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A robot arm for pushing elevator buttons

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***Abstract*—In this paper, a robot arm is designed and set on the top of the wheeled robot, which can recognize the numbers or signs and push the buttons. There is a micro-camera set on the tip of the robot arm for the image processing and pattern recognition. Then, the inverse kinematics is used to calculate the angle of each link of the robot arm to press the desired button correctly. Integrating the techniques of image processing, pattern recognition, and motion control, the robot is implemented to achieve the elevator-button pushing task.**

Keywords-mobile robots; inverse kinematics; image process; pattern recognition.

I. INTRODUCTION

There has been a lot of literature studying the motion control of the robot arm. The paper [1] considered the dynamic equation of a robot arm. Based on sensor signal feedback, a PID control is designed for the arm to achieve the desired position. The papers [2] and [5] established a simulation system of the robot arm so that the coordinates of each joint can be computed by the simulation system. Thus, the arm can be controlled to track an assigned trajectory. The reference papers [3] and [4] calculated the magnitude of the torque for each joint of the robot arm when the arm grabs an object. Using PA-10 robot arm made by Mitsubishi company as a platform, the paper [6] proposed a concept of a harmonic drive model to investigate the gravity and material influence to the robot arm. Moreover, the robot arm is controlled to track a desired trajectory and the motion error is analyzed. A two-link robot arm is controlled by a fuzzy sliding mode controller in which the parameters are adjusted by fuzzy-neural techniques [7].

In Taiwan, the thesis [8] used the real time image feedback to control the arm for tracking and catching the target. The thesis [9] combines two signals from force sensor and image sensor to the robot arm doing the posture control. The thesis [10] uses reverse and forward kinematics to derive the dynamic equation of the robot arm, and then presents the analysis and simulation. Furthermore, the papers [11] and [12] used the camera on the robot arm to identify the target and find its location, and then the arm can catch the target successfully.

The other task of this study is the character recognition to provide the vision ability to the robot arm. The robot arm needs to recognize the button characters of the elevator. In the thesis [13], the author developed a characters recognizing system to recognize the characters in chips, resistances, and tickets. The system uses many techniques, such as template matching, binary image, vertical projection, and artificial teaching etc., to increase the recognition accuracy. In the recognition of car license plate characters, the thesis [14] proposed a template matching method to achieve the goal in which a neural network based intelligent algorithm is proposed. The authors are satisfied with the performance of recognition accuracy and computation speed. Moreover, Messelodi and Modena [15] first used vertical and horizontal projection histogram to detect the region of character, and then find the characteristics of each character. Finally, template matching and probability classification are used to recognize the characters.

In this paper, we implement a robot arm which is with a micro-camera and can recognize the numbers or signs on the elevator button plate. The inverse kinematics is used to calculate the angle of each link of the robot arm to press the desired button correctly. An experiment is given in the last to show the feasibility of the proposed robot system.

II. SYSTEM STRUCTURE

There are two parts in the system structure, one is the computer system and the other is the robot system. The computer system deals with the picture capture, image processing and decision making (see the left of Fig.1). The robot system includes the wheeled robot, a robot arm, the micro-controller, motors and sensors (see the right of Fig. 1).

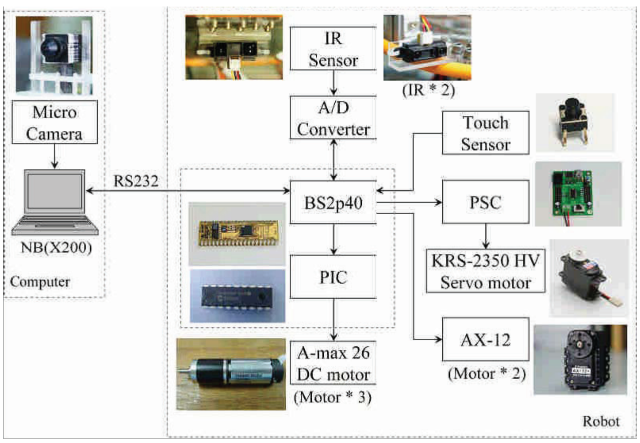


Fig. 1. The system structure.

Fig. 2. Macro-camera.

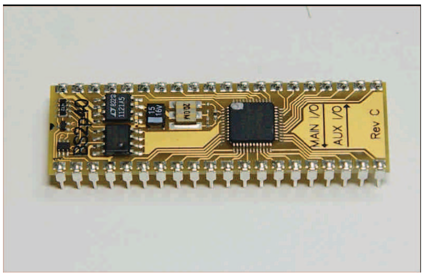


Fig. 3. The micro-controller BS2p40.

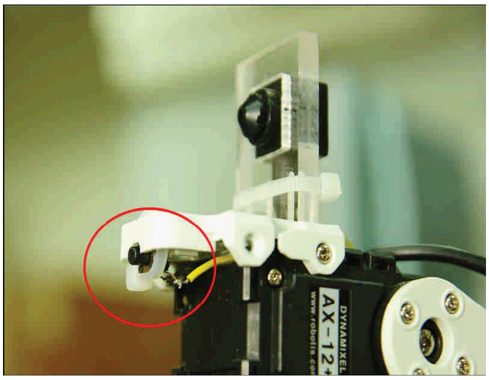


Fig. 4. The touch sensor.

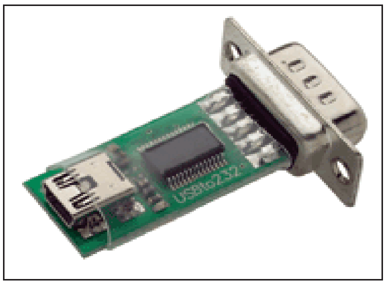


Fig. 5. USB to serial interface transformation board.

In the computer system, there is a micro-camera set on the tip of the robot arm, in which the image is captured. Those images are the environment around elevator which may contain color pattern around the buttons, the door of elevator, and elevator's button, etc. The micro-camera is with the size 1.4cm

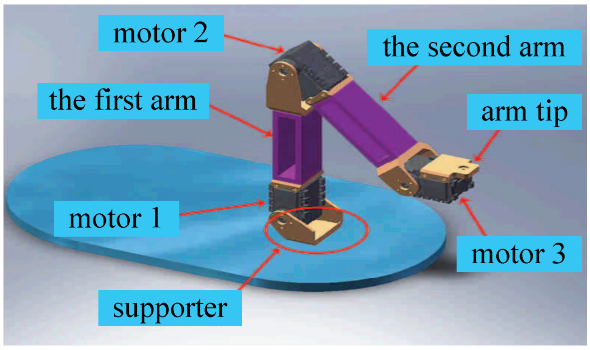


Fig. 6. The structure of the robot arm

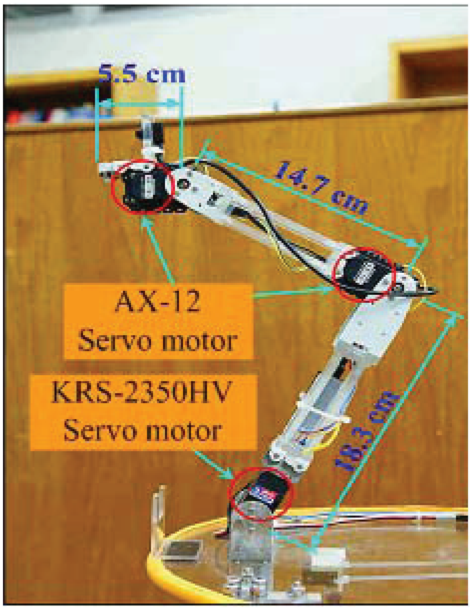


Fig. 7. The size of the robot arm.

x 1.4cm x 1.8cm and the weight 8g (see Fig.2). The control center is a notebook computer which takes charge the images processing and pattern recognition, decision making and motion control and computation of the arm. The notebook computer is of the type Lenovo X200 RY9, with a 2.4GHz CPU and 2GB RAM. Its weight is only 1.5 kg.

In the robot system, there are a micro-controller (BASIC Stamp 2p40 module), a touch sensor, a power supply and a transformation interface. The main tasks of the BS2p40 are to control the rotation degrees of the robot arm, give the motion command to the wheeled robot's wheels, and communicate with notebook computer. BS2p40 has 40 I/O pins and is shown in Fig. 3.

The touch sensor (see Fig. 4) is set on the tip of the robot arm too. When the arm extends and pushes the button of the elevator, the sensor can sense the touch and respond the command to BS2p40 to shrink the arm. If the sensor senses nothing, the arm will not shrink back for a while.

The power supply is a set of series four lithium cells which is 1.48V/2.6Ah and supplies the power to the micro-controller, micro-camera, sensors and the motors of the arm. Furthermore, the communication between the notebook computer and micro-controller BS2p40 is a USB to serial interface transformation board (see Fig. 5).

Finally, the hardware structure of the robot arm is introduced. The arm has two links with three motors (see Fig. 6). Motor 1 is set on the bottom of the arm with a platform of wheeled robot. Motor 2 links the first arm and the second arm and motor 3 connects the arm tip and a touch sensor. Motor 1 is a KRS-2350 HV servo motor with operation voltage 12 V, Motors 2 and 3 are AX-12 servo motors with operation voltage 10V. The maximum length of the arm extension is 38.5 cm, and each link's length is shown in Fig. 7. Therefore, when the elevator's buttons are located in the range (85cm, 105cm) height from the ground and within the distance [20cm, 30cm] from the robot arm, the arm can be guaranteed to push the button successfully. The total weight of the arm is 390g. KRS-2350 HV servo motor is controlled by PWM signal, but AX-12 servo motor is controlled by serial packets from BS2p40.

III. THE BUTTONS OF ELEVATOR

Before the robot arm pushes the buttons, the micro-camera should capture and the notebook computer should recognize the following patterns, such as the buttons of up and down, the buttons of floor numbers, and the light behind the buttons.

In the outside of the elevator, there is a green pattern pasted around the buttons of up and down; and in the inside of the elevator, there is a green line pattern between the two rows' number buttons. According to the color pattern, the robot arm can recognize the location of the buttons exactly (see Fig. 8). Moreover, when the light behind a button is on which means the button is pushed successfully; on the other hand, when the light is changed to off from on which means the elevator arrives the desired floor.

Since the *RGB* color mode is easily affected by the light change in the environment, the transformation of (1) from *RGB* to YC_bC_r models is needed. The reason is that YC_bC_r model is more robust to the light change in the around environment than *RGB* model.

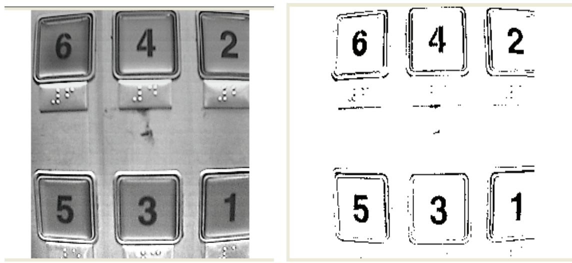
$$\begin{bmatrix} Y(x,y) \\ C_b(x,y) \\ C_r(x,y) \end{bmatrix} = \begin{bmatrix} 0.2549 & 0.5059 & 0.098 \\ -0.1451 & -0.2902 & 0.4392 \\ 0.4392 & -0.3647 & -0.0706 \end{bmatrix} \begin{bmatrix} R(x,y) \\ G(x,y) \\ B(x,y) \end{bmatrix} + \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} \tag{1}$$

Then based on a serial image processes, opening operation, erosion and dilation, the green and blue color patterns are detected to locate the positions of buttons. Furthermore, let us set three thresholds to determine whether the light behind the button is on or off. When

$0 \le Y(x,y) \le 255$, $122 \le C_b(x,y) \le 137$,

and $135 \le C_r(x,y) \le 150$,

Fig. 8. The color patterns around the buttons.



(a) (b)

Fig. 9. (a) The gray image. (b) the binary image

then the arm deems that the light is on; otherwise, the light is off.

Next, the buttons of the elevator should be recognized. Those buttons include up and down, floor numbers 1, 2, 3…. The number pattern recognition is performed by the following procedure.

Step 1. Transforming the captured color image to gray level image using the transformation

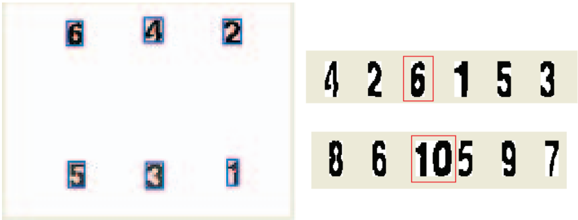
$$G_g = 0.299 \times \mathrm{R} + 0.587 \times \mathrm{G} + 0.114 \times \mathrm{B}$$

where G_g denotes the gray pixel value.

Step 2. Using average threshold method (2) and (3) to transform the gray image to the binary image (see Fig. 9). Let be the area size of the processed image, and $Area_g$ be the average gray value. Then we have

$$A_g = \frac{\sum_{h=0}^{239} \sum_{w=44}^{274} G_g(h,w)}{Area_g} . \tag{2}$$

Based on the average value A_g , the threshold is set as $Th_g = \beta A_g$, where is the experience value by trial and errors. Then



(a) (b)

Fig. 10. (a) Area of character. (b) Normalization.

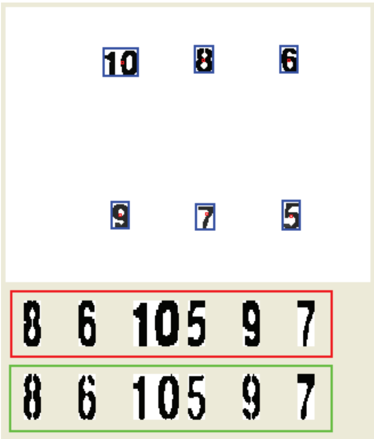


Fig. 11. Pattern matching.

$$N(x,y)=\begin{cases}255, \text{ if } G_g \geq A_g \\ 0, \text{ otherwise}\end{cases}, \tag{3}$$

Remark: Instead of using a fixed threshold, we used the average threshold to get the binary image. The reason is that the fixed threshold value will not change corresponding to the light variation of the environment or the different qualities of the captured image.

Step 3. Use medium filter and opening operation to the binary image such that the noise is decreased as few as possible.

Step 4. Capture the area of each character of the button by using connected component method and delete the pixels outside the area (see Fig. 10(a)).

Step 5. Normalize the area of each character by the following methods.

The area of a single digit number is normalized to 40x15 pixels; and the areas of each double digits number and "up" or "down" button is normalized to 40x40 pixels (see Fig. 10(b)).

Step 6. Doing pattern matching between the normalized character and the character in the data base (see Fig. 11). (The detail process can be found in the reference [16]).

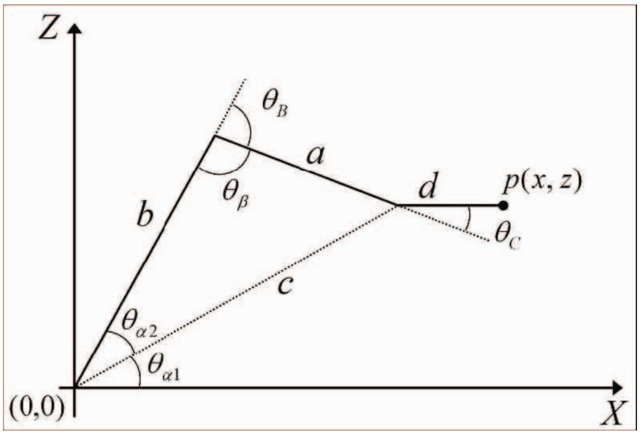


Fig. 12. Coordinate of the robot arm.

IV. The Motion Control of the Robot Arm

Suppose we know the distance between the robot arm's tip and the elevator's buttons. Based on the reverse kinematics and coordinate transformation, the rotation degree of each motor can be computed.

In Fig. 12, *a*, *b*, *d*, are the lengths of arm's three links, respectively. (*x, z*) is the location of the target point *p*. Let *c* be the shortest distance from the target point *p* to the origin. According to the geometry calculation, the angles of $\theta_{\alpha 1}$, $\theta_{\alpha 2}$, θ_β can be computed (5)–(7) and the degrees of three motor rotations θ_A, θ_B, θ_C are obtained from equations (8).

$$c=\sqrt{(x-d)^2+z^2}\ , \tag{4}$$

$$\theta_{\alpha 1}=\cos^{-1}\left(\frac{(x-d)^2+c^2-z^2}{2(x-d)c}\right), \tag{5}$$

$$\theta_{\alpha 2}=\cos^{-1}\left(\frac{b^2+c^2-a^2}{2bc}\right), \text{ and} \tag{6}$$

$$\theta_\beta=\cos^{-1}\left(\frac{a^2+b^2-c^2}{2ab}\right). \tag{7}$$

$$\theta_A=\theta_{\alpha 1}+\theta_{\alpha 2},\ \theta_B=180-\theta_\beta, \text{ and } \theta_C=180-\theta_A-\theta_\beta\,. \tag{8}$$

Then transforming (8) to the motor control values, the arm can press the button exactly and successfully.

V. Experiments

The experiment can be seen in the following website. http://140.115.70.172/xoops/modules/wfdownloads/viewcat.php?cid=6

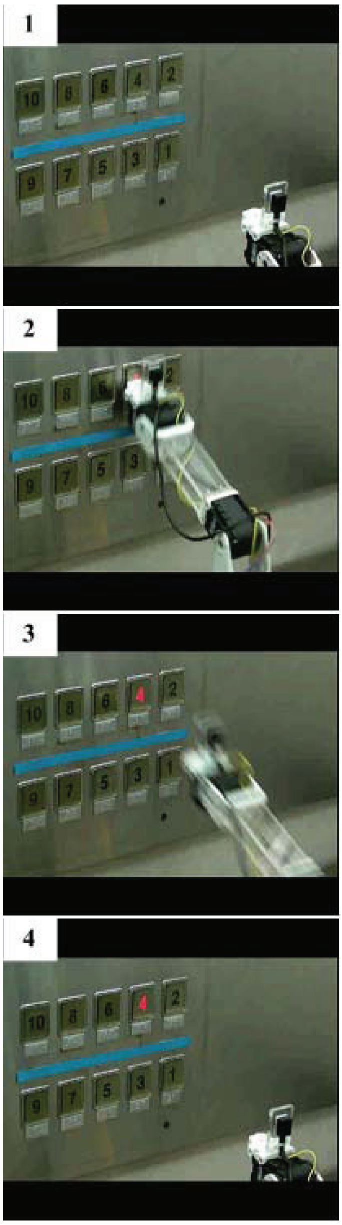


Fig. 13. Serial motion pictures for pushing the button.

The figures in Fig. 13 are the sampled serial pictures in which the robot arm recognizes the number button and presses the number 4.

VI. Conclusion

This paper has implemented a robot arm system which can recognize the numbers and signs on the elevator button plate. The proposed robot system can achieve the elevator-button pushing task correctly and successfully.

Acknowledgment

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