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Development of an Education System for Surface Mount Work of a Printed Circuit Board

H. Ishii, T. Kobayashi, H. Fujino, Y. Nishimura, H. Shimoda, H. Yoshikawa

Kyoto University
Gokasho, Uji, Kyoto, 611-0011, JAPAN
{hirotake,t-koba,fujino,nishimura,shimoda, yosikawa}@uji.energy.kyoto-u.ac.jp

W. Wu, N. Terashita

Mitsubishi Electric Corporation
8-1-1, Tsukaguchi Honmachi, Amagasaki, Hyogo, 661-8661, JAPAN
{Wu.Wei, Terashita.Naotaka} @wrc.melco.co.jp

Abstract

A part of the surface mount work of printed circuit boards is conducted by human workers and human error resulting from hand working is a serious problem. So the education of workers is very important in order to prevent human errors, but the present education methods using conventional video or paper are not so efficient. The goal of this study is to develop an education system for the surface mount work of printed circuit boards by utilizing a CCD camera, image processing techniques, a laser irradiation device and so on. This paper describes the outline design of the education system, developed functions and the results of their evaluations.

1 Introduction

It is difficult to automate all of the surface mount work of a printed circuit board (PCB), because there are various kinds of electric parts, and their size and shape are quite different. So a part of the surface mount work is conducted by human workers. But human workers may make a mistake and it can be occurred that the assembled PCB cannot be used and it may also become the cause of the accident. Therefore, it is very important to maintain and improve the skill level of the workers. But the workers who work at PCB factories are frequently exchanged, and the education cost of the workers is very high. Especially, in the case that the skilled workers educate the novice workers by explaining the basic knowledge and demonstrating the actual surface mount work, the cost for the education becomes very high. Moreover, it is very difficult to evaluate the skill level of the workers correctly. So it also happens that the workers who have received the education make a mistake frequently at a factory, and they turn out to need to receive the education again. Then in this study, the authors aims at developing an education system which can educate the novice workers so that they can make PCBs by themselves without troubling the other workers.

2 Surface Mount Work of Printed Circuit Boards

2.1 Configuration of surface mount work of printed circuit boards

At a PCB factory, some instruction documents which explain how to mount the electric parts onto PCBs are prepared and they are distributed to the workers in paper form. A PCB is located on a work bench and some parts boxes and instruction documents are located around the work environment. And one kind of electric parts are put into one parts box. The workers mount the electric parts onto the PCBs with their both hands based on the information described in the instruction documents and silk printing printed on the PCBs.

2.2 Present condition and issues of worker education

It is not easy to make PCBs, because it requires special knowledge about electric parts and needs to understand the complicated instruction documents. To be able to make the PCBs, the workers need to understand not only the basic knowledge about electric parts but also the following topics:

- There are various kinds of electric parts, and their size and shape are different. And there are some electric parts which shape is almost same but the kind is different
- There is a polarity in electric parts and the indication of the polarity is different according to the electric parts.
- The efficiency of making PCBs partly depends on the order of mounting electric parts. The best order is not instructed by the instruction documents and the workers are respected to find the best order by themselves.

To educate the novice workers, some strategies can be considered such as using a conventional paper or video material, demonstrating the actual mount work of PCBs and so on. But these strategies requires too much time of the educator so that an education system is desired with which the novice workers can learn the surface mount work by themselves.

3 Education Plan and the Outline Design of the Education System

3.1 Education plan of the surface mount work

The education plan designed in this study is as follows. (Step 1) The education system provides the materials to learn how to make PCBs in the form of conventional video and text. (Step 2) The education system guides the novice worker to conduct the surface mount work one by one. (Step 3) The novice worker conducts the surface mount work. (Step 4) The education system recognizes whether the worker conducted the surface mount work correctly, and judges whether more education is necessary or not. And if more education is necessary, (Step 5) the education system makes a plan to educate the topics the novice worker does not understand yet. From Step 2 to Step 5 are repeated until the novice worker masters the required skill for making PCBs by themselves.

3.2 System requirement

Before designing the education system, the authors determined the required features of the education system as follows:

- The novice workers can experience the surface mount work in the environment similar to the actual work environment. The education system does not restrict the worker's movement.
- The education system can be used easily.
- The skill level of the novice workers can be evaluated quantitatively.
- The education course can be changed according to the skill level of the workers.
- The development cost is not expensive and the burden of the educator is light.

3.3 Outline design of the education system

The functions of the education system can be divided into 2 categories. One is the functions to display the instructions to the workers (display function). The other is the functions to recognize the progress of the surface mount work (recognition function). Concerning to the display functions, not only the function to display the instruction documents, but also the functions to display additional information are necessary such as the kind, location, direction and parts box of the electric parts which should be mounted next. On the other hand, concerning to the recognition functions, not only the function to recognize the kind, location, direction of the mounted electric parts, but also the functions are necessary to recognize what kind of electric parts the worker takes and whether the mount work has been finished. Figure 1 shows the outline design of the education system designed in consideration of the above system requirements. The education

system consists of a LCD monitor, a laser irradiation device, a color CCD camera and a personal computer. The surface mount work conducted by the novice workers is captured by the color CCD camera located at the head of the work environment. And the progress of the surface mount work is recognized by image processing techniques. The instructions are displayed by the LCD monitor located in front of the worker and the laser irradiation device located at the head of the work environment. The reason that the color CCD camera is used to recognize the progress of the surface mount work is to avoid to restrict the worker's movement. The reason that the laser irradiation device is used to display the instructions is to make it possible for the workers to reference the guidance of the education system more intuitively by overlapping the instructions over the PCBs. But it is difficult to display all instructions necessary for educating the surface mount work only by using the laser irradiation device, so the LCD monitor is also used.

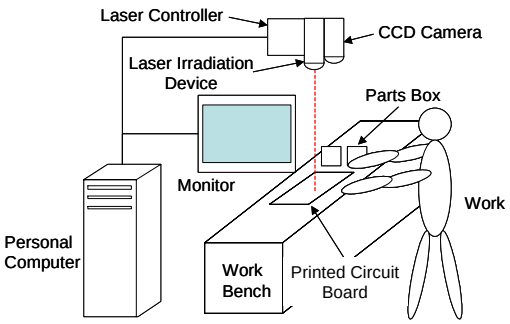

Figure 1: Outline design of the education

4 Required Functions of the Education System

To develop the education system, various kinds of functions need to be realised. This section describes the required functions to develop the education system.

4.1 Detect the location of the printed circuit boards

In order to recognize the progress of the surface mount work, it is necessary to detect the accurate location of the PCB, because the other information such as the location of the mounted electric parts can be recognized based on it. In this study, the location of the PCB is detected by using color information as follows. (1) Classify each pixel of the captured image into PCB-area and non PCB-area by comparing with a given threshold in green color component. (2) 4 edge lines of the PCB is detected by using Hough Transform[1]. (3) 4 vertices of the PCB is detected by calculating the intersection of the detected edge lines. (4) The color image of the captured PCB is extracted as a rectangle shaped image by using the information of the 4 vertices and the size of the PCB which information is registered to the education system in advance.

4.2 Detect the location of the worker's hands

In order to detect the location of the worker's hands, the method by using the skin-color information can be considered. But with this method, the location of the worker's hands can not be detected correctly in the case that the worker wears a half-sleeved shirt because the arm is also extracted when extracting the skin-color area. So in this study, the workers are supposed to wear blue color gloves and the location of the worker's hand is detected as the center of the blue area of the captured image.

4.3 Detect the location of the mounted electric parts

The location of the mounted electric part is detected as follows. (1)The differential image is calculated between the captured image of the PCB before and after mounting an electric part. (2) Classify each pixel of the differential image into parts-pixel and non parts-pixel by comparing with a given threshold. (3) The location of the mounted electric part is detected as the center of the largest cluster area of the parts-pixel.

4.4 Detect the kind of the mounted electric parts

There are some electric parts which kind is different but the shape is almost same. So it is very difficult to detect the kind of the mounted electric parts only by using the part's image if the CCD camera is not close enough to the PCB until it becomes the obstacle of the surface mount work. So, in this study, the number of the electric parts inside the parts box is counted instead of detecting the electric parts mounted on the PCB. That is, if the number of the electric parts inside the parts box is decreased, it can be supposed that the worker takes that kind of electric parts. Concretely, the authors have been designed circle-shaped markers as shown in Figure 2. The marker consists of 1 red circle, 1 blue triangle and 7 white or black triangles. The red circle and the blue triangle are used to detect the location and the orientation of the marker respectively. And 7 white or black triangles are used for coding the kind of the markers. With 7 triangles, we can recognize 128 unique markers. By detecting the circle-shaped makers pasted to the parts box, the education system can recognize the inside area of the parts box and the kind of the electric parts even if the location of the parts box is changed during the surface mount work. But to count the number of the electric parts inside the parts box, it is required for the electric parts to be separated each other inside the parts box.

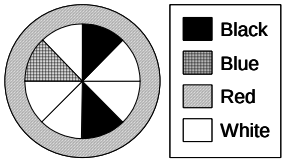

Figure 2: Circle-shaped maker.

4.5 Detect the direction of the mounted electric parts

There are some electric parts which shapes are almost symmetric. So it is difficult to detect the direction of the mounted electric parts only by using the image of them. To make it easy to detect the direction of the electric parts, it may be considered that some makers are added to the surface of the electric parts. But it is not desirable that the worker can detect the added markers for judging the direction of the electric parts, because at the actual factory, these makers will not be added. So in this study, 3 kinds of methods have been developed to recognize the direction of the mounted electric parts. First method is that the image of the mounted electric part is compared with the template images prepared in advance by using pattern matching such as cross-correlation coefficient. Second method is that the surface of the electric part is coated by infrared absorbent which is almost transparency for the workers and when capturing the images, the infrared rays are irradiated on the electric parts. The area coated by infrared absorbent is expected to be darker than the other area when capturing by an infrared CCD camera. Third method is that the surface of the electric parts are marked by color paint complicatedly so that the worker can not distinguish them and the direction of the electric parts are detected by using the color information. At the present stage, the authors have just developed these 3 methods and they will be evaluated to examine which method will be suitable for the education system.

4.6 Function to display the instructions

As mentioned in the subsection 3.3, the instructions to the workers are displayed by using the LCD monitor and the laser irradiation device. The LCD monitor is set as the external monitor of the personal computer and some instruction materials such as the explanation texts and the appearance of the electric parts are displayed on it. The laser direction is controlled by the galvano scanner and it is possible to draw simple figures such as a circle and a rectangle on the arbitrary surface around the work environment. The information for the instructions are stored in the XML format[2] by using special tools developed for constructing the instruction contents.

4.7 Process flow of the education system

The process flow of the education system for educating the novice workers is as follows. (Step1) Read the education scenario from the database. (Step2) Detect the circle-shaped markers pasted to

the parts boxes to recognize the kind of the electric parts and their located area. And the location of the PCB is also detected. (Step3) Display the instructions to the worker. (Step4) By watching the location of the worker's hands, judge whether the worker's hands move over the parts box. If the worker's hand moves over the parts box, go to Step 6, otherwise go to Step 5. (Step 5) Detect whether the electric part is mounted on the PCB. If mounted, go to Step 7, otherwise go to Step 4. (Step 6) Count the number of the electric parts inside the parts box. If the number of the electric parts is decreased, judge that the worker takes the electric parts from the parts box and go to Step 4. (Step 7) Extract the area of the mounted electric part. And detect the direction of it. (Step 8) The results detected at Step 5, 6 and 7 are verified with the correct working procedure of the surface mount work. If there is a mistake, display the instruction to fix the mistake. If there remains something to educate, go to the Step 2. Otherwise the education is finished.

5 Evaluation of the Developed Functions

The functions described in the section 4 were developed using Microsoft Visual C++ in Window 2000. Especially, the functions using image processing techniques were developed using Intel Image Processing Library and Open Computer Vision Library. For the evaluation of the developed functions, the authors have developed the temporal work environment. A color 1/3-inch CCD camera which focal length is 8mm was mounted at a height of 50cm from the work bench. The frame grabber has a resolution of 1024 by 768 pixels. The laser irradiation device which can irradiate class 2 laser was also mounted at a height of 50cm from the work bench. The light intensity around the PCB ranged from 600 to 800 lux. Concerning to the function to detect the location of the PCB, the detection error was within 3mm in the condition that the PCB was moved around the work environment. And even if a part of the PCB was hidden by worker's hand, the location of the PCB could be detected correctly. Concerning to the function to detect the location of the mounted electric parts, there were some cases that the location of the electric parts could not be detected correctly. The cause of the failure seems to be the shadow of the electric parts. When the light is irradiated from the side angle, there is a case that the shadow of the electric parts becomes larger than the size of the electric part. In this case, the education system fails to detect the location of the mounted electric parts. This problem will be avoided by locating the light at the head of the work environment. Concerning to the detection of the circle-shaped maker, there were some case that the detection was failed. The cause of the failure seems to be the reflection of the light on the marker. When the light is reflected on the marker, the black color area of the maker is looked as white color area. This problem can be avoided by making the marker from the materials such as suede or cloth which does not reflect the light.

6 Conclusion

The authors aims at developing the education system to educate the surface mount work of the printed circuits boards without troubling the other workers. In this study, several functions necessary for developing the education system have been developed and evaluated. As the future works, the developed functions will be improved and the whole education system will be implemented. After the implementation of the education system, the effectiveness of the education system will be evaluated by conducting the field trial.

References

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[2] Williamson, H. (2001). XML: The Complete Reference, McGraw-Hill Professional Publishing.