Design and Implementation of the SCARA Robot Arm

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Abstract

The article designs a four-joint SCARA robot arm using PLC-based control system. The control system (ASDA-SM) is all in one device to be produced by the DELTA Company, and contains four axis controllers and drivers. The robot arm contains four AC servomotors, four driver devices and a vision system. The PLC-based controller also programs motion commands of the gripper to finish the assigned tasks using Ladder Diagram (LG), Function Block Diagram (FBD), Sequential Function Chart (SFC), Instruction List (LL) and Structure Test (ST). Each driver has been tuned the parameters of the PID controller. The human machine interface (HMI) is a touch panel to be used for the robot arm. Users can control the motion path of any joint, and uses the DOPSoft language to design the human machine interface. In the experimental results, The SCARA robot arm catches a seal, and falls to stamp the assigned positions step by step, and identifies the precious of the robot arm, and moves eight objects to the assigned positions.

Keywords: SCARA Robot arm, PLC-based controller, AC servomotors, PID controller.

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 driven by some electronic motors, pneumatic devices or hydraulic actuators. A well-trained robot arm can help human to complete assigned tasks automatically. The purpose of the paper is to design and implement a four-degree-of-freedom SCARA robot arm. The robot arm is composed of four AC servomotors. In the control aspect, a PLC-based (ASDA-MS system) controller is used to control the robot arm.

There are some researches regarding the robot arm in the past. For example, Shafik et al. presented an innovative 3D piezoelectric ultrasonic actuator using flexural vibration ring transducer for machine vision and robot guidance applications [1]. Homayounzade et al. developed an observer-based impedance controller for robot arm during a constrained motion. The proposed controller 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. By controlling mode information, particular features or trends can be given to the robot's motion. Then a distinctive complex motion can be realized [4].

In some conditions, 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

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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].

2. System Architecture

The system architecture of the SCARA robot arm system is shown in Fig. 1. The system contains a computer, a PLC-based controller (ASDA-SM), a image system (Open CV), four AC servomotors, a solenoid and a gripper. ASDA-SM and four AC servomotors and a solenoid and a gripper integrate the SCARA robot arm. The solenoid drives the gripper to catch the assigned object.

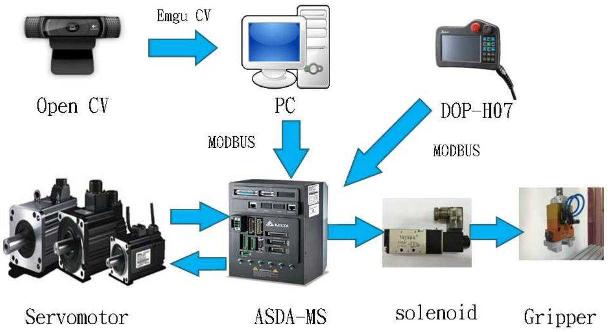

Fig. 1. System Architecture of the SCARA robot arm

The SCARA robot arm has four DOFs, (Degree of Freedom) to be shown in Fig. 1. 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 $\pm 157^0$, and the second joint is $\pm 142^0$. The movement displacement of the third joint is 150mm. the rotation angle of the fourth joint is $\pm 180^0$. The specifications of the SCARA robot arm are shown in the table1.

The prototype of the controller (ASDA-SM) shows in the Fig. 3. We explain each function of the controller. "A" part is the communication port. The controller can use MODBUS, RS485 or RS232 interface to connect with the computer. "B" part can display the operation status and error codes. Four AC servomotors will connect with the part "C" of the controller. "D" part is the standard input and output terminal with digital signals. The limit positions of each servomotor connect with the part "E", and decide the moveable range of each joint. "F" part connect with the encoder of each motor as feedback signal and measure the real-time rotation angle. The power input is the "G" part. The arrangement method of the controller is shown in Fig. 4 with AC servomotors. The connection pin of the power system is shown in Fig. 5.

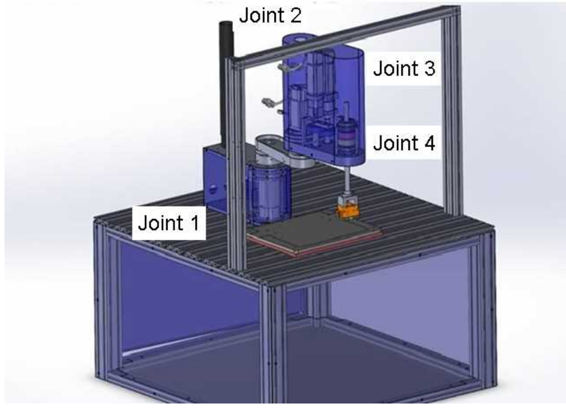

Fig. 2. Prototype of the SCARA robot arm

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	$\pm 157^0$
	Second joint	$\pm 142^0$
	Third joint	150mm
	Fourth joint	$\pm 180^0$

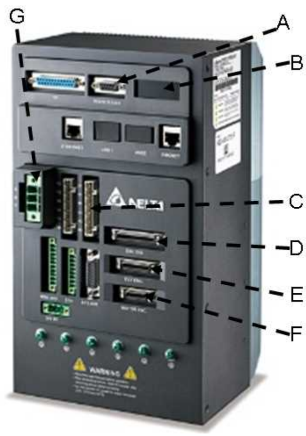

Fig. 3. The PLC-based controller(ASDA-SM)

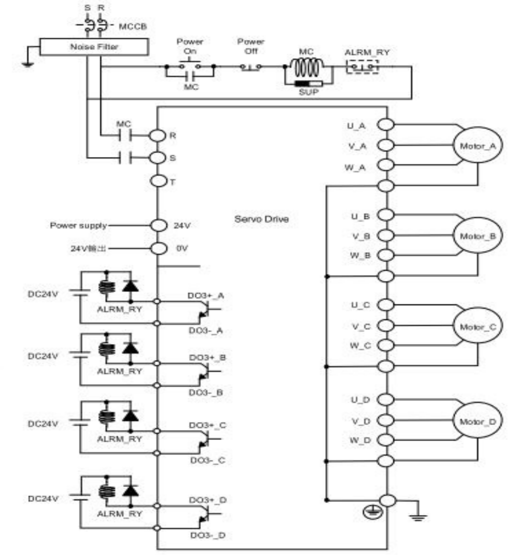

Fig. 4. Arrangement method of four servomotors

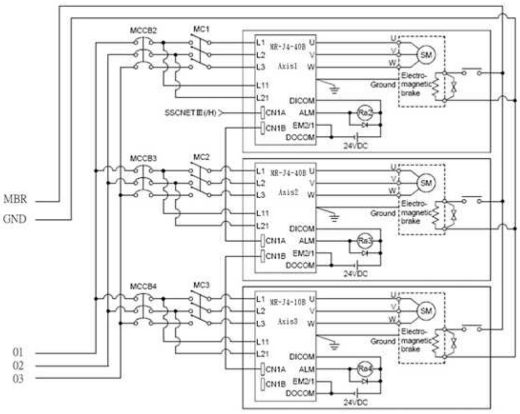

Fig. 5. The power connection method

In the assigned task, the SCARA robot arm can complete various assigned tasks such as coming and going on two points, moving multiple objects to the assigned positions and working on the multiple positions. Finally the robot arm can catch the color object moving to the assigned position according to the detection result of the image system..

3. Experimental Result

We implement the functions of the SCARA robot arm in two aspects. The robot arm catches a seal to stamp the seal on eight positions in the first experiment, and moves eight objects to the assigned positions in the second experiment.

In the first experiment, the robot arm executes catching a seal and stamps the seal on eight positions. The positions of the working space are shown in the right side of Fig. 6, and the relation distance of each working position is shown in the left side of Fig. 6. The robot arm must control the seal to stamp in the circle. The radius of the circle is 12mm. The robot arm programs a series trajectories using point to point control technology. First the robot arm moves to the initial position shown in Fig. 7(A), and catches the seal moving to the assign position "A", and falls to stamp the seal on the position shown in Fig. 7(B)-(D). Then the robot arm rises up and moves to the second position "B", and falls to stamp the seal on the assigned position shown in Fig. 7(E)-(H). The robot arm finishes the others step by step shown in Fig. 7(I)-(O). Finally the robot arm moves to the eight position, and falls to stamp the seal on the assigned position. Then the SCARA robot arm moves to the initial position and puts down the seal on the original position to stop shown in Fig. 7(P).

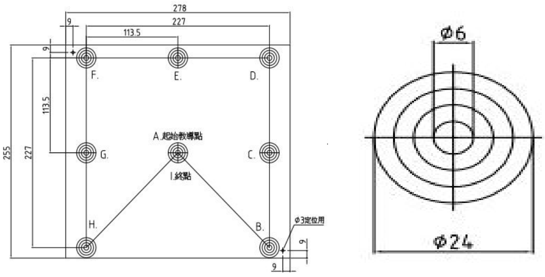

Fig. 6. The working space of the first experiment

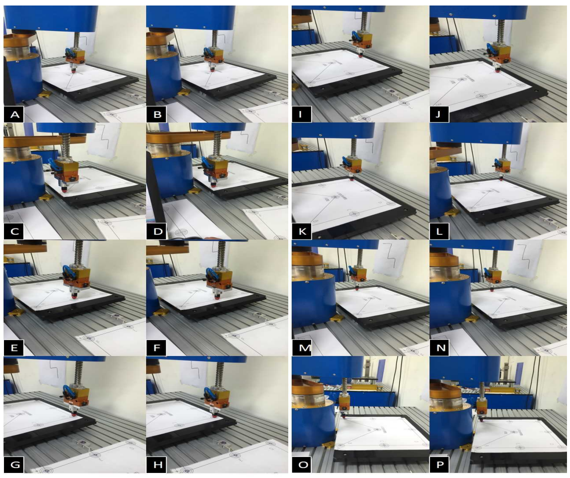

Fig. 7. The first experimental result

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In the second experiment, the robot arm catches eight objects with the same size on the left side of Fig. 8, and moving to the right side with the same relation position. The size of each object is cube to be 1cm in length, width and height respectively. The robot arm programs a series trajectory using point to point control technologies, too. First the robot arm moves to the initial position shown in Fig. 9(A), and catches the first object on the right-up side. The object moves to the same position on the right side show in Fig. 9(B) and (C). Then the robot arm rises up and moves to the left-up position shown in Fig. 9(D), and catches the object moving to the assigned position shown in Fig. 9(E) and (F). And then the robot arm catches the others step by step, and moves and falls to the assigned position show in Fig. 9(M)-(Q). Finally the robot arm catches the last object on the left-down side and moves and falls on the assigned position show in Fig. 9(R) Then the robot arm moves to the initial position and stop.

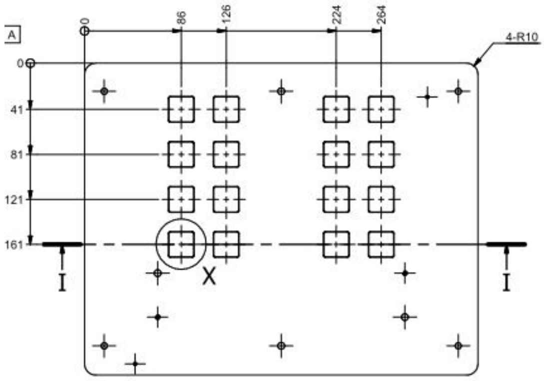

Fig. 8. The working space of the second experiment

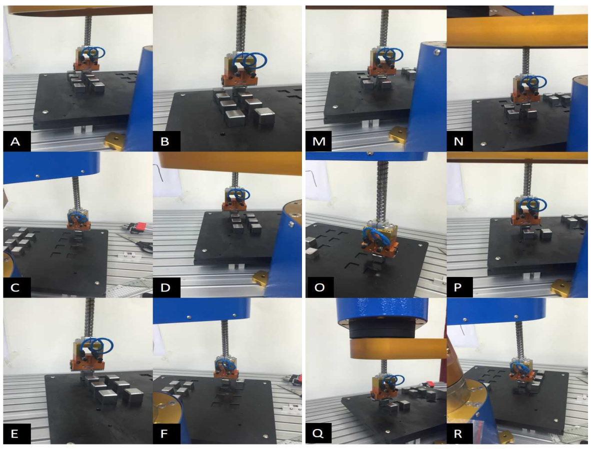

Fig. 9. The second experimental result

4. Conclusion

The papers designed and implemented a four joints SCARA robot arm, and controlled the robot arm using PLC based system. The PLC based system is ASDA-MS 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 results, first the SCARA robot arm catches a seal, and falls to stamp the on eight positions one by one. Then the robot arm catches the eight objects moving to the assigned locations according to the programmed motion paths..

Acknowledgements

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