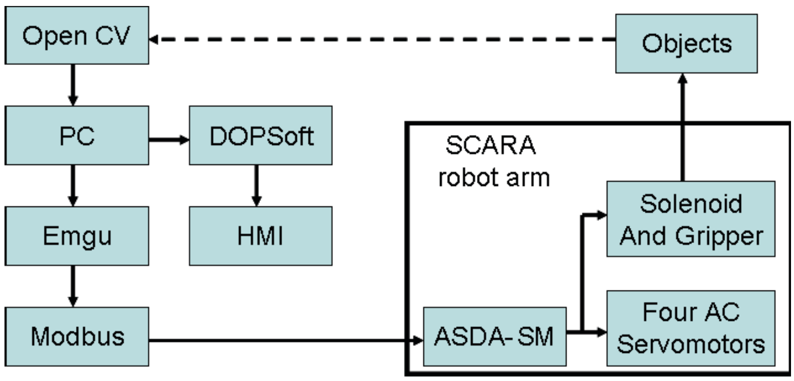


Figure 1. System architecture

The prototype of the controller (ASDA-SM) is shown in Figure 2. The controller can use MODBUS, RS485 or RS232 interface to connect with the computer in the part "A". The part "B" is the communication port with the HMI device. The part "C" can display the operation status and error code. The controller can use EtherNet, USB1, USB2 or DMCNET interface to connect with the computer in the part "D". Four AC servomotors will connect with the part "E" of the controller. The part "F" is the standard AC power input (R,S,T). The part "G" is the break signals. The part "H" is output terminal with safe torque detection.

The part "I" is the DC power input (24V). The part "J" is the input digital signals with 24 points for users. The limit positions of each AC servomotor connect with the part "K", and decide the moveable range of each joint. The part "L" connects with the encoder of each AC servomotor as feedback signal and measures the real-time rotation angle. The system signals (8 input points and 8 output points) are shown in the part "M".

3. **Robot Arm.** The theoretical foundation and motion planning of the SCARA robot arm can be referred in [1]. The structure of the SCARA robot arm has four DOFs (Degree of Freedom) to be shown in the left side of Figure 3. The first and second joints rotate along the Z axis. The rotation radius of two joints is the same to be 205mm. The rotation angle of the first joint is $\pm 157°$, and the second joint is $\pm 142°$. The movement

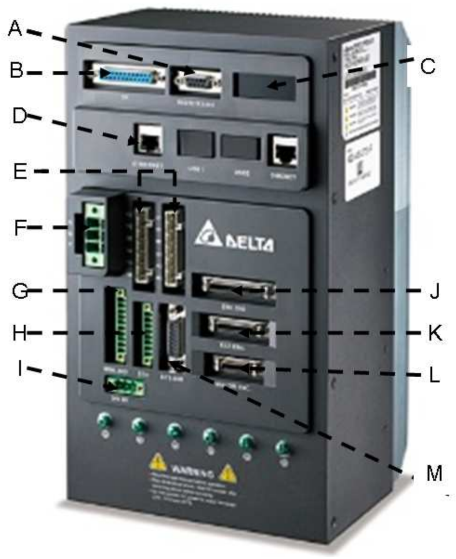


Figure 2. The PLC-based controller (ASDA-SM)

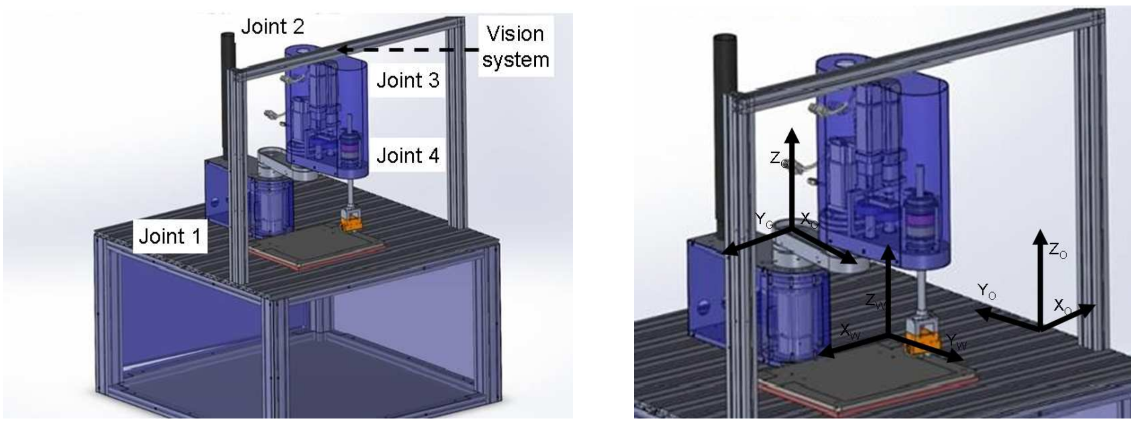


Figure 3. Prototype of the SCARA robot arm

Table 1. Specifications of the robot arm

Functions	Joint	Range
Length of the robot arm	First joint	205mm
	Second joint	205mm
Rotation and displacement range	First joint	±157°
	Second joint	±142°
	Third joint	150mm
	Fourth joint	±180°

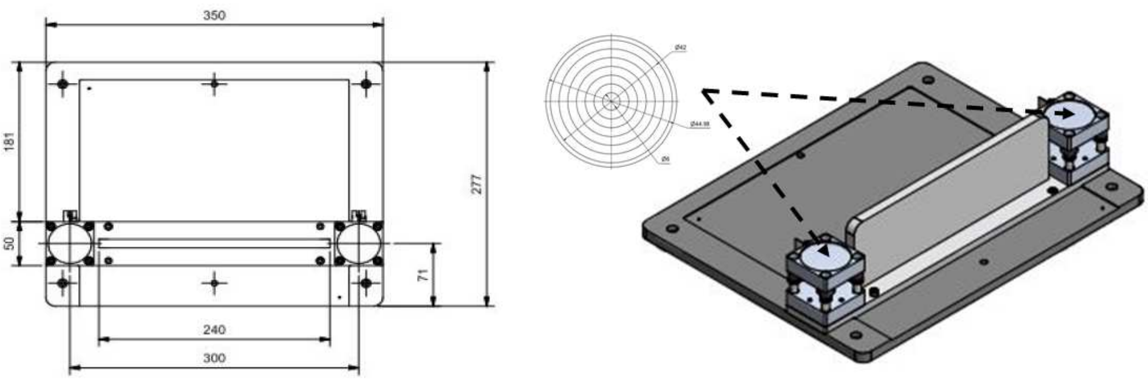
displacement of the third joint is 150mm. The rotation angle of the fourth joint is ±180°. The specifications of the SCARA robot arm are shown in Table 1. The vision system is fixed on the top of the working space. The definition of the global coordinate axis (X_G, Y_G and Z_G) is shown in the right side of Figure 3. Then we define the coordinate axis of the working space (X_W, Y_W and Z_W) and the object space (X_O, Y_O and Z_O) shown in right side of Figure 3, too. The Z direction is the same (moving up) for the defined coordinate system.

In the application field, the SCARA robot arm can complete various assigned tasks such as coming and going on two points, using the vision system to recognize the color and shape of each object. In the first task, we want to test the precision of moving and positioning precious for the SCARA robot arm. In the second task, the robot arm integrates the vision system to catch object of the working space moving to the assigned basket according to the color and shape of the object. The vision algorithms use Hough transform algorithm and Otsu algorithm to be referred in [7].

4. **Experimental Results.** We implement the functions of the SCARA robot arm in two aspects. In the first experiment, the robot arm catches a seal to stamp on two positions, and moves back and forth for 50 times. The robot arm catches twelve objects moving to the assigned basket with the same color in the second experiment.

In the first experiment, the SCARA robot arm catches a seal and stamps on two positions. The working space and the relation distance of each working position are shown in Figure 4(a). The working tool is shown in Figure 4(b). The SCARA robot arm must control the seal to stamp in the circle. The radius of the circle is 6mm. The robot arm programs a series of trajectories using point to point control technology. First the robot arm moves to the initial position, and catches the seal moving to the right side of the working tool, and falls to stamp on the assigned position shown in Figures 5(A) and 5(B). Then the SCARA robot arm rises up and moves to the left side, and falls to stamp on the other position shown in Figures 5(C) and 5(D). Then the SCARA robot arm has been finished 50 times repeat. Finally, the robot arm moves to the initial position and puts down the seal on the original position to stop.

In the second experiment, the robot arm catches twelve objects with the same size, and moves to the plastic basket with the same color. The size of each object is cylinder to



(a) Working space (b) Working tool

FIGURE 4. The working device of the first experiment

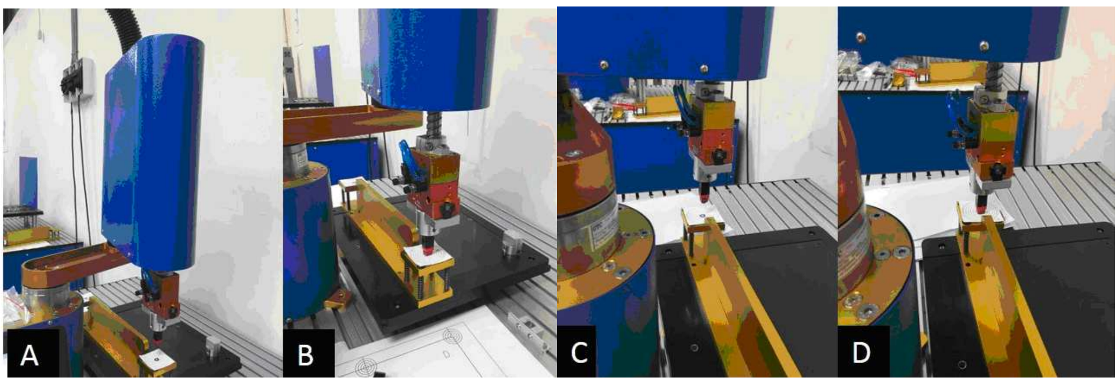
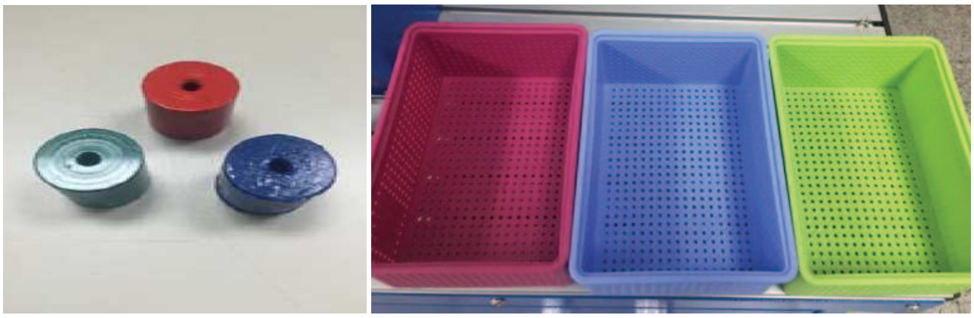


FIGURE 5. The results of the first experiment



(a) Objects (b) Plastic baskets

Figure 6. (color online) Objects and baskets of the second experiment

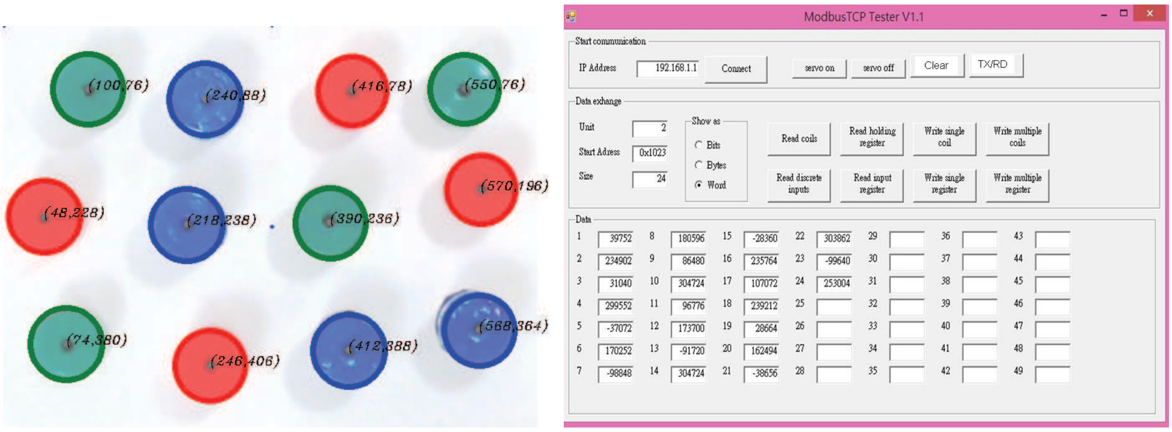


Figure 7. (color online) Results of vision recognition

be 3cm in radius and height respectively. The color of these objects will be red, blue or green shown in Figure 6(a). The plastic baskets have three peaces in red, blue or green as shown in Figure 6(b), too.

First the vision system recognizes the position of twelve objects (four red objects, four blue objects and four green objects) according to the color and shape shown in the left side of Figure 7. The user interface of the PC system can display the coordinate values on "X" and "Y" directions of each object shown in the right side of Figure 7. Then the robot arm moves to the initial position shown in Figure 8(A). Next the SCARA robot arm catches the first green object on the right side of the working space. The object moves to the same color basket on the right side of the working space by the robot arm shown in Figures 8(B) and 8(C). Then the robot arm catches the other objects to be green and moves to the same color basket shown in Figures 8(D)-8(H).

Next the robot arm catches the four blue objects moving to the assigned color basket according to the vision recognition result shown in Figures 8(I)-8(O). And then the robot arm catches the four red objects step by step, and moves to the assigned color basket shown in Figures 8(P)-8(W). Finally, the robot arm catches the last object on the left-down side of the working space and moves to put down on the red basket shown in Figures 8(X) and 8(Y). Then the robot arm has finished catching all objects. Finally the SCARA robot arm moves to the initial position and stops shown in Figure 8(Z).

5. **Conclusion.** The paper designed and implemented a four joints SCARA robot arm, and controlled the robot arm using PLC based system. The PLC based system is ASDA-SM that is produced by DELTA Company in Taiwan. We calculated motion displacement and rotation angle of each joint from the inverse kinematic equations. In the experimental

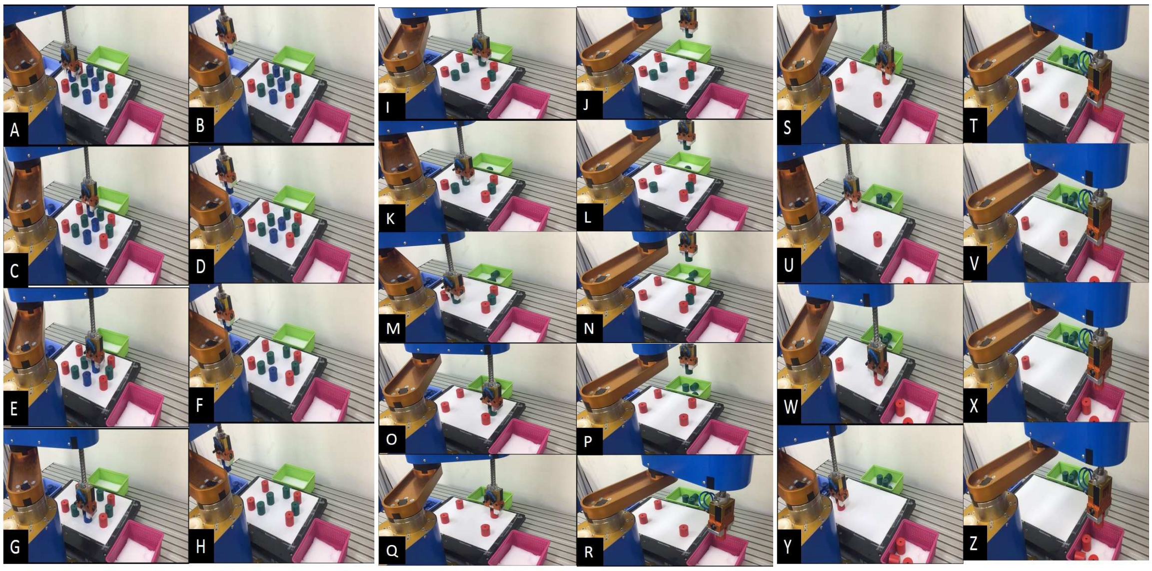


Figure 8. (color online) The second experimental result

results, first the SCARA robot arm tested the positioning precious to be nice. Then the robot arm catches the twelve objects moving to the assigned basket with the same color according to the result of the vision recognition.

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