High Precision Detection System of Circuit Board Based on Image Location

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Abstract. With the increasing integration of the control system and the continuous development of the PCB processing technology, the testing of PCB becomes more and more difficult. The manual detection of PCB fault points can no longer meet the needs of the industry. In this paper, a universal circuit board detection system based on image automatic positioning is proposed. The system can accurately collect the coordinates of the measured points by using the image information, and record the edge information of the circuit board. The position error caused by the fixed position of the circuit board is corrected in real time. At the same time, the automatic correction function of the pressure drop of the system can automatically correct the voltage drop produced by the hardware circuit and improve the accuracy of the measuring system. The experiment proved that the fault point detection system based on image location can effectively improve the efficiency, accuracy and universal of circuit board detection.

Keywords: Circuit board · Fault point detection · Image location · Error correction

1 Introduction

In the past, many experts and scholars have made outstanding contributions in the field of automatic detection of circuit boards, and they have achieved notable results. Li [1] and his teammates have developed a set of PCB automatic detection system for a mining circuit board, which improved the detection efficiency. Luan [2] and his teammates have developed a set of circuit board vision positioning system based on Vision Pro which Improved the positioning accuracy to 0.3 mm. In the research of circuit board location, Wang [3] and his teammates have improved the accuracy of detection and shortened the detection time by using the improved Hough transform. On the basis of the existing detection technology, an intelligent detection equipment based on automatic image location and automatic correction of pressure drop error is proposed in this paper. The equipment is based on the image positioning system, and combined with the flying-needle detection system and the automatic error correction system, which greatly improved the efficiency, accuracy and generality of the detection of the circuit board.

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2 Total Design of the System

2.1 Structure of the System

To make the detecting system efficient, accurate and universal, the system is divided into five parts:

1. A flying-needle system based on the movable needle.
2. An image positioning system based on the FT- GW36C camera.
3. An automatic measurement and pressure drop correction system based on high-precision multimeter and oscilloscope.
4. A slave computer control system based on STM32F407IGH6.
5. A master computer total control system based on VS+ C#.

The needle bed system makes use of the fixture to ensure that the circuit board within the specified size range can be effectively fixed and that every point on the circuit board can be contacted with the needle. The image positioning system can obtain and store the "datum coordinates" of the target and the "datum edge" of the circuit board through the image when we don't know the coordinates of the measured point. The "datum coordinates" and the "datum edge" can provide the exact coordinate information and position error correction basis for the formal measurement circuit board, which ensure that measured points can be accurately detected by the flying-needle. The measurement and pressure drop automatic correction system based on high precision meter can make the measurement process efficient and accurate, besides, the system can also eliminate the influence of the hardware measurement circuit on the measured signal. The master computer system and the slave computer system are responsible for the control and execution of the whole measurement system.

2.2 Main Workflow

For the circuit board whose target point coordinates are unknown, the workflow of the detection system is divided into two processes: system calibration and formal measurement.

The system calibration process includes data acquisition and system initialization. The quality of system calibration will directly affect the accuracy of the formal measurement. The process divides into five steps: (1) the target point calibration and coordinate extraction based on the image; (2) extracting the edge of the circuit board; (3) setting the standard signal value of the target point; (4) setting the physical properties of target points and distributing the flying-needle; (5) automatic pressure drop correction.

The formal measurement process, based on the coordinate data collected in the system calibration process and the standard signal values of the measured points, finishes the testing and locking the fault points. The process divides into six steps: (1) The "handshake" between the master computer and the slave computer; (2) Correcting the position error of the circuit board automatically; (3) The testing safety under the low voltage power supply state; (4) Collecting signal in normal working voltage state; (5) Analyzing acquisition value and standard signal value comparatively; (6) Locking fault points.

3 The Design of Key Hardware System

3.1 The Design of Needle Bed System Based on Movable Flying-Needle

In order to improve the universality of the equipment, ensure that the pressure value can make equipment work well in a variety of measuring environment and ensure the accurate contact between the measured point and the flying-needle, the system is analyzed in two aspects, the variety of then physical size of the needle and the safety grade of the flying-needle. On this basis, a set of flying-needle selection scheme is given.

IEC (International Electrotechnical Commission) set up an international standard for testing instruments: IEC 1010. According to the fact that the dangerous high-energy voltage is gradually attenuated by the transmission in the line, the standard divides security of the power system into four grades, that is, CAT I, CAT II, CAT III, CAT IV. The higher the safety level is, the higher the instantaneous high voltage that can be borne will be. The applicable objects of different safety levels are shown in Table 1:

Table 1. The applicable objects of different safety levels

Classification	CAT I	CAT II	CAT III	CAT IV
Applications	Indoor electrotechnical equipment with protective measures	Household socket and its equipment	Three phase distribution circuit and industrial lighting circuit, etc.	Three phase public power supply equipment
Example	Fax, Scanner	Fridge, Washing machine	Machine tool in the workshop, Interior lighting circuit of large building	Outdoor transmission circuit

The needle bed equipment belongs to the indoor application equipment. The range of the voltage measurement of the equipment should be taken into consideration when the needle is selected. According to Table 1, it is analyzed that the selected flying-needle of this system should meet the safety standard of CAT III.

Based on the above safety analysis and combined with the physical size diversity requirements of flying-needles, this paper presents a set of flying-needle selection schemes, as shown in Table 2:

Limited by the structure of the needle moving system, the needle bed system consists of 4 movable flying pins. Each pin has different models, characteristics and applicable conditions. It can meet the measurement requirements of the industrial circuit board and improve the universality of the needle bed system.

Table 2. The flying-needle selection schemes

Model number	Head type of flying-needle	Head diameter/mm	Application
HSS150 306 400A5002M	Flat head	4.0	Measuring the position where large current and high voltage appear
GKS004-206-396A2000	Plum blossom head	3.96	Measuring the direct pin or the position where high voltage appears
GKS100217170A2000	Trigonometric point	1.7	Measuring via. reducing the damage to the circuit board
GKS050291050A2000	Sharp head	0.5	Measuring the larger pins, avoiding short circuit connection due to flying-needle too thick

3.2 The Design of Image Location System Based on FT-GW36C Camera

The image automatic positioning system collects the circuit board image through the FT-GW36C camera. In the system calibration step, the pin yellow edges of the measured point that is calibrated by the master computer system are shown in Fig. 1. By calling the function cv2-moments () in the OPENCV library [4], the master computer software calculates the center coordinates of the calibrated point, then it inputs the coordinates into the coordinate library as the datum coordinate information of the measured point. At the same time, the standard signal value, data type, pin type and flying-needle type, which corresponding to the measured point, are input into the master computer database. When each target point is traversed, the camera captures the overall images of the circuit board. The master computer detects the edge of the circuit board through the Canny algorithm, and calculates the edge size information and the centroid coordinates of the circuit board through the function of cvMinAreaRect2 (). Meanwhile, the base shape information of the circuit board edge is stored. The whole process is shown in Fig. 2:

During the formal measurement process, the circuit board is clamps on the test stand. By collecting the edge size information of the circuit board and calculating the center coordinates of the edge of the circuit board at the moment, the system calculates the error vector ‘U’ by comparing with the datum-edge shape information in the database. Combining the error vector ‘U’ and the datum coordinate value of the target

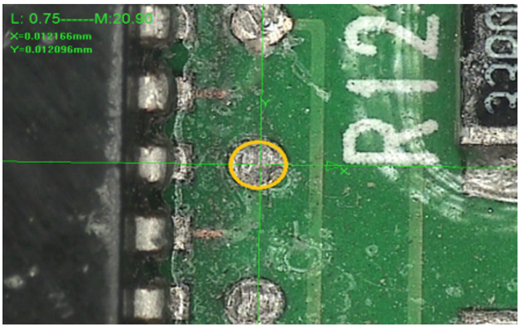

Fig. 1. Coordinate measuring diagram of target point

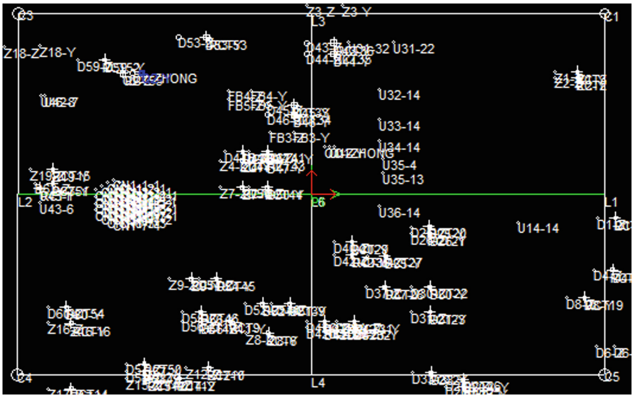

Fig. 2. Points and edges detection diagram

point stored in the database, the real-time position coordinates of the measured points in the formal measurement process are calculated. The calculation process of the real-time position coordinates is as follows:

Taking rectangular circuit board as an example, it is assumed that the ‘O’ coordinates of the edge reference centroid collected in the process of system calibration are (a0, b0), and the reference coordinates of any target in the database are (c0, d0). In order to accurately measure the position of the circuit board and the angle deviation of the reference position, it is taken as the reference direction that the initial direction of the upper edge of the circuit board in the system calibration process, which is recorded as: ∠ = 0. At the time of formal measurement, it is assumed that the centroid coordinates of the circuit board are (a1, b1), and the angle between the upper edge and the reference direction ∠ = θ, and the error vector is recorded as U = (△ X, △ Y). As shown in Eqs. (1) (2) (3), the coordinates of the target points in the formal measurement process can be simplified as the following mathematical model:

$$\Delta \mathrm{L} = \sqrt{(a_0 - c_0)^2 + (b_0 - d_0)^2} \tag{1}$$

$$\Delta \mathrm{X} = (a_1 - a_0) + \Delta L \cdot \sin\theta \tag{2}$$

$$\Delta \mathrm{Y} = (b_1 - b_0) + \Delta L \cdot (1 - \cos\theta) \tag{3}$$

The corrected coordinates of the measured points are $(a_0 + \Delta X\,, b_0 + \Delta X)$, and the master computer coordinates the corrected coordinates as the real time coordinates of the formal measurement to ensure that the flying-needle can move accurately to the position of the measured point.

3.3 High Precision Measurement and Voltage Drop Automatic Correction System

In the process of circuit board detection, how to measure electrical signals will directly affect the efficiency and accuracy of measurement, and further affect the testing quality of testing equipment. Two high precision measuring equipment are used in this system: 'Keysight' multimeter and 'Micsig' oscilloscope, Two measuring devices are controlled by two relays, and the multimeter (or oscilloscope) sends a data to the upper computer through LAN communication every time the measuring devices finish testing a target point.

In the measuring process, the impedance of the hardware measurement circuit will make the measured voltage appear a certain amplitude of voltage drop. In order to improve the measuring precision of the equipment, the system sets the standard 13 reference voltage [5]: −15 V, −10 V, −5 V, −3.3 V, −2 V, −1 V, 0 V, 1 V, 2 V, 3.3 V, 5 V, 15 V, 24 V. According to the 13 references, the measured voltage range is divided into 14 measuring intervals. When measuring the voltage drop produced by the hardware circuit, 13 reference voltages were collected 10 times continuously, which are recorded as

$$X_1, X_2, X_3 \ldots\ldots X_{10}$$

The correction value of the voltage drop of the circuit X is shown in Eqs. (4) (5) (6):

$$\Delta X_1 = 5V - X_1 \tag{4}$$

$$\Delta X_{10} = 5V - X_{10} \tag{5}$$

$$\mathrm{X} = \sqrt{\frac{\Delta X_1^2 + \Delta X_2^2 + \ldots + \Delta X_{10}^2}{10}} \tag{6}$$

According to the above principles, 14 corrections can be obtained: $X_1, X_2, \ldots\ldots X_{14}$

In the formal measurement process, according to the measured voltage value $\mathrm{V_m}$, the voltage correction value is selected in real time. Thus the actual voltage value V can be recorded as Eq. (7):

$$\mathrm{V} = V_m \pm V_i (i = 1, 2.\ldots..14) \tag{7}$$

4 The Design of the Master Computer System

As a platform for human-computer interaction, the master computer has many functions such as reading, analyzing, storing data, controlling the action of the slave computer, controlling the image acquisition system, generating the reports, and so on. The work flow is shown in Fig. 3.

To facilitate the maintenance and upgrading of the master computer, the master computer must have good extensibility and versatility. In order to meet the above

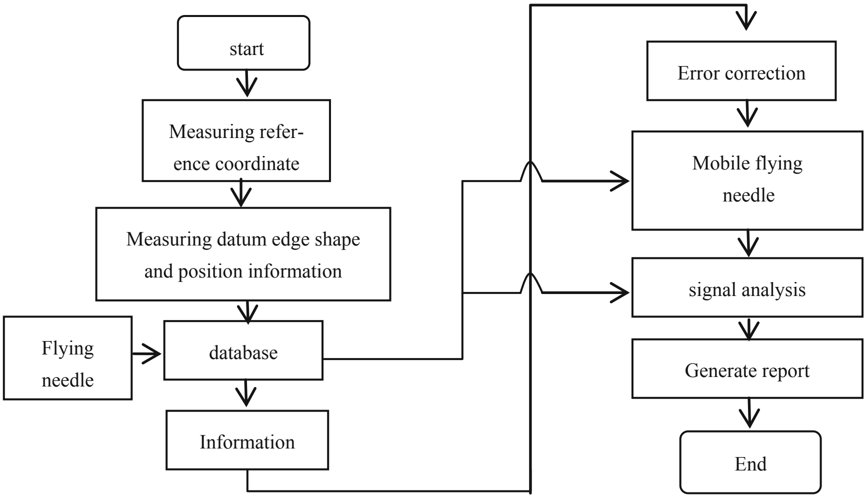

Fig. 3. Working flow chart of master computer control

requirements, the master computer is designed to be divided into 5 modules, image acquisition and analysis module, flying-needle control module, data acquisition module, data analysis module and data report module. This modular design reduces the complexity of the program, and makes program design, debugging and maintenance more convenient.

5 Experiment

In order to test the efficiency, accuracy and generality of the system, 5 different types of circuit boards with known faults are measured in the experiment. The experimental data are recorded and analyzed. The experimental collection interface is shown in Fig. 4, and the experimental data is like Table 3.

In the process of experimental data analysis, considering the characteristics of circuit work, the voltage signal of non-zero standard value is allowed to have a

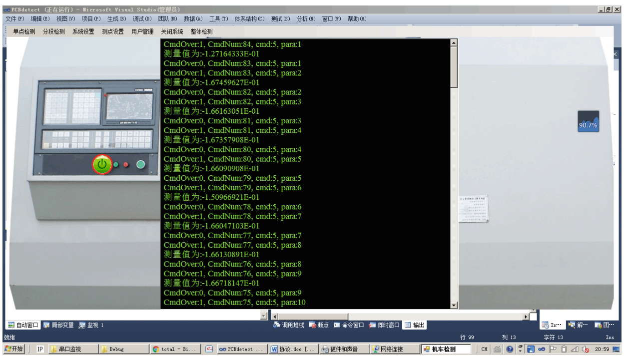

Fig. 4. Experimental collection interface

Table 3. Experimental data table

Circuit board	Number of measured points	Number of known fault points	System calibration time/min	Measurement time/s	Accuracy rate
Reversing radar circuit	24	2	12	50.4	100%
Voice playback circuit	67	5	30	129	100%
Resistance capacitance protection circuit	70	2	29	152.7	100%
Lower computer circuit board	104	6	37	212	100%
Traction motor circuit	203	8	134	452.7	99.51%

measurement error of $\pm 3\%$, and the voltage data with zero standard value is allowed to have an error of ± 0.8 V. When the measured value exceeds the specified range, it is demarcated as abnormal data.

The experimental results show that the fault point detection system based on automatic image positioning can accurately locate the target points, and the different types of movable flying pins guarantee the generality of the measuring system. At the same time, the correction function of target coordinates error and the circuit voltage drop improved the accuracy of the detection system enhanced the intelligent level of measuring equipment.

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