Research on Intelligent Reading System of High-precision Pointer Instrument

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Abstract: Aiming at the problems of poor accuracy of reading and periodic verification of high-precision pointer meters, poor degree of automation, and high labor intensity of operators, according to measurement theory and image recognition theory, a line extraction method combining LSD method and least square method was adopted to simulate the working process of human eyes, and according to the position verification requirements of "three points and one line". The intelligent reading system of high-precision pointer instrument is designed, and the data is intelligently processed. Through the process of design, prototype production and function test, it is proved that the method can improve the reading accuracy, improve the verification efficiency, avoid human error, reduce the intensity of human eye fatigue and improve the automation level.

1. Introduction

High-precision pointer type instrument is widely used in industrial production because of its high precision and low price. However, the reading and regular inspection of high-precision pointer meters are operated manually, the work efficiency is low, the reading accuracy is not high, and the level of automation and intelligence is poor. It is necessary to design a high-precision pointer meter reading automation system [1].

For the automatic verification of pointer meters, the research at home and abroad focuses on image processing and reading recognition. Gu Siyan studied line extraction at sub-pixel level [1]. Wang Yanhua et al. proposed the method of HSV space transformation to eliminate the influence of pointer shadow [2]. Shi Rui used SVM method to identify the reading above the scale line, and then used area morphology to obtain the features of the scale line and identify the reading [3]. Pei Liqiang et al. proposed a new reading method based on look-up table method to eliminate viewpoint errors [4]. Most of these researches are aimed at the common pointer type instrument, and the particularity of the automatic verification of the pointer type instrument with higher precision is relatively few.

In this paper, a line extraction method combining LSD method and least square method, and a verification method of "three points and one line" are used to eliminate the viewpoint error, improve the efficiency of verification, and promote the automation and intelligence of instrument reading.

2. Current status of automatic reading of pointer meters

2.1. Identify methods and problems

There are two main identification methods: Angle method and distance method.

The Angle method refers to the method that calculates the actual number by the mapping relationship between the rotation Angle of the pointer and the range. The method extracts the pointer and its deflection Angle by subtracting the input image and the template image. For example, the clock face image without pointer is used as a reference image, and the pointer is obtained by making a difference with the input image.

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Least square method: Through wavelet transform algorithm, the pointer and scale line are extracted from the complex instrument image, and then the least square method is used to fit the position information of the pointer line, which eliminates the influence of many external noise such as light on the reading, but the calculation is large and the error is large.

The distance method means that the mapping relationship between the pointer and the scale is constructed through the relative position relationship between the pointer and the scale line to complete the final meter reading. Foreign scholar Alegria[5] first proposed the method of reading the number represented by the pointer instrument by the distance method, which converted the polar coordinates into linear scale and obtained the specific reading according to the pointer position.

Problem: The silhouette method has poor robustness because it is easily affected by illumination. The light intensity is prone to errors. Both image processing and position adjustment need to be improved continuously.

2.2. Reading methods and problems

To improve the accuracy of automatic reading, the scale line clusters are extracted by using the texture feature differences, and the two nearest scale lines to the pointer line are found, and the reading is calculated according to the different distances between the pointer line and them [6]. Some scholars have proposed a method that combines the central point projection method and Hough transform to extract pointer information, which has faster processing speed and smaller calculation, and can accurately detect the pointer position [7].

Photography is a kind of projection, different angles, different projections. It is difficult to align the center of the instrument in the process of photographing, resulting in viewpoint error.

Problem: For the problem of viewpoint error, the current method can reduce the impact of error, but it is complex to implement and has poor practicability. Continued research is needed: improving interference immunity and versatility.

2.3. A solution to the problem

This paper studies the reading method of pointer type instrument and designs the automatic verification system of pointer type instrument. The image processing algorithm is studied to correctly select the tick mark and pointer image.

The "three points and one line" method combining template matching and position alignment method is used, and the programming control precision displacement table is used to drive the vision system to move accurately, so that the vision center moves to the top of the checked scale line, and the "three points and one line" of the vision system center, the pointer and the shadow of the pointer in the mirror are realized. The hardware platform of the system is built and the software system is designed in accordance with the national verification regulations. Finally, the performance of the system is experimentally verified.

Aiming at the problem that the system is sensitive to light, an intelligent lighting system is designed to automatically control the exposure time according to the average gray value of the image. The software system is designed modularly, and the system verification interface is designed.

3. Overall system design

3.1. Principle of operation

Instrument automatic reading system is an industrial camera instead of human eyes to complete the identification, measurement, positioning and other functions. It can replace manual completion of pointer position detection, improve the speed and accuracy of instrument detection, improve work efficiency, reduce labor costs, and prevent misjudgment caused by eye fatigue.

General visual inspection system is composed of camera, lens, light source, computer, position adjustment mechanism, etc. This system consists of: computer, vision system, standard source and displacement platform. When verification, the system controls the displacement platform to drive the vision system to move to the inspected point, so that the inspected point is aligned with the center of the vision system to ensure the "three points and one line". The computer controls the standard source to generate driving signal, and the vision system collects the instrument image in real time and recognizes the meter reading. The computer adjusts the output power of the standard source according to the meter reading to ensure the monotone change, and judges the error between the display data of the meter and the output data of the standard source to complete the verification of the meter.

3.2. Overall structure design

The overall structure of the system is shown in Figure 1. The monocular vision system is fixed on the support of the precision displacement platform, and its movement is controlled by computer for alignment operation. The instrument is connected to the standard source; The computer system controls the standard source and precision displacement platform through serial port, and receives the returned coordinate information and power information. The computer system is connected to the vision system through the network cable, takes pictures and processes the returned pictures to obtain the meter readings; At the same time, the computer is also connected to the network in order to detect the remote transmission or printing of data.

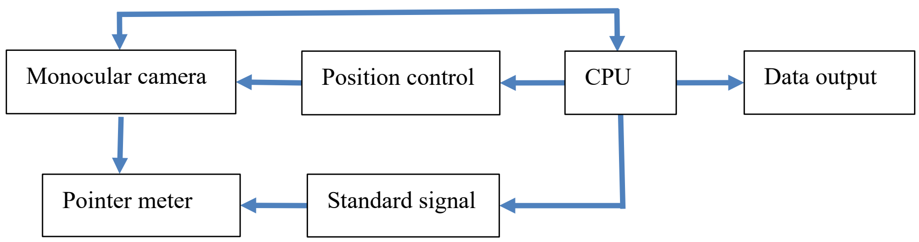

Figure 1 This caption has one line so it is centred.

3.3. Verification process design

The verification process should meet the requirements of relevant regulations. Taking the full inspection range of 0-100mA ammeter as an example, there are 101 scale lines on the dial, each two scale lines represent 1 mA, and the points to be verified are 10, 20,...... Integer scale of 100.

The system automatically determines the number and coordinate position of the detected points. The computer controls the displacement platform to move in place according to the stored coordinates. The vision center is directed to the detected point by using the "three point and one line method". And ensure that the electricity monotone rise, at the same time, the computer constantly take photos, and obtain the pointer reading, according to the verification requirements, when the pointer is just aligned with the calibration line, that is, when the difference between the pointer reading and the calibration is less than the specified value, read the standard source display electricity value, use the value to calculate the error, so far, complete the verification of a detection point. Continue to increase the output of the standard source, and control the camera to move to the second point, repeat the process, and so on. After the completion of the uplink verification, the control pointer exceeds the range, and then gradually monotonically decreases to complete the downlink verification. The computer automatically fills in the verification results and prints the verification certificate.

4. Components

4.1. Hardware Platform Composition

Standard source: for the high-precision pointer type instrument studied in this topic, the maximum allowable error is 0.5%, so when selecting the standard source, its accuracy should not exceed 0.05%; TDA-30D multimeter verification device is selected, its accuracy is (0.03%+0.02%)/ year, high stability, can verify 0.5 grade various types of AC and DC voltage ammeter, its range can cover the instrument to be tested, the output frequency range is wide, the power adjustment range is 0~110%, can ensure the pointer monotone continuous, meet the verification requirements;

Moreover, the standard source has RS232 serial port to meet the demand.

Precision displacement table: MC600 series motion controller, precision ball screw, high precision linear slider guide rail, can ensure the accuracy of repeated positioning, closed-loop resolution of 5 um, ensure straightness and parallelism, straightness and parallelism are not more than 10 um, the maximum center load 30 kg.

Vision system: The vision system is used to replace the human eye to collect images of the instrument to be tested. A general vision system consists of two main parts: an image sensor and a lens.

Image Sensor Image sensor acquisition is a necessary component of images, and its essential task is to capture digital images. CMOS can acquire electrical signal while collecting optical signal, and process information in parallel, so its processing speed is much faster than CCD, and the energy saving effect is better.

This system selects Insight-7000 series vision system, using CMOS image sensor and auto focus lens, with lighting function, can automatically obtain enough clear meter pictures, the image resolution is 1280x1024, when the vision system is located 4 cm above the inspected point, each scale line width is about 6 pixels. The number of pixels between the two scale marks is about 23, which meets the design requirements. It has 512MB image processing memory, which can complete the storage of pictures in the process of instrument verification, and has a network cable interface, which can transmit data with the computer in real time. Smart lighting system: The purchased Insight vision system has built-in lighting and can control the exposure time..

4.2. Software System Implementation

Development Platform: This system use c + + programming language, development environment for Microsoft VisualStudio 2013, using MFC interface design, and combining the OpenCV image processing visual library work, MFC (MicrosoftFoundationClasses, MFC (Microsoft Foundation Class Library) is short for Microsoft Foundation Class library, which is implemented by Microsoft for C++ environment, and mainly encapsulates most of the windows API functions [3-4]. At the same time, MFC contains the framework of the application, which saves a lot of work for developers. OpenCV is an open source vision library, including a large number of C language functions, at the same time, also has a small number of C++ classes, integrated with a large number of image processing algorithms, call is very convenient. This system uses Opencv3.0 to process the image.

Initialization and parameter selection module The module first carries out the initialization work, zeroing the content of each list of the interface, opening the displacement table and the standard source serial port, establishing TCP/IP connection with the vision system, and zeroing the value of the standard source and displacement platform, then selecting the type of instrument and the full inspection and non-full inspection range, and inputting the environmental temperature and humidity, verification personnel and other parameters.

The control module of the displacement platform and the computer transmit coordinate data to each other, and calculate the distance that the displacement platform needs to move according to the returned coordinate value, which can control the precision displacement platform to move in the x axis, y axis, z axis three directions.

The standard source control module controls the output power of the standard source, and calculates the difference between the meter reading read by the system and the measured quantity, and reduces the difference by one time to increase (or reduce) the output power size of the standard source, and the closer to the measured value, the greater the reduction of the increase, in order to prevent the pointer from exceeding the checked scale and ensure that the pointer changes monotonously. The vision system control module controls the exposure time of the vision system to change the light intensity to control the vision system to take pictures in real time and send the image back to the computer.

The image processing module preprocesses the returned image and extracts the scale lines and pointer features, and uses the "three points and one line" method to recognize the pointer reading.

The data calculation and processing module compares the standard source value read out with the standard value of the detected point, and calculates the point error and the backhaul difference. The verification certificate generation module will automatically fill in the calculated data in the verification certificate, and control the printer to automatically print the verification certificate.

5. Experimental verification

5.1. Objective of the experiment and Process of experiment

According to verification regulations, the automatic verification of pointer type instrument is to read the indication value of the standard source when the pointer of the instrument is aligned with the checked scale line, and calculate the error according to the difference between the indication value and the standard value. For the experimental verification of the system, the error result data of the department verification and the error result data of the professional verification personnel are compared and analyzed from various aspects, so as to verify whether the system meets the design requirements. In general, the main indicators to be verified in the experiment are:

Accuracy of system verification; Repeatability of system verification data; Whether the verification efficiency of the system is up to the standard; The versatility of the system.

The experiment uses T19/1-V AC and DC non-uniform pointer type instrument from Shanghai Liangbiao Instrument Co., LTD. The scale on the instrument is 0, 30, 40,..... , 150, the scale to be verified is 50, 60,...... , 150, the full detection range is 0~150V, the maximum allowable error is 0.5%. When the experiment was carried out, the ambient temperature of the laboratory was 22C and the humidity was 45%HR. Firstly, the instrument was verified by the system, and then in the same environment, the instrument verification professionals verified the same table again, and the two were compared and analyzed from the aspects of accuracy, repeatability and verification efficiency. Then in the selection of the same type of another instrument, the verification of its work, analysis of the verification data is correct.

5.2. Experimental results

En value is an index recognized by international organizations for evaluating laboratory calibration and verification capabilities. In this project, the En value will be used to verify the verification capabilities of the system. According to ISO/IE guidelines, the En value is calculated as follows:

$$E_n = \frac{x - X}{\sqrt{U_{lab}{}^2 + U_{ref}{}^2}}$$

X - the measurement results of the developed system;

X - the reference value of the reference laboratory;

Ulab - the developed system measures extended uncertainty;

Uref - Extended uncertainty of reference laboratory measurement

The En value can reflect whether the measurement result is in the specific measurement uncertainty of the reference value. When | En | 1 or less, that reference laboratory measurements of difference within reasonable expectations, and a reference laboratory has the capability of the school and verification, on the other hand, does not have this ability.

In order to calculate the En value, it is first necessary to calculate the extended uncertainty Ulab of the measurement results of the reference laboratory, taking into account the components of each uncertainty.The resolution of the visual system is 1280x1024, the scale of the measured AC/DC ammeter is 100 grids, and the image taken near the detection point can be taken with 1280 resolution to cover 60 small grids, so the resolution error corresponds to 3/64 of 1 small grid.

The closed-loop resolution of the displacement system is 1um, and the moving distance between the image pixel and the displacement platform is 17 pixels: 1mm. The 1280 resolution of the image covers 60 small grids, so the value of the resolution error corresponding to 1 small grid is 0.000797V.Uncertainty component U(VF) introduced by the resolution of the table inspected.

When the value of the AC/DC voltmeter is 150V, the resolution is 0.75V. In the interval of 0.375V, the current value is taken at any value. According to the uniform distribution, U(VF)=0.2165IV.

5.3. Experimental results

The working stability of the system is expressed by the repeatability error of the data. In this paper, the same instrument was verified five times successively, and the repeatability of the data was analyzed by calculating the verification error of each point. The statistical verification error is shown in FIG. 2. :

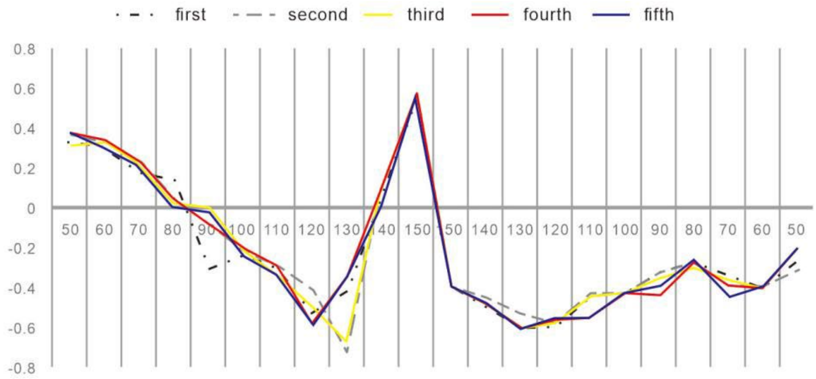

Figure 2 Statistical line chart of five verification errors at each point.

In terms of verification efficiency, because the manual verification process includes manual verification and data calculation two parts, for T19/1-V AC and DC pointer instrument detection, the general verification personnel to complete the entire verification process takes about 60 minutes, but the system only takes 32 minutes, the verification efficiency is greatly improved.

In order to verify the universality of the system, the experiment verifies three instruments of T19/1-V with different sizes. The maximum error of the system verification correction value of each meter is 0.2V, and the calculated En value is 0.67.

5.4. Error analysis

Errors in hardware: All hardware in the system can be a source of errors.

The closed-loop resolution of the precision displacement platform is l um, and the system needs to use this equipment to complete the accurate position alignment between the vision center and the scale line. However, the internal grating displacement sensor is very precise. If it is worn out with the increase of use time or external factors, the accuracy of the displacement platform will be seriously affected, resulting in systematic errors.

For the vision system, lens lens distortion will lead to lens distortion, which is difficult to eliminate. At the same time, CMOS image sensor, in the process of collecting images, may lose part of the data, affecting the recognition of images, resulting in errors.

The error in the software is mainly reflected in the error caused by the algorithm: in the early image processing algorithm of this project, although the bilinear gray interpolation algorithm can retain most of the image details, there are still a small number of details lost;

For the "three points and one line" method used in this topic, there may be deviation when the template matching algorithm matches the number, which affects the accuracy of scale mark recognition. At the same time, if the height of the visual system changes due to external factors, the center of the visual system may not reach the center of the image according to the original distance, and the system may also produce reading errors.

6. Conclusion

Aiming at the problem that the viewpoint error is difficult to eliminate and the versatility is poor in the automatic verification system of high-precision pointer instrument, this paper designs and implements an automatic verification system based on "three points and one line" method. In order to ensure the accuracy and stability of the pointer reading recognition system, a precision displacement table is used to accurately control the coordinate position of the vision system. The meter is photographed in real time and the image processing algorithm is used for reading. The results are as follows:

(1) In order to ensure the accuracy of image recognition, the gray-level interpolation algorithm is used to locally enlarge the processed image.

(2) In order to extract the straight line features of scale lines and Pointers accurately, on the basis of studying and implementing the LSD method based on sub-pixel level, a method of extracting the straight line of scale lines and Pointers based on the combination of LSD and least squares method is proposed.

(3) Aiming at the viewpoint error when the camera takes the instrument picture, a three-dimensional error model is established, in which there is an Angle between the lens plane and the instrument plane, and there is a displacement between the lens optical center and the pointer rotation center.

(4) In order to ensure the accuracy of the reading of the detection point, a reading recognition method of "three points and one line" is proposed. The intersection of the calibration line and the calibration arc of the detection point is used as the matching point.

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