Visual Servo Motion Control Study of Screw Holes Alignment

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Keywords: Electric energy meter sealing, Screw holes alignment, Visual servo motion control.

Abstract. According to electric energy meter sealing in electrical metrology industry, the automatic screw holes alignment visual servo motion control technology is studied. Identification and positioning of the screw hole is conducted with digital image processing technology, the visual servo motion control procedure is designed, and finally the control software is operated in actual platform. The operating results verify that the visual servo motion control system has good progressiveness and reliability.

Introduction

In the state power industry reform environment, the State Grid Corporation in order to promote the standardization and unification of the industry, using a new type of electric meter anti-theft seal. It is different from the current meter seal. Therefore, there is an urgent need to unify the promotion of new energy meter seal work for the national grid company. Study the corresponding new automatic sealing technology, Development of new automatic sealing machine, to further enhance the innovation of project research.

Realize the automatic sealing of the energy meter, need to be flexible sealing wire through the screw hole, and then seal the block on both sides set tight and pressing. The action may seem simple, but automatic processing through the electromechanical device requires both a very smart organization and a very intelligent motion control software to implement the subtle control of the whole work.

Before the lead is sealed, it is necessary to automatically align the holes of the screws, and obtain the exact position of the hole, and the position information is transferred to the subsequent threading seal module, to provide protection for the reliable sealing wire. The main work of this paper is to introduce the technology of machine vision, through the design of the camera system design of software and hardware platform of smart technology, visual servo motion control research of hole screw, automatic hole function of adaptive lifting screw, automatic sealing equipment intelligent system reliability and system level.

Hardware and Software Platform of the System

The hardware platform of the system is shown in Figure 1. It is mainly composed of screw locking device, motor, camera and light source device, electric meter clamping mechanism, industrial control computer and so on. Screw nail diagram as shown in Figure 2, which moves up and down the screwing device on the motor control, the meter screw on the tight screwing rotation motor control screwdriver, electric meter by the line clamping device for positioning and clamping.

The camera system consists of an industrial camera, a point light, and a prism. The camera system is built as shown in Figure 3. The utility model is characterized in that the point lights to the screw hole lighting, then install the prism transparent reflection screw hole for industrial camera.
The system software runs in the industrial computer system with windows7 embedded version. Using the OpenCV visual library, in the Visual Studio 2010 environment using C++ language development.

Figure 1. Hardware platform structure of the system.
Figure 2. Schematic diagram of screwing nails.
Figure 3. Sketch map of camera system.
Figure 4. Screw hole position is positive.

Visual Recognition of Screw Hole Position

Real-time acquisition and recognition of the image of the screw hole is the basic condition of the servo servo to the hole motion control. Figure 4 to Figure 6 shows the camera to collect the screw hole light transmission situation, the Figure 4 for the hole alignment, point light source can completely through the screw hole, so the image formed a good round bright area, Figure 5 and Figure 6 are images of holes when the hole position is not correct.
Because of the relative position of the prism and the camera is fixed, in order to improve the speed of image processing, Only the image corresponding to the prism should be processed, Thus, extracting the image of the prism as shown in Figure 4~Figure 6, obtains the image of the region of interest processing shown in Figure 7.

In order to identify and locate the bright areas, Using an algorithm processing flow shown in Figure 8, including binarization and contour extraction of the image, and then the contour image morphological processing contour processing area, sub-pixel contour and higher accuracy in the region extraction, then the sub-pixel contour linear and circular segmentation, contour extraction by screening arc, merge and ellipse fitting of arc, based on the size and fitting degree is in that state and hole hole position.

For Figure 7, according to the actual situation, the 200 is taken as a threshold value and the contour is extracted to obtain the contour image shown in Figure 9.

The contours obtained in Figure 9 are subjected to expansion treatment and the area obtained by the expansion is now limited in the processing range in Figure 7, and the resulting new image of interest is shown in Figure 10. The sub-pixel contour extraction is further performed on the graph and segmented by a straight arc, and the contour line shown in Figure 11 can be obtained.
The contours of Figure 11 are arc screened and merged. Then, fitting by arc get the result shown in Figure 12, the blue fitted ellipse. Finally, it is judged whether the hole is right by the ratio of the length of the ellipse and the two value of the image contained in the ellipse. The center of gravity of the hole is further obtained by the position of the ellipse. So as to achieve the judgment and positioning of the screw hole.

**Visual Servo Control of Hole Movement**

The actual control flow of the system is shown in Figure 13. First, the upper and lower moving motor shown in Figure 1 and Figure 2 control screwdriver moves down, aligns and presses the upper left corner screw of the meter, and then the screw is screwed to control the screwdriver, and the camera captures the image in real time. After the end of the hole, the position information of the hole is obtained according to the result of the visual processing, and the screwdriver.
The frame of the visual screw servo control is shown in Figure 14. First of all, given the parameters of the standard round hole (mainly including the radius of the hole, the arc of the fit), while the nail at the same time, real-time collection of circular hole images, and screw holes for visual recognition. Set the parameters to compare, when close to the given value (given the allowable error), stop the motor movement.

![Figure 14. Visual screw servo control framework.](image)

Since the screw is a cross hole, it is only necessary to rotate the 1/4 ring at the worst case to achieve accurate alignment. Therefore, the camera frame rate used in this paper is 60 frames per second, the rotation speed of the screwdriver is 60 degrees per second, then the hole accuracy of 1 degree can be ensured. The system delay and stop delay and interrupt timer error and other factors are taken into account, the worst case with 3 degrees on the hole accuracy, which fully meet the practical application requirements.

In the practical application, set the interrupt cycle of 20 milliseconds, in the interrupt program to control the screw and the image processing, interrupt the program flow shown in Figure 15. Actually, the interrupt routine should be activated while the screw motor is started. Every 20 milliseconds, enter the interrupt program, first through the industrial camera to capture the current image, and then deal with the image, identify the hole parameters, and then compare with the given parameters, if the alignment conditions, then immediately stop the screw motor. And get the location information, or continue to wait for the next cycle to come, loop the process.

![Figure 15. The visual servo interrupt program flow of the screw to the hole.](image)

**Summary**

In this paper, according to the electric power industry in the sealing work, designed a visual screw-to-hole mechanism and control system. Based on the digital image processing technology of OpenCV, the obtained screw hole image preprocessing, sub-pixel contour extraction, arc fitting, etc., to obtain the fitting degree and position of the hole, to achieve the intelligent visual screw nail control. The results of the project has been applied to the EPRI's automatic gauge control system for energy meter, which greatly improves the automatic level of the seal and the reliability of the system.

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