ICIC Express Letters
Part B: Applications
Volume **7**, Number **3**, March **2016**
ICIC International ©2016 ISSN 2185-2766
pp. 717–723

DEVELOPMENT OF THE MOTION CONTROL FOR A ROBOT ARM

Shen-Ta Su[1] and Kuo-Lan Su[2,*]

[1]Graduate School of Engineering Science and Technology
[2]Department of Electrical Engineering
National Yunlin University of Science and Technology
No. 123, University Road, Sec. 3, Douliou, Yunlin 64002, Taiwan
*Corresponding author: sukl@yuntech.edu.tw

Received August 2015; accepted October 2015

Abstract. *The article designs a seven-joint robot arm using PC-based controller. The robot arm contains seven DC servomotors, seven driver devices, a vision system and two four-axis motion control cards. Proximity sensors are used to locate the limit position of each joint. The PC-based controller also programs motion trajectory of the gripper to finish the assigned tasks. Users can tune the parameters of the PID controller for each joint of the robot arm. The user interface is developed using Visual Basic on the PC-based controller for the robot arm. Users can program the motion path of any joint on the user interface. In the experimental results, users can program English or Chinese words or plot assigned graphs on the user interface. The robot arm catches the pencil to write the assigned words on the platform, and plots the house outlook, and writes English words and plots the assigned graph on an uneven platform, and builds a church using some wooden blocks.*

Keywords: Robot arm, PC-based controller, DC servomotors, PID controller, Visual Basic

1. **Introduction.** Search strategy is a very important research topic for robot arms. For many path-planning methods, how to find a fast and effective way to program the motion trajectory 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 seven-degree-of-freedom robot arm. The robot arm is composed of seven DC servomotors. In the control aspect, a PC-based (Personal Computer) controller and two DSP-based (Digital Signal Processor) 4-axis motion control cards are used to control the robot arm.

There are some researches regarding the robot arm in the past. For example, Ahmad discussed the drive-train errors of a robot arm. During the backlashes, the eccentric joints influence the flexibility of the driving axes on the accuracy and repeat accuracy of the robot arm, and use linear positioning compensation to obtain good effects [1]. Veitschegger and Wu developed a kinematic adjustment model of the PUMA560 six-axis robot arm. They used the model on compensating the positioning tolerance of the manipulator [2]. Zhuang et al. worked on the adjustment of a robot arm and proposed a new kinematic analysis method which could avoid the tolerance caused by the singularity of kinematic analysis [3].

Shafik et al. presented an innovative 3D piezoelectric ultrasonic actuator using flexural vibration ring transducer for machine vision and robot guidance applications [4]. Homayounzade and Keshmiri 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 [5]. 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 [6]. 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 [7].

2. **System Architecture.** The dimensions of the seven-axis robot arm are 165cm, 118cm and 110cm in length, width, and height, respectively. The arm includes shoulder with two DOFs, (Degree of Freedom) elbow with one DOF, wrist with three DOFs and gripper with one DOF. The prototype of the robot arm is shown in Figure 1. Figure 2 shows the user interface of the robot arm which presents the writing function on the platform. The user interface contains two parts: one is the motion programming area and the other is the display of the writing results obtained by the image system. Users can program four joints of the robot arm in the motion programming area. The robot arm only uses four joints to catch the pencil and write the assigned English words on the writing area. The controller of the robot arm is a PC-based system. The PC-based system is arranged in the left hand side of the writing area. First, users can write English words in the monitor of the user interface. Then the PC-based controller converts the information of the written words to the motion commands of each joint, and controls the robot arm to catch the pencil. Then the robot arm writes the assigned words on the writing area step by step.

In the next assigned task, the robot arm can complete various assigned tasks such as writing Chinese words, stamping a seal and plotting a graph on the platform shown in Figure 3. The writing area of the robot arm which is classified for writing, stamping and plotting is 42cm in length and 43cm in width. The operation area of the robot arm is

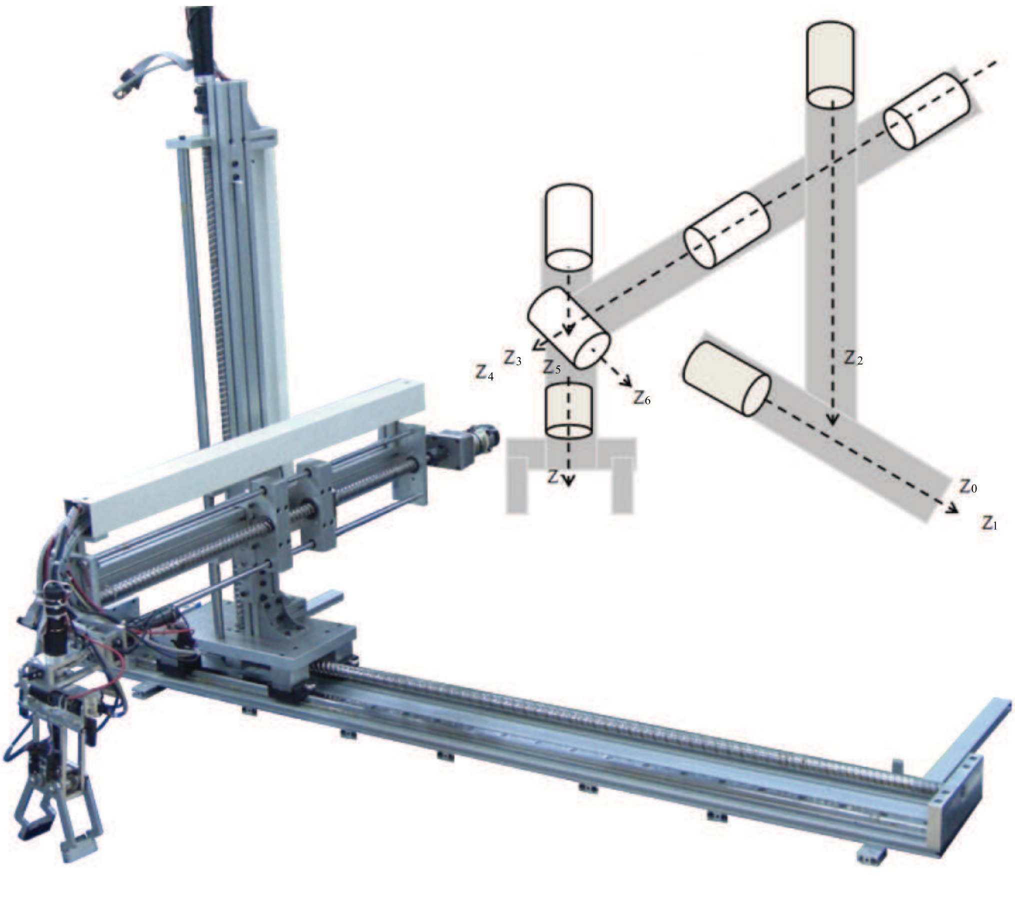


FIGURE 1. Seven-axis robot arm

FIGURE 2. User interface for writing function

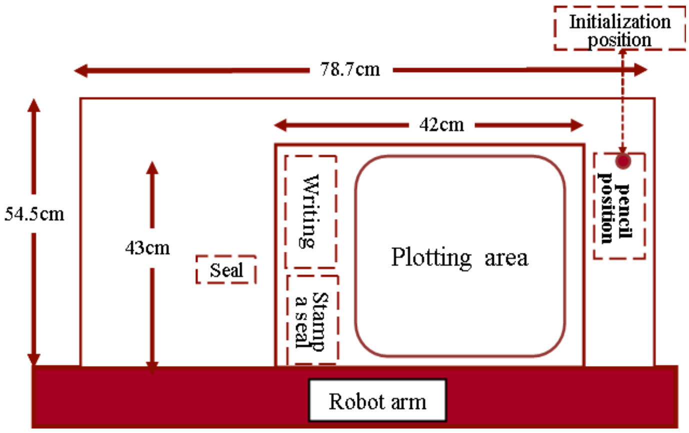


FIGURE 3. The operation area for case I

the case I shown in Figure 3. The robot arm moves to the initialized position to catch a pencil, and writes two Chinese words on the left side of the operation area (writing). Then the robot arm puts down the pencil on the original location, and catches the seal and moves to the left side of the writing area. The robot arm stamps the seal on the platform, and moves the seal to the original location to put it down. Finally, the robot arm catches the other pencil to draw a house on the plotting area.

Figure 4 shows the operation area of writing and plotting on an uneven platform for the robot arm as the case II. The length and width of the writing area are 71cm and 70cm, respectively. The robot arm is fixed on the bottom of the writing area and catches the pencil to write English words and plot a humanoid robot outlook. When the assigned work is finished, the robot arm will move the pencil to the original location. The robot arm must tune the height of the gripper to write and plot on the uneven platform.

3. **Experimental Results.** We implement the functions of the robot arm in three aspects. They write two Chinese words and plot a house outlook on the platform, and write three English words and plot a robot on the uneven platform, and catches some wooden

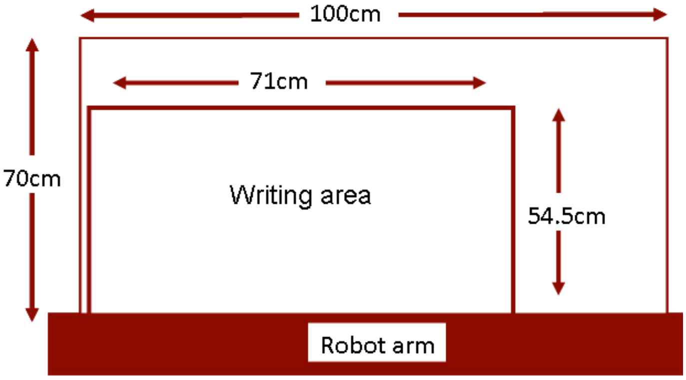


FIGURE 4. The operation area for case II

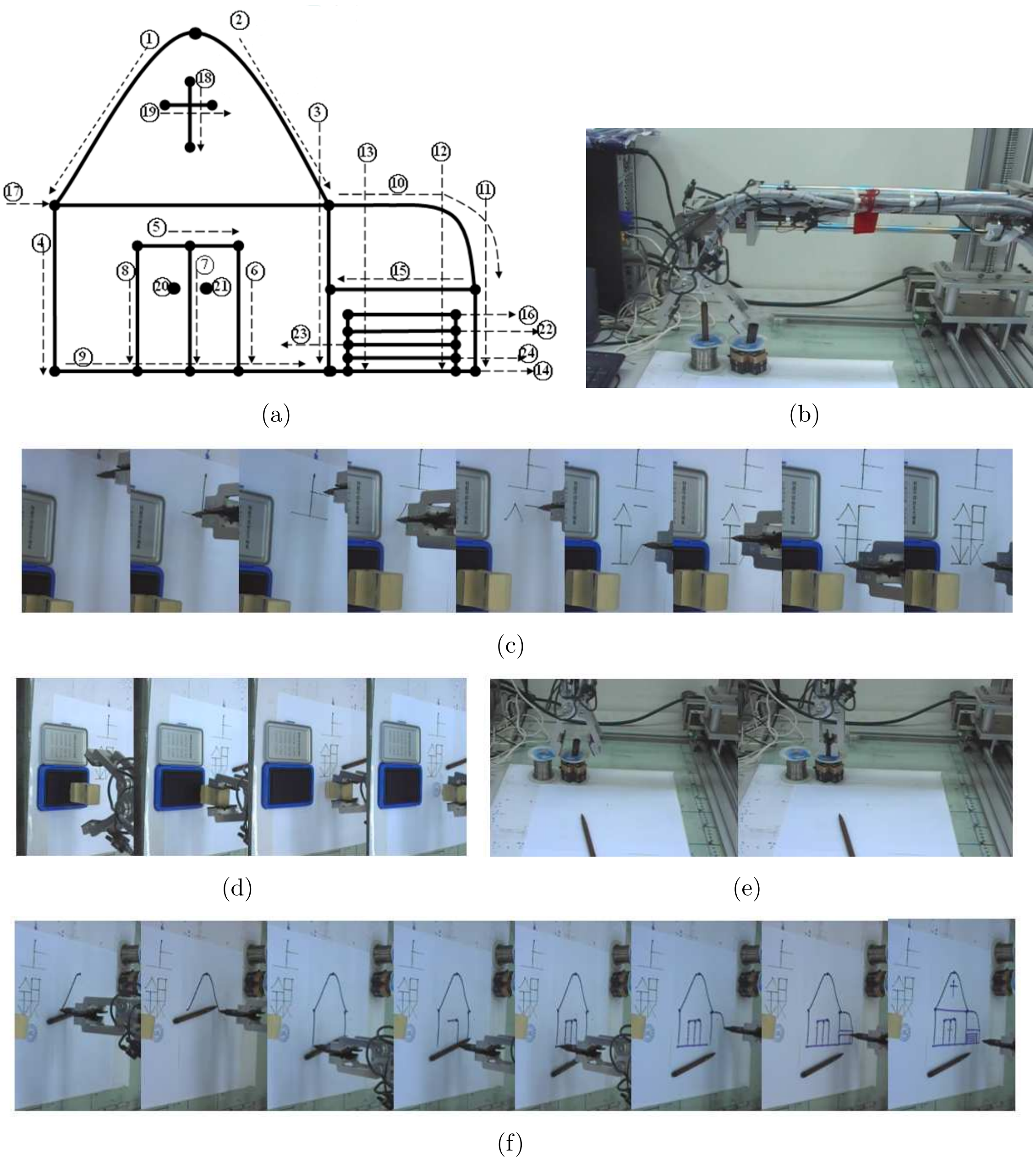


FIGURE 5. The stamping and plotting process of the robot arm

blocks to build a church. The green and red labels in the user interface represent the status of the joints. The green label means that the joint is in the motion process, and the red label means that the joint stops.

In the first experiment, the robot arm executes various tasks on the platform. The tasks include writing two Chinese words, stamping a seal and plotting a house outlook. The robot arm programs a series of trajectories using point to point control technologies. The robot arm writes Chinese words using the same method as writing English words. Hence, we only explain how to plot a house outlook in the following. At first, some fixed paths using numbers are set as shown in Figure 5(a). The controller records the start and end positions of each fixed path. The first motion trajectory plots the left side of the housetop as the path numbered in 1. Then the robot arm plots the right side of the housetop as the path numbered in 2. There are totally 24 paths in this graph. The robot arm plots the house outlook step by step by repeating the process. Hence, the graph can be completed.

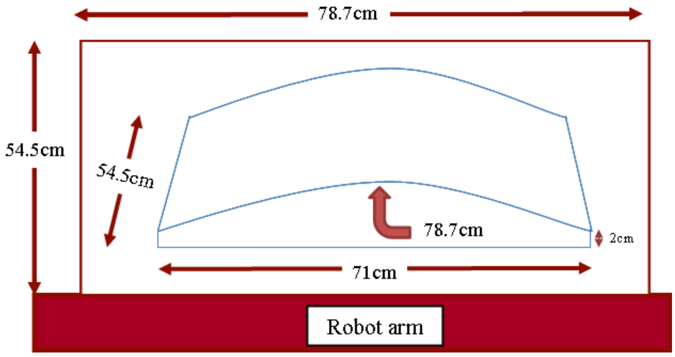
In the second experiment, the robot arm catches the pencil on the right side of the platform, and moves the pencil to the writing area to write the first Chinese word, as shown in Figure 5(b). Then the robot arm moves the pencil to the bottom of the first word to write the second Chinese word. After the two words being completed, the robot arm moves the pencil to the original location to put it down, as shown in Figure 5(c).

Then the robot arm catches the seal on the left side of the plotting area. After stamping the seal on the assigned position of the platform, the robot arm moves the seal back to the original location and puts down the seal, as shown in Figure 5(d). Then the robot arm catches the other pencil to plot the house outlook in the final step. The experimental result is shown in Figure 5(e). The robot arm plots the house outlook using the proposed method. We can see that the plotted house outlook by the robot arm is very similar to the programmed one, as shown in Figure 5(f).

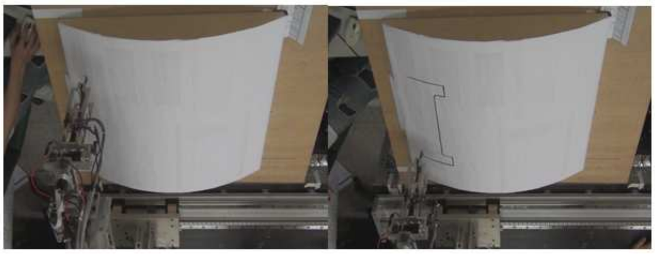
In the second experiment, the robot arm plots English words and a graph on an uneven platform. The controller of the robot arm controls the height of the pencil to write the assigned words, and detects the current output of each driver to know the force of the robot arm and to adjust the height of the gripper. The size of the platform is shown in Figure 6(a). Figure 6(b) shows that the robot arm catches the pencil to write the first word “I”. Then the robot arm detects the current of each driver to increase, and raises the pencil to write the second word to be “S”. Finally, the robot arm plots an outline of a humanoid robot embracing a word “L”. The plotting process in sequence is shown in Figure 6(c).

In the third experiment, the robot arm catches some wooden blocks to build a house on a platform. The controller of the robot arm controls the height of the gripper to put down some wooden blocks on various floors. First the robot arm catches four wooden blocks to put down various positions, and builds the first floor of the house shown in Figure 7(a). Then the robot arm tunes the height of the gripper to catch three wooden blocks to build the roof of the first floor. Next the robot arm catches three wooden blocks to build the second floor of the house, and uses two wooden blocks to build the roof shown in Figures 7(b) and 7(c). Finally, the robot arm tunes the height of the gripper, and catches a church. The wooden church is put down on the upper part of the second floor shown in Figure 7(d).

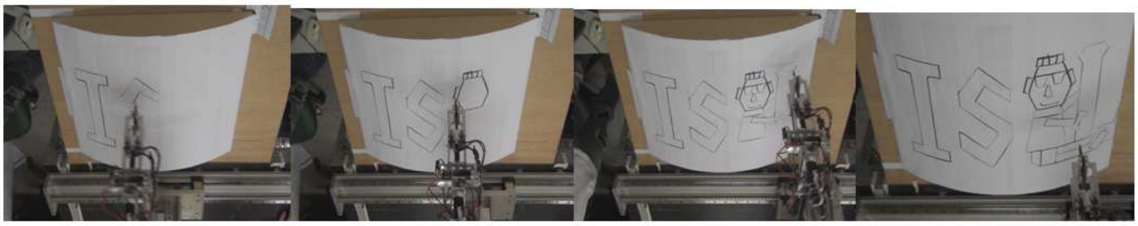
4. **Conclusion.** The paper designed and implemented a seven-axis robot arm, and verified the robot arm’s motion trajectories, and computed the rotation angle of each joint. The PC-based controller could control the robot arm to catch a pencil using the gripper and use this pencil to write the assigned English words and plot the assigned graph on the writing area autonomously. The robot arm can also write words and plot the humanoid robot on an uneven platform, and tune the height of the gripper to adapt the writing position on the uneven platform. The user interface can display the movement status of the



(a)

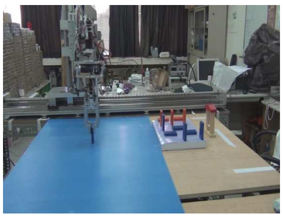


(b)

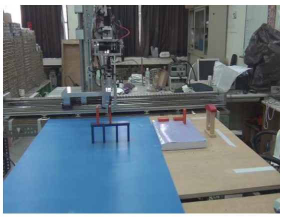


(c)

FIGURE 6. The plotting process on an uneven platform

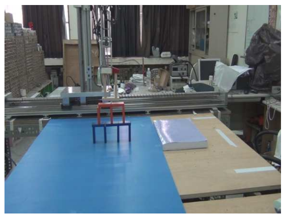


(a)



(b)

(c)



(d)

FIGURE 7. The operation processes for building a house

robot arm in real time through the vision system. In the future, we want to compute the kinematic equations of the seven-joint robot arm, and calculate the motion displacement of each joint using inverse kinematic equation.

Acknowledgment. This work was supported by National Science Council of Taiwan. (NSC 103-2221-E-224-029).

REFERENCES

[1] S. Ahmad, Analysis of robot drive train errors, their static effects, and their compensations, *IEEE Journal of Robotics and Automation*, vol.4, no.2, pp.117-128, 1988.

[2] W. K. Veitschegger and C. H. Wu, Robot calibration and compensation, *IEEE Journal of Robotics and Automation*, vol.4, no.6, pp.643-656, 1988.

[3] H. Zhuang, Z. S. Roth and F. Hamano, A complete and parametrically continuous kinematic model for robot manipulators, *IEEE Trans. Robotics and Automation*, vol.8, no.4, pp.451-463, 1992.
[4] M. Shafik, B. Nyathi and S. Fekkai, An innovative 3D ultrasonic actuator with multidegree of freedom for machine vision and robot guidance industrial applications using a single vibration ring transducer, *International Journal of Engineering and Technology Innovation*, vol.3, no.3, pp.168-179, 2013.
[5] M. Homayounzade and M. Keshmiri, Observer-based impedance control of robot manipulators, *International Conference on Robotics and Mechatronics*, pp.230-235, 2013.
[6] R. Karthikeyan, P. Mahalakshmi and N. GowriShankar, Smart laser based tracking system for robotic arm, *International Conference on Communication and Signal Processing*, pp.903-907, 2013.
[7] T. Kenmochi, N. Motoi, T. Shimono and A. Kawamura, A motion control method of dual arm robot based on environmental modes, *IEEE International Conference on Mechatronics*, pp.458-463, 2013.