Automatic disassembly and recovery device for mobile phone circuit board CPU based on machine vision

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Abstract. Aiming at the problem of dismantling and recycling the circuit boards of used mobile phones, A device based on machine vision to automatically disassemble and recycle the CPU on the mobile phone circuit board is proposed. The device is equipped with a visual inspection system, a feeding device, a heating device, a CPU transfer device, a robot, and a visualization system to realize automatic disassembly and storage of the CPU on the mobile phone circuit board. Finally, experiments show that the device can achieve stable and reliable CPU disassembly and recovery.

1. Introduction

With the development of technology and the increasing prosperity of the economy, the penetration rate of mobile phones is increasing day by day, coupled with consumers’ continuous pursuit of mobile phone styles and functions, making the pace of mobile phone upgrades also accelerated sharply, accompanied by demand and waste Increasing[1]. The recycling treatment of waste circuit boards mainly includes three aspects: the disassembly of components on waste circuit boards, the recycling of components and the recycling of circuit board substrates, and the current weak links are mainly the first two [2]. So far, although the assembly and assembly process of electronic products has achieved a high degree of automation, in terms of disassembly, it is still in a low-tech manual disassembly state[3]. There are a large number of components that can be used on the circuit boards of used mobile phones, such as CPU and ROM. The CPU and ROM with good performance can be directly reused, and the problematic ones can be reprocessed to extract useful materials for recycling. Manual disassembly of circuit boards has problems, such as low efficiency and hidden safety hazards. This article only considers the disassembly of the CPU on the mobile phone circuit board, and designs an automatic disassembly and recovery device for the CPU on the mobile phone circuit board based on
machine vision, which can greatly improve the efficiency of CPU disassembly and ensure human safety.

2. Design

2.1. Automatic disassembly device module unit

The composition of the automatic disassembly device is shown in Figure 1. The automatic disassembly device includes a feeding device, a visual inspection system, a heating device, a CPU transfer device, a robot, a visualization system, a CPU storage unit, and a circuit board storage unit. The feeding device realizes the supply and preheating of the circuit boards to be disassembled. The visual inspection system realizes the identification and positioning of the mobile phone circuit board. The heating device melts the solder around the CPU on the circuit board. The CPU transfer device realizes the transfer of the disassembled CPU to the CPU storage unit. The robot grips the circuit board and moves to the designated position. The visualization system realizes the display equipment operation status. CPU storage unit realizes storage CPU. The circuit board storage unit realizes the storage of the circuit board that has been disassembled by the CPU.

![Figure 1. Automatic disassembly device composition](image)

2.2. Equipment operation flow

The equipment operation flowchart is shown in Figure 2.

![Figure 2. Equipment operation flow](image)
3. Visual inspection

3.1. Camera calibration

The pictures collected by the camera will be distorted due to the influence of the camera lens and the camera itself, so it is usually necessary to calibrate the camera to obtain the internal parameters or internal and external parameters of the camera, and then correct the distortion of the camera itself [4]. This article uses the calibration assistant that comes with the halcon software to collect the marker points for camera calibration. The calibration flowchart is shown in the Figure 3. The description file is a collection of pictures taken from different angles of a 30mm*30mm standard calibration board. The content of the description file is shown in the Figure 3. The calibration result is shown in the Table 1 and Table 2.

![Calibration process](image)

Table 1. Internal parameters of the calibrated camera

| f(mm)  | Kappa(1/m²) | Sx(μm) | Sy(μm) | Cx    | Cy     |
|--------|-------------|--------|--------|-------|--------|
| 3.67057 | -809.403    | 2.20647 | 2.2    | 1136.84 | 1064.02 |

Table 2. External parameters of the calibrated camera

| x(mm)   | y(mm)   | z(mm)   | RX(°) | RY(°) | RZ(°) |
|---------|---------|---------|-------|-------|-------|
| 29.0517 | -11.8443 | 242.762 | 0.3944 | 0.507229 | 287.921 |

After the camera calibration obtains the internal and external parameters of the camera, the distortion is corrected by using the internal parameters of the camera. Use map_image() in the halcon software operator library to correct image distortion.

3.2. Robot calibration

Hand-eye calibration is an important step to eliminate the lack of accuracy of the robot system caused by geometric errors. There are generally two methods for hand-eye calibration, Eye-in-hand and Eye-to-hand[5]. This article uses the method of Eye-to-hand. The robot hand-eye calibration process is shown in the Figure 4.
The calibration process involves the transformation of pixel coordinates and robot coordinates. The principle of coordinate transformation is as follows: the robot coordinate system is obtained by translation and rotation transformation of pixel coordinates [6]. The transformation relationship between camera XY plane coordinate system and robot XY plane coordinate system:

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = R \begin{bmatrix} x \\ y \end{bmatrix} + M$$  \hspace{1cm} (1)

$$\begin{cases} x' = ax + by + c \\ y' = a'x + b'y + c' \end{cases}$$  \hspace{1cm} (2)

The robot uses three points to calibrate, and puts the three-point coordinates into the above formula, and the result is as follows:

$$\begin{cases} x_0 = ax_0 + by_0 + c \\ x_1 = ax_1 + by_1 + c \\ x_2 = ax_2 + by_2 + c \end{cases}$$  \hspace{1cm} (3)

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = R \begin{bmatrix} x \\ y \end{bmatrix} + M$$  \hspace{1cm} (4)

The expansion and transformation of the above two coordinates is a matrix multiplication to obtain a transformation matrix. The result is as follows:

$$\begin{bmatrix} x_0 & y_0 & 1 \\ x_1 & y_1 & 1 \\ x_2 & y_2 & 1 \end{bmatrix} \begin{bmatrix} a \\ b \\ c \end{bmatrix} = \begin{bmatrix} x_0 \\ x_1 \\ x_2 \end{bmatrix}$$  \hspace{1cm} (5)

$$\begin{bmatrix} x_0 & y_0 & 1 \\ x_1 & y_1 & 1 \\ x_2 & y_2 & 1 \end{bmatrix} \begin{bmatrix} a' \\ b' \\ c' \end{bmatrix} = \begin{bmatrix} y_0 \\ y_1 \\ y_2 \end{bmatrix}$$  \hspace{1cm} (6)

According to the coordinate transformation formula, it can be seen that the robot coordinate system can be regarded as the pixel coordinate system multiplied by the transformation matrix. Only need to calculate the transformation matrix, combined with the coordinate position of the object in the pixel coordinate system, you can easily calculate the coordinate position of the object in the robot coordinate system.
4. Template matching

The whole process of NCC is Normalized cross correlation, and it is a common image processing method to compare the similarity of two images. Ideally, the similarity measure should not change with any changes in illumination. The similarity measure that can meet this requirement is the normalization coefficient (NCC), which is based on correlation-based template matching [7]. This article uses the NCC template to train three mobile phone circuit board templates of Huawei, Xiaomi and Apple. A new mobile phone circuit board image is collected through a visual inspection system, matched with three mobile phone circuit board templates to obtain three template scores, and obtain the maximum value of the three template scores and output the maximum value. The process is shown in Figure 5.

![Template matching process](image)

Figure 5. Template matching process

The result of template matching is shown in Figure 6.

![Template matching results](image)

Figure 6. Template matching results

The experimental results are shown in Table 3.

| Model  | Disassembly temperature (°C) | First time (s) | First demolish rate (%) | Second time (s) | Second demolish rate (%) | Test numbers (sheet) | CPU removal rate (%) |
|--------|------------------------------|----------------|-------------------------|----------------|--------------------------|----------------------|---------------------|
| Huawei | 330                          | 36             | 65                      | 21             | 85                       | 100                  | 100                 |
| Xiaomi | 330                          | 36             | 79                      | 21             | 88                       | 100                  | 100                 |
| Apple  | 330                          | 36             | 84                      | 21             | 92                       | 100                  | 100                 |

The CPU disassembly temperature of the circuit board of the mobile phone is different, and the CPU disassembly efficiency is also different. The test quantity of three kinds of mobile phone circuit boards is 100 pieces. Due to the stratification of the three board CPUs, the experiment set the first heating time and the second heating time. When the heating temperature is 330 degrees Celsius, the first heating time is 36 seconds, and the second heating time is 21 seconds, test the first disassembly rate and first disassembly rate of the CPU on the circuit boards of Huawei, Xiaomi, and Apple. In the first heating time, the CPU is not completely disassembled. The device uses the second heating time to repeatedly heat the circuit board CPU until the CPU disassembly is complete. Experiments show that all three types of mobile phone circuit boards can finally disassemble the CPU. In view of the
relatively low rate of disassembly of Huawei’s CPU for the first time, it is analyzed that because the experiment first disassembled the Huawei circuit board CPU, the heat gun was not preheated in advance, resulting in a relatively low rate of disassembly for the first time.

5. Summary
This article provides a device based on machine vision to automatically disassemble and recycle the CPU on the mobile phone circuit board for disassembling mobile phone CPU. Using machine vision and robotics technology, the automatic disassembly of the CPU on the circuit board of the mobile phone was realized, and the disassembly experiment results were satisfactory. This device is currently in the research stage, and the CPU disassembly of the three boards has been completed at this stage. The equipment will be re-developed in the future to realize the dismantling of the CPU and other components of various circuit boards.

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