Design of PCB Automatic Optical Defect Detection and Control System Based on PLC

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Abstract. This paper introduces the automatic optical defect detection and control system of the array camera PCB with PLC as the core and gives the PID control of the PCB motion device, the area camera and the Kalman filter. According to the set process conditions of the industrial assembly line, the whole system is controlled to acquire the defect detection image of the PCB. Compared with the scanning of the line camera, the image acquisition time is reduced, and the detection efficiency is improved.

Keywords: PLC Area array camera array Kalman filter PID control.

1. Introduction

With the continuous development of electronic products and their derivatives, precision and intelligence are the main directions for the development of their key technologies. As a carrier for connecting various sophisticated electronic components, the printed circuit board connects the key electronic components as an intermediate layer. With the diversified development trend of modern electronic products, PCBs are also developing in the direction of high density, multiple layers, high performance, and miniaturization. These have raised higher requirements for the design, manufacture, and inspection of PCBs. At present, PCB manufacturing accuracy can reach 0.10~0.12mm line width and stitch length, and the board layer can reach at least 46 layers. With the rapid development of processing and processing technology, PCB electronic components are also moving toward miniaturization and precision development. How to ensure the reliability of the PCB and the transmission integrity between the chips after the design, manufacture and manufacture are particularly important. Modern electronic product manufacturing and PCB are closely linked. All related production companies are very concerned about the quality of the PCB board. The PCB board with excellent design, exquisite structure, stable performance and long service life can bring good reputation and rich profits to the company. However, PCB boards with poor design, interference from connected copper wires, interference from connected layers, electromagnetic radiation interference, and overheating of components have seriously affected the stability, safety, and service life of the electronic products carrying such PCB boards. These will bring incalculable losses to the company. At present, automatic optical inspection technology will still have such problems in the engineering practice stage, including common product defects such as missed detection and false detection, affecting inspection efficiency, equipment costs, and maintenance and

repair costs. Therefore, how to improve the performance of testing equipment to achieve intelligent detection has become the focus of the PCB industry, and also has important research value. Traditional human eye detection and on-line detection of probes due to limited contact are not well suited to the needs of intelligent manufacturing technology development. Optical detection creates trends for PCB manufacturing. As a common detection method in industrial production and processing, automatic optical detection uses imaging and its supporting equipment to obtain the surface state of the finished product and uses the difference in image comparison to obtain defects and abnormalities. Visual inspection has obvious advantages in the detection of PCBs: (1) High stability, no fatigue, and significant increase in effective inspection time. (2) Non-contact, without the binding of the fixture, also ensures the integrity of the test object. (3) High-precision and high-efficiency, aiming at streamlined production operations, which effectively reduces repetitive labor costs. At present, for the visual inspection, the PCB inspection industry is a rising star with obvious advantages.

2. Surface array camera PCB detection motion device control system design

The automatic optical inspection system of PCB realizes the detection of PCB defects through electromechanical equipment instead of the traditional manual detection method and identifies defects in the process of production: short circuit, open circuit, leakage line, residual copper, hole breakage, etc., reducing the product repair rate and improving products` productivity and quality. Surface array camera array PCB automatic optical defect detection control system realizes automatic optical inspection of the PCB board with pipelined PCB control device and array camera array.

Shooting process of the array camera array: The PCB is fixed on the moving device workbench and follows the moving device platform to synchronously move the pipelining. Each time the motion device platform moves an equal distance, the connected motion interval is 3 seconds. Immediately after each segment of motion stops, the PLC immediately controls the eight array camera arrays to synchronize the PCB board on the motion platform. Eight cameras capture the image of a fixed size area using global exposure. Because the movement of the PCB board is synchronized with the shooting of the area array camera array, in order to obtain high quality PCB photo information, the PCB board is partitioned by eight area array cameras, and the combination is firstly divided into blocks to form an entire PCB image.

Making reasonable path planning for the PCB motion device platform, make the PCB board move according to the established streamlined path, and obtain more complete and clear images, reducing the difficulty of subsequent image splicing. Reasonable motion path planning can effectively reduce the idle stroke of servo motor and improve the collection efficiency and quality of PCB images. Eight array camera arrays are parallel to the platform of the PCB motion device, and the fixed array camera array plane. The motion platform on which the PCB board is placed is streamlined along the Y-axis to achieve relative motion between the PCB board and the camera. Plan multiple journeys of motion to collect multiple pictures, and finally splicing PCB images into a complete picture.

The entire PLC control system has two modes of operation: automatic and manual. Manual mode: Each time the manual mode button is pressed, the servo motor drives the PCB slider device to move forward for a certain distance. The setting can only be moved three times. The distance of three movements is equal. Automatic mode: Press the auto mode button, the servo motor drives the PCB slider device to move forward to stop at the limit sensor, stop after moving forward three equal distances, and pause for 3 seconds between each segment of the camera for the area camera to collecting images.

The PCB motion device is driven by a servo motor. The time function of the speed of each segment of the servo motor is a reminder function, that is, the first acceleration and then the uniform motion, the final deceleration and stop, the acceleration and deceleration before and after, and the speed of the uniform process in the middle process is not stable, which will lead to the PCB board in motion. In a certain degree of jitter, the position of the PCB is shifted, affecting the quality of the area camera's shooting and image acquisition. According to a reasonable path planning in advance, the motion error caused by the motion of the motion platform is reduced, and the entire motion process is completed through uni-directional motion and motion compensation. Through the establishment of a simple experimental model, the camera is arranged in a spaced arrangement and cooperates with the motion of

the platform of the PCB moving device along the Y axis. Each time the motion device stops moving, it takes pictures immediately. Through this intermittent shooting mode, the complete image information of the entire PCB is obtained at one time. Error compensation of motion compensation with displacement sensor in platform movement of PCB motion device. A series of sensors, such as Hall sensors and inductive proximity switches in the entire control system, can ensure the accuracy of movement and reduce the error of the entire PLC motion control.

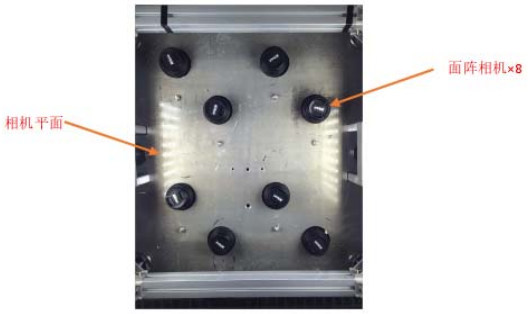

Figure 1. area array camera array device

By adjusting the motion displacement of the PCB motion device platform as shown in the figure, while ensuring the sampling rate and the camera image quality, the number of movements of the PCB motion platform should be reduced as much as possible. Matlab simulation and mathematical calculation results show. When the movement distance of the PCB motion platform is 70mm, the highest sampling rate and the minimum number of movements can be achieved.

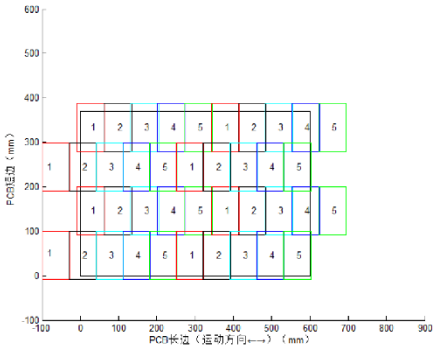

Figure 2. Motion Displacement Diagram

3. Area camera photo control

Real-time control of motion control platform based on programmable control technology PLC. Whether in automatic mode or manual mode, the PLC precisely controls eight array camera arrays and simultaneously photographs the PCB board when the servo motor drives the PCB motion device platform to stop moving. The camera's own parameter settings and placement height and angle have a great influence on the acquired image quality and subsequent image stitching. Although the PLC can control eight cameras to shoot the PCB at the same time, there is no guarantee that all eight cameras are in the same horizontal plane, resulting in the missing information of the stitched image during the subsequent splicing of the captured partial PCB photos. Due to the multi-camera array acquisition method, the parameters of each camera are different even if the calibration is performed in advance, and the image distortion is different. By observing and studying the working principle of the line camera, combined with the characteristics of the area camera itself, we creatively propose eight array camera array arrangements with pipeline-based motion platform collaboration to achieve segmented and

partitioned shooting of the PCB, and finally through the image. Splicing method to get a complete PCB board image and information [5].

Currently available camera types include digital cameras and industrial cameras. Industry has always existed in the form of a low profile in the fields of industrial production and processing. Its technology is relatively conservative, and its performance is mainly known for its stability, so as to deal with a variety of complex production and processing environments. Industrial cameras have the advantages of customization and miniaturization, the production of more complex and cumbersome processes, resulting in expensive. Digital camera as a daily shooting tool, with the introduction of a variety of major manufacturers, its performance is constantly improving, with the continued popularity of SLR cameras, its cost-effective higher and higher, its application areas are gradually changing from the entertainment field to the industry field. In this control system, the Nikon D3300 camera is used for the area array camera. The maximum resolution is 6000×4000 pixels, and the accuracy requirement is 0.018mm, so the area of 108mm×72mm can be shot. For PCBs with a size of 600mm x 370mm, to ensure full coverage of the shooting area while minimizing the number of cameras.

According to the research and analysis, the arrangement of the area camera is different, and the image information collected is also different. Large-area layout, the area camera can capture images with a large enough field of view, but the number of SLR cameras increases, equipment redundancy and cost increase, clearer small area images will increase the difficulty of image splicing [6]. To achieve fast and efficient PCB image acquisition, it is necessary to coordinate the relationship between the number of cameras and the camera arrangement. Reasonable motion control and path planning are also used to compensate for distortions such as image stretching, compression, and blurring caused by motor acceleration and deceleration so that images can be captured better.

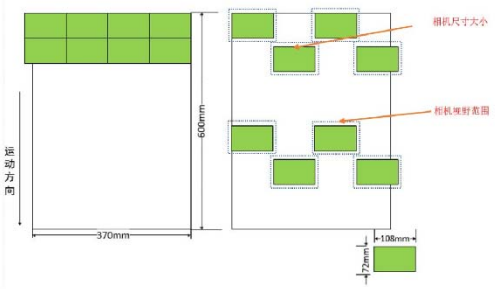

Figure 3. Arrangement

Through the analysis of the number of cameras and shooting efficiency, the final decision to choose eight SLR cameras. The figure shows the non-interval arrangement and spacing arrangement. Comparing the interval arrangement with the non-interval discovery through experiments, the interval arrangement can improve the shooting accuracy when the requirements are satisfied, and the shooting redundancy can be achieved by photographing the overlapping area. In the case of ensuring the same shooting efficiency, the sampling rate is increased, thereby improving the accuracy and efficiency of subsequent image stitching.

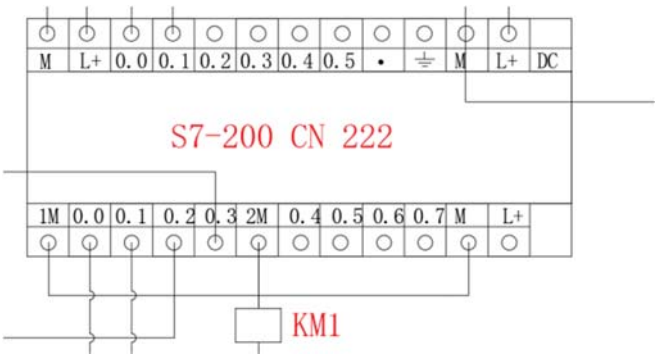

Figure 4. PLC and area camera relay electrical diagram

As shown in the figure, eight area cameras connect the I/O connection between the intermediate relay and the PLC, and simultaneously control the eight area array cameras via the PLC. Whenever the pipeline movement of the PCB motion device platform stops, the PLC immediately controls the eight area array cameras to shoot to obtain the image of the PCB board, and the subsequent image stitches out a complete PCB board image.

4. Kalman Filter Based PID Control Algorithm

PID is simple because of its principle, easy to set, adjust applicability, applicable to a wide range of control, regulation performance indicators are not very sensitive to changes in the characteristics of the controlled object [7], the effectiveness of the regulation is sufficient, convenient and convenient, so in the process control, PID controller has been the most widely used automatic controller. PID control has also been the most widely used control algorithm in many control methods. The calculation process of the PID algorithm has a direct relationship with the output value [8]. In practical production applications, any control system is unavoidably interfered with by various random factors. Since the control system is always subject to uncertainty, it is necessary to filter the detected signal in the actual control process to obtain the state quantity information as accurately as possible. Filtering is filtering out noise signals and extracting useful signals. Kalman filter is the most current recursive filtering method based on Wiener filtering. The Kalman filter can obtain the current state estimate based on the recurrence formula based on the previous moment's estimation and the current measurement data [9]. Kalman filter has characteristics of spatial state description by system model and optimal solution by recursion formula. Based on the above advantages, the array camera PCB automatic optical defect detection and control system uses a PID algorithm based on Kalman filter. In this control system, because the servo motor driving the motion platform has made several equidistant movements during a pipeline operation, as the number of movements increases, the displacement error of the PCB motion apparatus platform will continuously accumulate, ie, the array camera array. The area where the PCB image was captured will deviate from the ideal image area. In order to obtain a constant motion displacement, the control system uses Kalman filter to filter the linear velocity of the detected track, and then uses the PID algorithm to control the output speed of the servo motor, thereby controlling the displacement of the motion device platform [9]. As shown in Figure 6 based on the Kalman filter PID constant speed control flow chart. The input value in the control system is the linear speed of the servo motor. The displacement of each motion device platform is required to be 70 mm. The speed encoder is installed inside the servo motor.

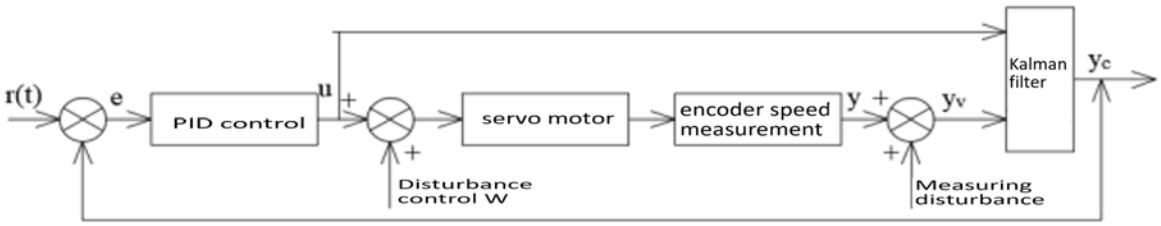

Figure 5. PID control flow chart based on Kalman filter

$$G(s) = \frac{K_1}{TS^2 + S + KK_1} \tag{1}$$

K--magnification of servo motor,
K1--optical encoder magnification
Let the process noise W(k) and v(k) have a covariance of 1 and white noise with an amplitude of 0.02, that is, Q=1 and R=1. Simulate white noise with the random function rand () in matlab. When the initial value P (0) =BQBT is simulated, T=0.4, K=3, K1=2, and τ=3; according to the Kalman filter principle, the linear stochastic differential equation of the moving speed detection mechanism can be listed:

$$X(k) = X(k-1) + 0.012U_i(k) + W(k) \tag{2}$$

$$Z(k) = X(k) + V(k) \tag{3}$$

First, update the Kalman filter time:

$$X(k) = X(k-1) + 0.012U_i(k) \tag{4}$$

$$P(k \mid k-1) = P(k-1 \mid k-1) + Q \tag{5}$$

Status update:

$$X(k \mid k) = X(k \mid k-1) + K_g(Z(k) - X(k \mid k-1)) \tag{6}$$

$$K_g(k) = P(k \mid k-1)[P(k \mid k-1) + R]^{-1} \tag{7}$$

$$P(k \mid k) = P(k \mid k-1) - K_g(k)P(k \mid k-1) \tag{8}$$

This continuous iteration can get the optimal estimate of the detection quantity. Kalman filtering simulation using matlab, the red curve represents the measurement feedback signal containing noise, red is the output response curve. Recursively for every 0.1S, we can see from the blue curve that at about 15S, we have reached the steady-state value, and there is no overshoot, the sampling period is 0.5S, and the line speed is set to 0.25m/s.

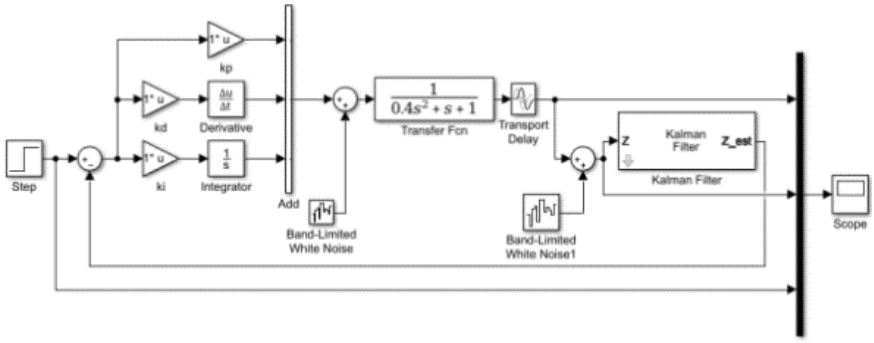

Figure 6. Block diagram of Simulink simulation based on Kalman filter

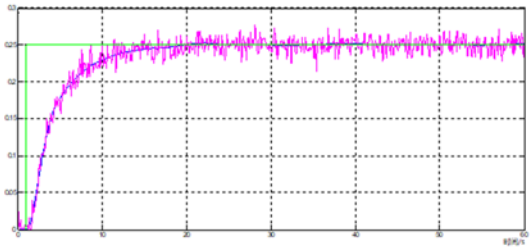

Figure 7. Matlab simulation of PID based on Kalman filter

5. Summary and outlook

In the design of PLC-based array camera PCB automatic optical defect detection control system [10]. The PLC simultaneously controls eight area array cameras to capture the image of the PCB board moving on the imitation pipeline [11], providing material for subsequent automatic optical defect detection. The motion of the PCB motion device and the shooting angle of the camera placement position have a great influence on the quality of the PCB image. The PID control of the Kalman filter of the PCB motion platform is used to achieve position compensation, achieve accurate positioning and motion compensation, and improve effectively. PCB defect detection system stability and efficiency, reduce the development difficulty and cost of the motion module. Because the area camera is more intuitive to measure, and can obtain more image details, reduce the difficulty of subsequent automatic optical defect detection.

Acknowledgments

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References

[1] Liu Yubo. Siemens SMT Mounter Test Automation System Development [D]. Tongji University, 2006.
[2] Lin Yuewei. Algorithm research of PCB quality inspection [D]. Chongqing University, 2007.
[3] Wei Qingchun. IC wafer image feature extraction and defect detection [D]. Guangdong University of Technology, 2010.
[4] Jia Peigang, Li Mingzhe. Research on Motion Compensation Methods of Attitude Sensor Based on Kalman Filter Algorithm[J]. Manufacturing Automation, 2015, 37(24): 41-43.
[5] Deng Qingmei. Research on Inverted Midpoint Line Detection Technology of Circuit Board[D]. Huazhong University of Science and Technology, 2008.
[6] Zhao Shurui. Research on Key Technologies of Panoramic Image Mosaicing[D]. University of Electronic Science and Technology of China, 2013.
[7] He Zhibin. Fuzzy PID control based on hydraulic king crane of Kingview DY200010-00[D].

Dalian Maritime University, 2005.
[8] Liu Renfa. Application of PID in Industrial Automatic Control[J]. Research on Theory of Urban Construction: Electronic Edition, 2011(21).
[9] Deng Xianming. Research on Warp Tension Control and Equipment of Ultrafine Wire[D]. Tianjin Polytechnic University, 2017.
[10] Yang Jiliang. Research on glass defect feature extraction method based on dual threshold segmentation [D]. North University of China, 2012.
[11] Wang Jianzhuang. Research and implementation of high-speed image processing algorithms based on FPGA[D]. Huazhong University of Science and Technology, 2011.