Image Recognition for PCB Soldering Platform Controlled by Embedded Microchip Based on Hopfield Neural Network

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***Abstract*—In the study, embedded BASIC Stamp 2 (BS2) microchip controller is used to design with Hopfield neural network (HNN) as the foundation of sample training, which applies for a soldering platform of mechanical vision and accomplishes PCB soldering positioning technology. The proposed system design method in this paper can be divided into two parts: 1) the control rules of RC servo motor is designed by BASIC, and 2) human-machine interface is established to acquire images for pre-processing via C++ Builder. For the method of system image recognition, HNN is employed to do PCB soldering recognition positioning. The system is verified by MATLAB and Simulink to set up the simulation of PCB image soldering positioning. The experiment proves that the proposed method improves the traditional low efficiency of PCB soldering technology, and to achieve the feasibility of PCB image positioning and promote the soldering quality.**

***Keywords*- embedded microchip,Hopfield neural network (HNN), mechanical vision, PCB image positioning**

I. INTRODUCTION

Conventional soldering is manually performed, which can easily cause time consumption, low efficiency, high cost, not conforming to economic benefit, eye exhaustion in long-term work and easy to happen working safety accident. Therefore, it is very important to study how to improve the disadvantages above-mentioned.

Image processing technologies combining with mechanical vision on each field have been increasingly available, such as applying non-destructive test on parts and soldering quality inspection[4][1]. Current researches in image processing can be approximately classified as three types: (1) Probability Statistic Technology: this method needs to provide a lot of data of target object to do data probability distribution. The disadvantages are the bad processing efficiency and low recognition rate. (2) Fuzzy Category: The method is to make the image characteristics fuzzy and then make use of training rules to categorize these fuzzy data in order to obtain the recognition results. The disadvantage is that the classification of fuzzy image characteristics and the process has become complicated because the characteristic is fuzzy and the category difficulty is increased. (3) Neural Network System: It makes use of association and learning memory to do parallel processing so that it can allow some noise on object under test. The system can still proceed recognition and the cognition effect is good. Therefore, Hopfield neural network (HNN) is used for the method of image recognition. We expect to practice the image cognition technology in PCB electronic industry and to promote the electronic industry competition. Hopfield neural network was a method proposed by a famous physicist, John Hopfield, in the 1980's. Energy function is applied in this network as the basis of network stability. Recently, HNN has been widely applied for figure recognition and image processing [5][7]. Nasrabadi and Li [7] first applied HNN to recognize the plane profile. However, their methods have higher error rate and can't overcome profile contrast with the scale change. Therefore, Li and Lee [6] proposed the combination of several HNN outputs to recognize overlapped object images and learn the possible direction of image move by position estimation. Chang [2] proposed Contextual Hopfield neural network (CHNN) to apply in detection of crystalline grain distribution. HNN can also simplify 3D Hopfield neural network (2 layers) into 2D structure. Meanwhile, it has no damaged advantages of image pixels characteristics and pixel dots surrounding structure information. Chang [3] and others suggested applying self-organizing neural network (SONN) and Hopfield neural network (HNN) two kinds of algorithms to detect the defected location in wafer images, which have a very good application effect of detection. We also proved that the image processing is not affected by the amplification.

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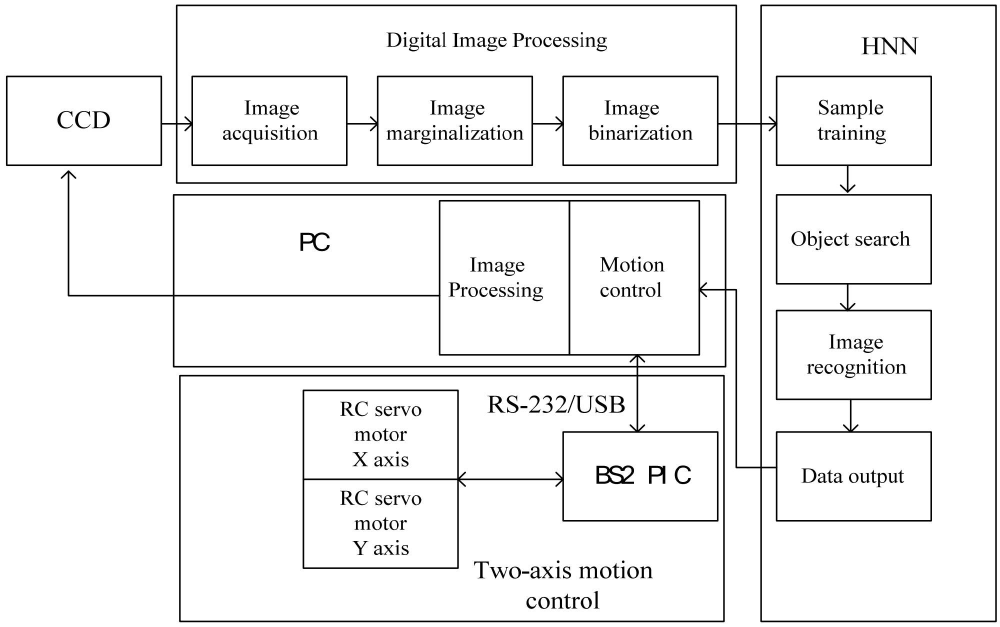

Figure 1. Research setup

This paper not only employs neural network with robust redundancy and high associate memory for image recognition, but also using BASIC Stamp (BS2) microchip to do embedded control in order to control the server, so that PCB solder template can automatically position accurately. Production line applications will completely or partially replace the manual in order to improve soldering quality and reliability. In addition, it can shorten working hours, promote the working quality efficiency and help to cut down the cost. The setup in this paper is as shown in Fig. 1.

II. DIGITAL IMAGE PROCESSING

Images source in this paper is to retrieve PCB template image by CCD, marginalized and binarized to establish image characteristics via image processing. Where, marginalization is carried out according to image brightness rate and design space mask value by Laplacian .

There are three methods commonly used for space mask: (1) Shift-and-difference, (2) Gradient, and (3) Laplacian.

Laplacian marginalization is one of special filters, emphasizing the part of image margin at high frequency. The operation makes the second differential on pixel gray level, similar to Laplacian operation as shown in (1)

$$\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}=\nabla^2 \tag{1}$$

where there are three space masks commonly used as follows

$$Mask1=\begin{bmatrix}-1 & -1 & -1\\ -1 & 8 & -1\\ -1 & -1 & -1\end{bmatrix}$$

$$Mask2=\begin{bmatrix}0 & -1 & 0\\ -1 & 4 & -1\\ 0 & -2 & 1\end{bmatrix}$$

$$Mask3=\begin{bmatrix}1 & -2 & 1\\ -2 & 4 & -2\\ 1 & -2 & 1\end{bmatrix}$$

The sum of weighed coefficient for these masks is usually zero. The middle is larger positive integer, and the surrounding is smaller positive or negative integer. Fig. 2 shows original PCB image. Fig. 3., Fig. 4., and Fig. 5 respectively show the experimental results of three space mask. In order to achieve the PCB image positioning, the enhanced image needs to be clarified so that this paper selected Mask1 as experimental mask as shown in Fig. 3. The system proceeds edges strengthen treatment and binarization to the outline of PCB welding round hole. It will reduce the computational capacity and promote the sample training and round hole recognition efficiency.

Figure 2. Original template of PCB image

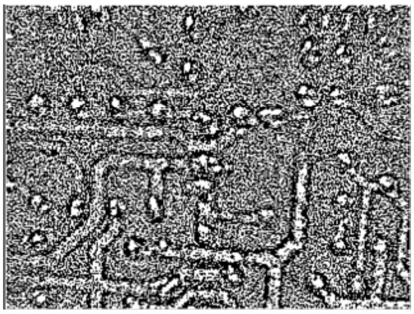

Figure 3. Mask1 marginalization

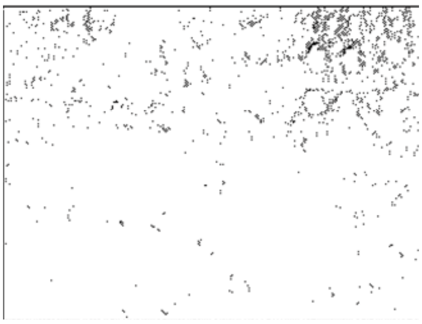

Figure 4. Mask2 marginalization

Binarization is to convert image as two colors (black and white). For inputting a gray-level image, the threshold value can be set as T_0. When the value is over the threshold one, it is set as white. On the contrary, it is set as black. The equation is

$$T(f)=\begin{cases}0 & f<T_0\\ 255 & f\ \geq T_0\end{cases} \tag{2}$$

PCB round role is binarized and the result is shown as Fig. 6. This template is used as sample to recognize image acquired by CCD after trained by HNN. It makes the prior processing of PCB recognition positioning image.

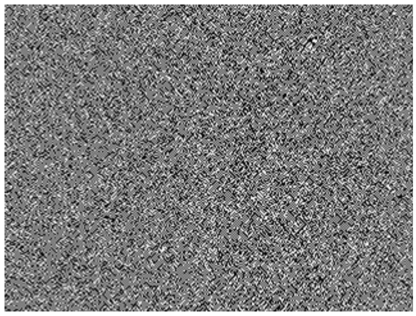

Figure 5. Mask3 marginalization

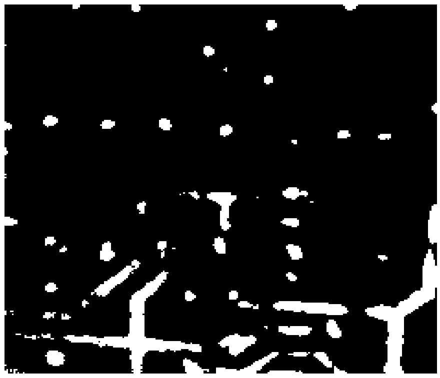

Figure 6. Binary output figure of soldering round hole

III. HOPFIELD NEURAL NETWORK (HNN)

HNN is one kind of associate learning network mode. So-called associate learning is a training example mainly taken from problems, and memorizes the rules from learning to apply in new example. In this network, we first introduce a conception of energy function as a basis to determine network stability. This neural network is mainly applied for the systems of automation control, self-associate memory, and image processing and so on.

The architecture of HNN is as shown in Fig. 7.

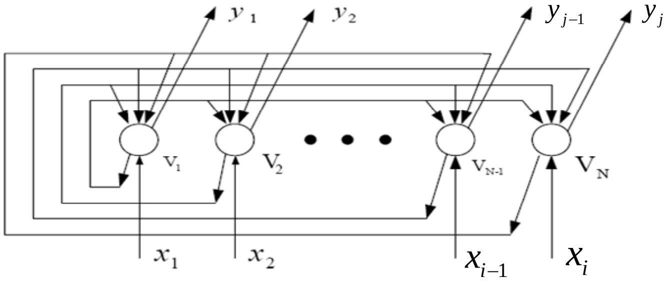

Figure 7. Hopfield neural network

where $V_1, V_2, ..., V_N$ are the value of neuron state; $x_1, x_2, ..., x_i$ are the value of input state; $y_1, y_2, ..., y_j$ are the value of convergent output after operating.

This paper makes use of Hopfield algorithm to detect the image distribution of each soldering point on PCB. The detection results show excellent effects. Meanwhile, the information on characteristic pixel of an image and pixel surrounding is also retained. The total input of HNN neuron can be expressed as [6]

$$Net_{x,i} = \sum_{y=1}^{N}\sum_{j=1}^{N} W_{(x,i);(y,j)} V_{y,j} + I_{x,i} \qquad (3)$$

And operating function is defined as

$$V_{x,i}^{n+1} = \begin{cases} 0 & \text{Net}_{x,i} < \varphi \\ \dfrac{1}{1+e^{\lambda \text{Net}_{x,i} V_{x,i}^{n}}} & \text{otherwise} \end{cases} \qquad (4)$$

where φ is a critical parameter, and λ is a slope parameter of sigmoid function.

Lyapunov energy function can be determined by (3) and (4).

$$E = -\frac{1}{2}\sum_{x=1}^{N}\sum_{y=1}^{N}\sum_{i=1}^{N}\sum_{j=1}^{N} V_{x,i} V_{y,j} W_{(x.i)} W_{(y,i)} - \sum_{x=1}^{N}\sum_{i=1}^{N} I_{x,i} V_{x,i} \qquad (5)$$

The above equation (5) is based on the system PCB positioning recognition. When energy function overlapped in HNN algorithm shows no obvious change, the system will reach the convergence state. Therefore, the network convergence state can determine the soldering spot of image. In equation (5), if $V_{x,i}$ is the operating state, it represents pixel at (x,i) in an image can be attributed to that for soldering via. In order to effectively make HNN convergence, energy function must meet the following limits:

1. Sampling the gray-level distribution of via image in PCB template needs to be similar to that for test via image.
2. The area of soldering via image should be centralized without any damage.

According to rewriting two limits above, original energy function in (5) can obtain new energy function of HNN as expressed in (6):

$$E = \sum_{x=1}^{N}\sum_{y=1}^{N}\sum_{i=1}^{N}\sum_{j=1}^{N} f(y,j)\phi_{x,i}^{p,q}(y,j) V_{x,i} V_{y,j} \qquad (6)$$

where $f(y,j)$ is defined as

$$f(y,j) = \log[h(g(y,j)) + 1] \qquad (7)$$

where $g(y,j)$ is the gray-level value of pixel, $h(x)$ is the number of $g(y,j)$, and histogram $\{h(x)\}$ is obtained from template images. $\phi_{x,i}^{p,q}(y,j)$ can be used to decide (y,j) exists at (x,i) as the center and in a rectangle with p,q as length and width. Comparing (5) and (6) can determine link weight $W_{x,i,y,j}$ input by neuron:

$$W_{x,i,y,j} = -\frac{1}{2} f(y,j)\phi_{x,i}^{p,q}(y,j) \qquad (8)$$

Taking (8) into (3) can determine the total sum of each neuron is

$$Net_{x,i} = -\frac{1}{2}\sum_{y=1}^{N}\sum_{j=1}^{N} f(y,j)\phi_{x,i}^{p,q}(y,j) V_{y,j} \qquad (9)$$

So system PCB template positioning can find out the welding spot on PCB template by HNN template training and make a mark. Then, the required round spot image information is captured by image processing for the use of image characteristic recognition. Fig. 8 shows a convergence curve of energy function. Fig. 9 shows an output diagram of soldering via recognized by HNN.

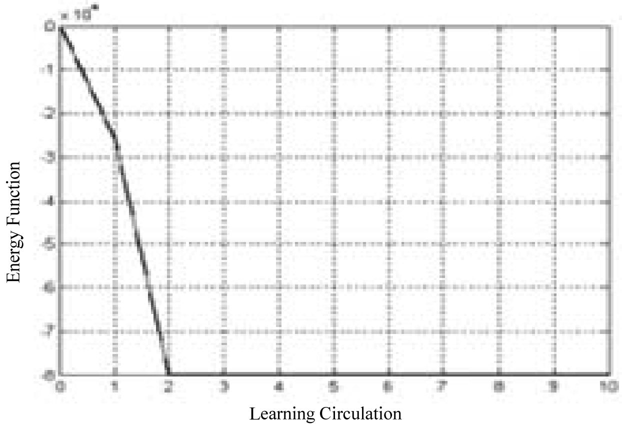

Figure 8. Convergence curve of energy function

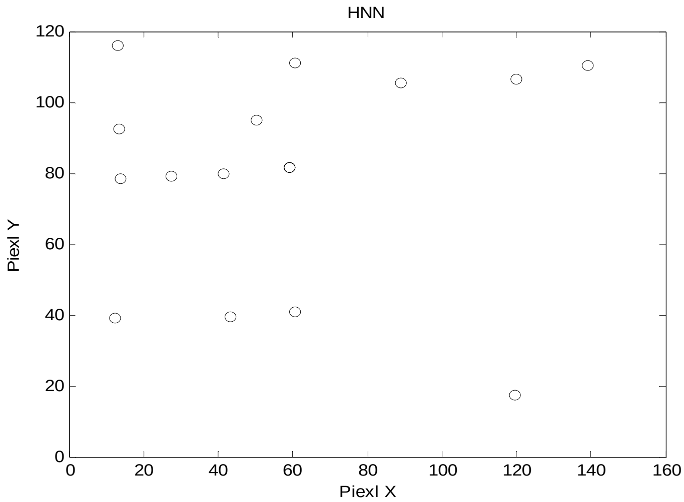

Figure 9. Output diagram of soldering via recognized by HNN

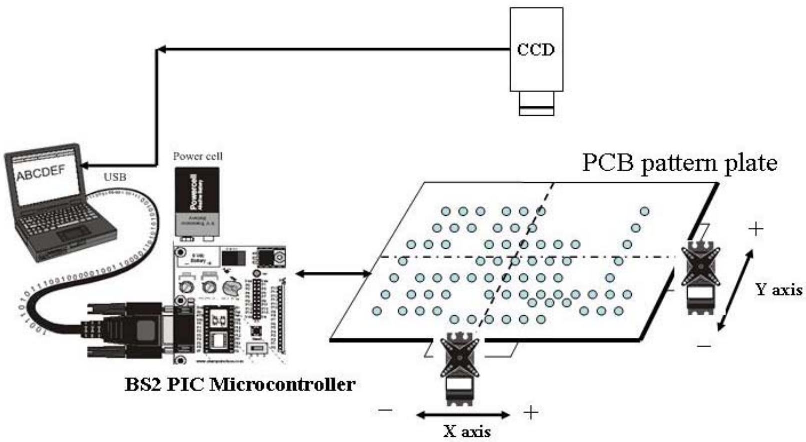

Figure 10. PCB template image positioning design organization

IV. EXPERIMENTAL RESULTS

The microchip clock frequency of this system is 20MHz and the electronic removable program read-only memory (EEPROM) is BS2 PIC (PIC16C57 SMD) embedded microchip controller of 2K Byte, serial PC to make the design of PCB template image positioning, as shown in Figure 10. The system makes image prior processing of PCB template round hole and then the HNN training image store the location coordinates of recognition results and transfers to BS2 embedded microchip controllers for motion control. Then, the PCB template can be positioned accurately.

Servo motor response to continuous pulse acquired through BS2 is as shown in Fig. 11 for the position characteristic. When the period of continuous pulse is 0.5 seconds, the range of rotational angle is from 0^o to 50^o. The motion mode of servo motor is established according to this characteristic response. The response error of RC servo motor is as shown in Fig. 12. The accumulated error is approximately a maximum of 2.5.

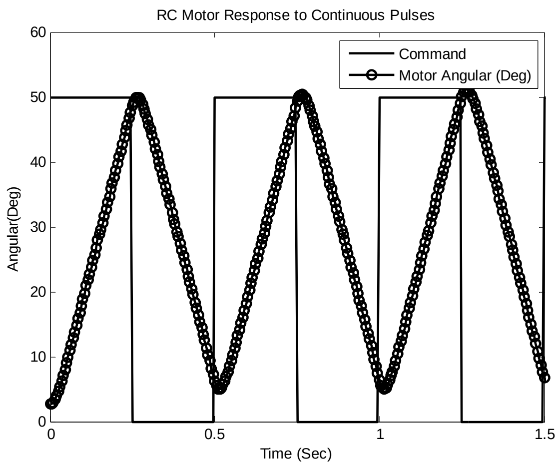

Figure 11. Servo motor response to continuous pulses

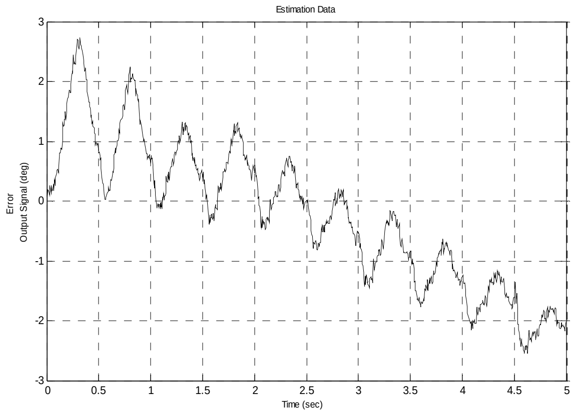

Figure 12. Response error accumulated by RC servo motor

After the characteristics of servo motor are set, coordinates taken from are sent to BS2 PIC chip. 10 coordinates acquired by image pixels projected on soldering points of real template are sorted on Table 1. The real position and HNN position is as shown in Fig. 13, where the positive and negative sign represent the positive and reverse rotation of servo motor. The coordinate position is based on the image pixel center (160, 120) acquired by CCD as positioning point. Because one image pixel is equivalent 2 mm on real PCB and 1 unit pulse is about 1 mm, the control system takes a position of coordinates points (25,78) as an example of PCB template round hole. From the platform moving position, we know that X axis needs to input 135 unit pulses and Y axis needs to input 42 unit pulses in order to move the round hole soldering spot of PCB template. When the PCB template welding is completed, the controller command RC servo back to the center position (160,120), and then determine the next round hole coordinates. The system overcome the delay situation of RC servo moving platform and simulate by MATLAB Simulink to establish RC servo model. We find out the response of mechanic platform is slower. Besides, the actual position welding movement and simulation response have some errors. The simulation model command is 191mm, as shown in Figure 14. Figure 15 is the actual platform welding position and the response figure of simulation position. We can see actually the motor has an effect of delayed start about 0.2 seconds slightly slower, but the system control the efficiency response should be up to 1.5 seconds to fully conform to the position. The error is about 1mm which is allowed by the system control so that the system recognition rate is up to 90% though simulated verification. Therefore, the system application of design in this paper is proved to be feasible.

TABLE I. HNN OUT COORDINATES AND REAL POSITION

	HNN output coordinates (pixel)		Real position (mm)	
			X	Y
1	25	78	135	42
2	56	80	104	40
3	87	79	73	41
4	121	82	39	38
5	28	157	132	-37
6	27	185	133	-65
7	26	232	134	-112
8	55	158	105	-38
9	83	160	77	-40
10	118	163	42	-43

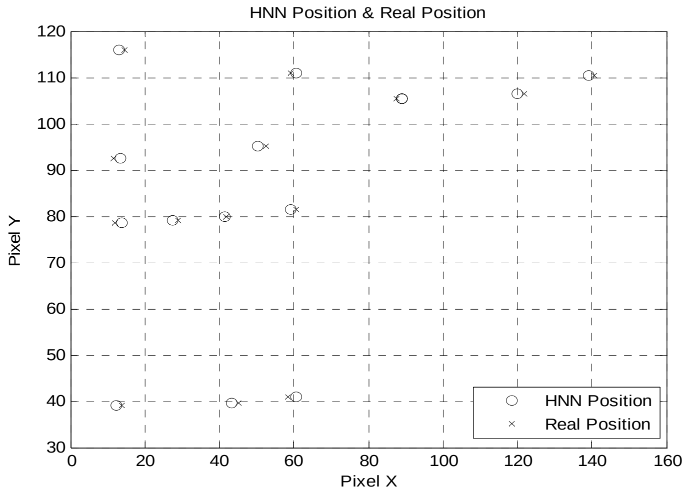

Figure 13. Position of real soldering point and recognition point

After the characteristics of RC servo motor are obtained, this RC servo motor model is established by MATLAB Simulink to simulate. After verification, we can realize there is some error in the real motion and Simulink response due to slower response to machine platform.

Fig. 14 shows the model established by MATLAB Simulink, whose command is 191 mm. Fig. 15 shows the response of real position and Simulink position. As shown in Fig. 15, a motor actually has the effect of start delay, slower about 0.2 seconds. The final position is 190 mm with an error of approximately 1mm. From the results above-mentioned, the results of simulation verification are pretty matched with those for real position.

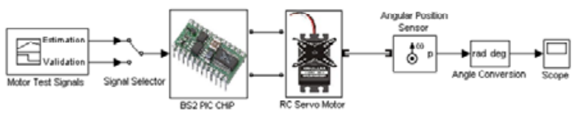

Figure 14. RC servo motor model established by MATLAB Simulink

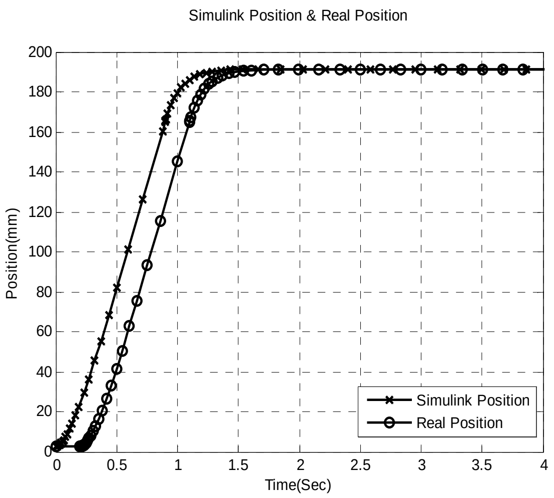

Figure 15. Simulink position and real position response

V. CONCLUSION

The design of embedded image recognition in this paper can partially replace the manual soldering operation and greatly increase working efficiency after simulation verification. It helps a lot to promote the PCB template soldering competition of electronics industry. The design of this system applied C++ Builder to proceed image recognition programming which includes image marginalization, binarization, HNN memory and associate algorithm. From the experimental results, HNN algorithm can effectively recognize images. The averaged time only takes 3 seconds from each associate of template training to recognition output.

In the system recognition and positioning, the results of image recognition coordinate are precisely sent to BS2 microchip controller, so that RC servo motor can correctly and quickly move to the soldering position.

Finally, the moving speed of 1.5 seconds to reach the exact position can even more ensure the recognition efficiency and stability of the system design in this paper.

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