Automatic Value Identification of Pointer-Type Pressure Gauge Based on Machine Vision

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Abstract—**This paper presents a new method of value identification of pointer-type pressure gauges based on machine vision, by which an automatic calibration system can be designed. Hough Transformation, image subtraction and image thinning technique are employed to obtain the coordinate of the pointer rotating center. Through removing the pixels data outside of the circumference of the pointer in the single panel image, the linear equation of the pointer is achieved after the processing of image thinning and Hough transformation. Experiments are carried out on a pressure calibration device. The results show that the accuracy and speed of the automatic identification of the pressure gauge is improved.**

Index Terms—**Machine Vision, Hough Transformation, Gauge panel**

I. INTRODUCTION

The calibration of pointer-type pressure gauges is an inefficient job due to the large number of these gauges and difficulties of reading the values on the panel by eyes without any impacts of subjective factors, such as the angle between the line of sight and the panel, the distance and the mood of the operator. Because of the limitation of human eyes, a man can only identify the pointer position roughly when it locates between two scale lines. Different results will be obtained to the same value by two operators. Unreliable results will be occurred because the repetitive action of reading panels is a tiring work.

Many experts are committed to solve this problem. F. Corra Alegria [1,2] illustrated the identifying process of the pointer instrument using machine vision. Firstly, two images of the pointers in different places will be collected. Through the Hough algorithm, the included angle of the two pointers in the subtracted image is obtained. After the geometric transformation is taken to the original images, the scale lines are arranged by horizon while vertical with the pointers. Finally, the value of the instrument can be calculated based on the position of pointer and scale lines. This method may have some mistakes when the grayscales of the two images' background are a little different. These noise points from the background could affect the accuracy of results.

Sablatnig R and Kropatsch W.G [3] came up with another idea to identify the value of the pointer-type gauges which are distributed only on one circumference such as the meter and centigrade meter. The rotating range of the pointer is 360 degree, so Sablatnig can use the Hough transform to get the angle of the pointer directly after the dividing of the images to ensure the correct value of the pointer-type gauges. Because of the existence of the field of view between the camera and gauge, the accuracy of this method is affected.

Liu Shuguang [4] introduced a new method which applied the wavelet transformation and least square method. Wavelet transformation is used to obtain the set of the edge points of the pointer and scale lines, and least square method is used to detect the lines. Then determine the value of the gauge based on the linear equation of pointer and scale lines. This method needs to know the set of all the scale lines and the pointer. But Hough Transformation could determine the line in an image directly without the set of the scale lines and the pointer.

Some efforts still have to be made to achieve more accurate values, especially for the calibration system. The quality of lighting condition has a great influence on the image processing of getting the value of a gauge. Some algorithm needs a large storage capacity and a large amount of calculation. A new method based on machine vision technique is proposed to get the value of pressure gauge automatically in this paper. The speed of the automatic identification of the pressure gauge is improved.

II. THE STRUCTURE OF SYSTEM

The system structure of the hardware is show in Figure 1, which is mainly composed of the computer, industrial CCD camera and lens, installation device and the pressure gauge. The resolution of CCD camera, connected with PC by USB 2.0, is 1280*1024, with the manual zoom and aperture lens.
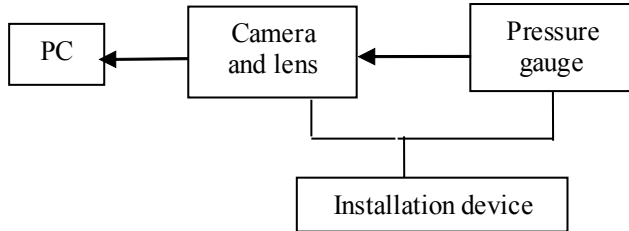
Figure 1.   Hardware structure

The camera is adjusted properly and vertically with the pressure gauge with the installation device to ensure that the images of the panel will fill the screen of camera. The picture will be captured and transferred to PC through the USB interface.

III. THE ALGORITHM

The algorithms of image binary, image subtraction, image thinning and Hough transformation are applied to process the pictures.

A. Hough Transformation

Hough transformation is widely used to detect the lines in an image due to its accuracy and the strong anti-jamming capability[5,6,11]. But large storage capacity and large amount of calculation is required for this algorithm. The core thoughts of the algorithm are transformation of the lines in the Cartesian coordinates to the points in the Polar coordinates.
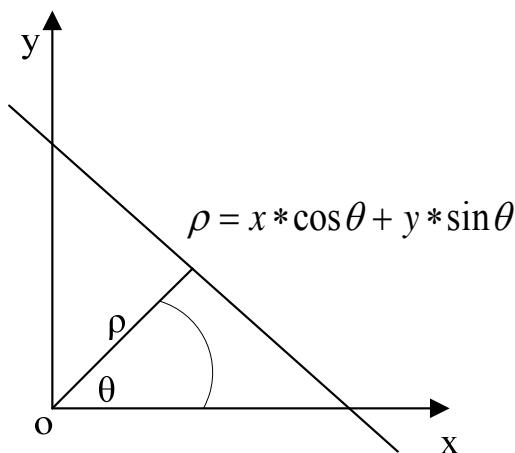
$$\rho = x * \cos\theta + y * \sin\theta$$

Figure 2.   Cartesian coordinates to Polar coordinates

The formula is as follows[7,8]:

$$\rho = x * \cos\theta + y * \sin\theta \qquad (1)$$

where ρ denotes the distance of normal line between the origin of coordinates and the line. x, y denote the abscissa and the ordinate. θ denotes the angle between the normal line and the X axis.

In the transformation, (ρ, θ) is divided into many small units firstly. The step-size is set to $1/20°$ in this paper to ensure the accuracy. Then all the 0-gray-scaled pixels (the black pixels) calculated according to formula (1) to obtain a set of values ρ. An accumulator is set up. The accumulator of this point plus one when a point in the Polar coordinates is obtained. After the transformation of all these black pixels, the equation of the longest line in this image can be achieved by searching the maximum value in the transform domain.
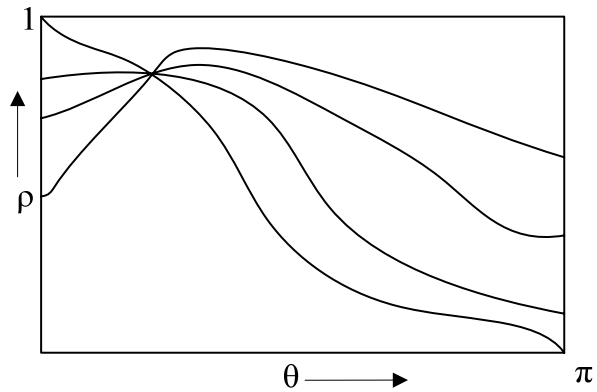
Figure 3.   Hough Transform

B. Image Thinning

Image thinning is actually seeking image skeleton, namely the central part of the image [9,10]. The formula can be expressed as:

$$S = X - X \uparrow B \qquad (2)$$

where S is the set of pixels after the image thinning, X is the set of pixels used by image thinning. $\uparrow$ denotes the hit-miss transformation.
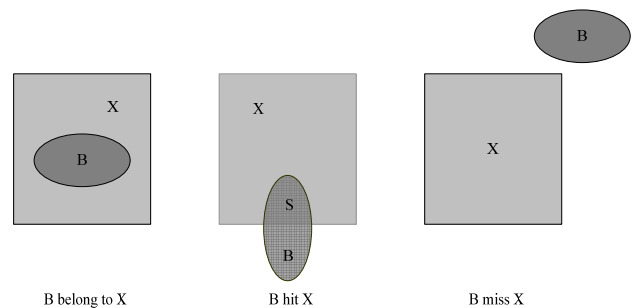
Figure 4.   Hit-miss transform

The Hilditch algorithm is applied to get the bone of the images in this work. The speed of Hough transformation will be faster after the image thinning.

The middle square is the pixel waiting to be decided to delete or not. It depends on the eight pixels around it. The pixels like (3) and (4) in figure 5 should be deleted and the others should be remained. In the processing of image thinning, repeat the step of deleting the pixels which meet the conditions till no pixels meet the conditions.
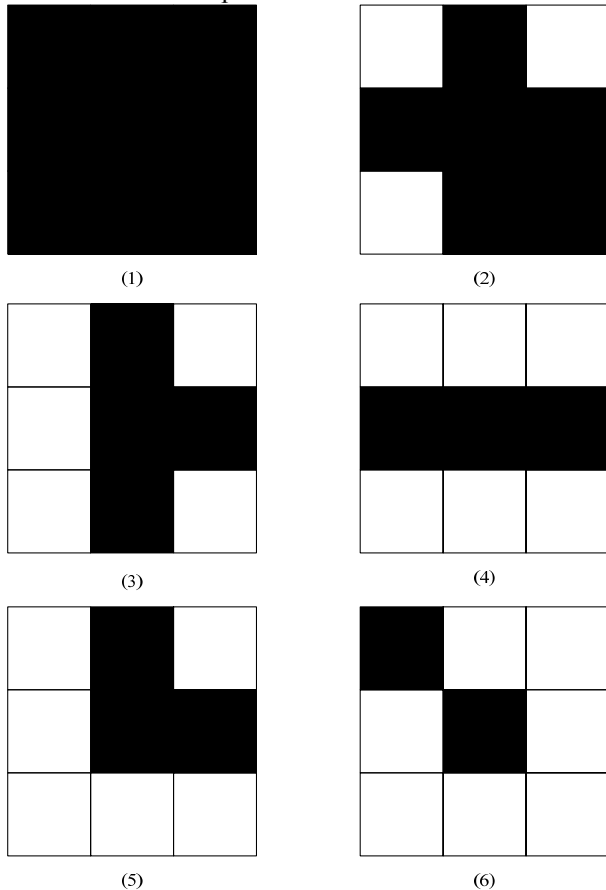

Figure 5.   Image thinning

The aim of using image thinning is to get the bone of the pointer, reduce the amount of computation of Hough transformation when detecting the pointers.

C. Image Subtraction

The useless parts of the image can be removed and the parts which are essential to values identification are remained by image subtraction [1,2], which is usually used to detect the moving objects, and in this work, is used to calculate the rotating center of the pointer. A panel image is subtracted by another one which is captured in different pressure. The background of the panel is eliminated and only tow pointers are left in the image.The formula can be expressed as:

$$g(x, y) = \left| f_1(x, y) - f_2(x, y) \right| \qquad (3)$$

where $g(x, y)$ is the gray value at the position of (x, y) after the subtraction; $f_1(x, y)$ and $f_2(x, y)$ are the gray values at the position of (x, y) of two origin images.

D. Binarization

Binarization transforms the gray image to 0-1 scale image. The whole image only has black or white pixels after the binarization. The image data are simplified by this step[12-14].

The threshold is obtained by iterative methods. Its formula can be expressed as:

$$T = (\mu_1 + \mu_2)/2 \qquad (4)$$

where T is the threshold   of the binarization transforms ; μ_1 and μ_2 is the average   gray value of pixels whose gray value is bigger than T and smaller than T in the image.

$$g(x, y) = \begin{cases} 255, f(x, y) \geq T \\ 0, f(x, y) < T \end{cases} \qquad (5)$$

where $g(x, y)$ denotes the gray value at the position of (x, y) after the binarization ; $f(x, y)$ is the gray value at the position of (x, y) before the binarization.

The initial value of T is 127. Put the new T , μ_1 and μ_2 into formula (4) till the value of μ_1 and μ_2 doesn't change anymore. Then transform the image to binary valued by formula (5) .

Binarization is used to distinguish the object of interest and background. This paper use binarization to highlight the pointer shape.

IV. EXPERIMENTS AND RESULTS

The algorithm of the image processing mentioned above is employed to identify values of the pressure gauges automatically. Detailed steps are shown in Figure 6.
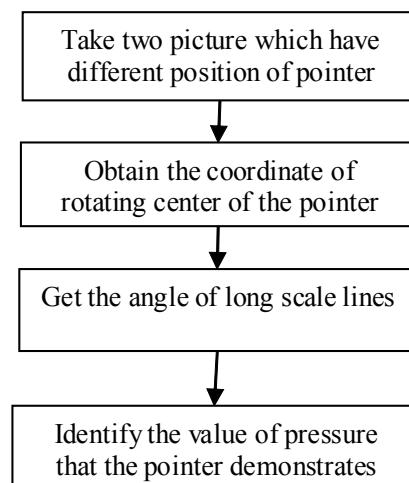

Figure 6.   Detailed steps of value identification

A. Extract the Radius and the Rotating Center of Pointer

Two pieces of images having different pointer positions are subtracted. The image contained only two pointers is achieved by setting the right threshold to

binarizate and refine it. The included angle of this two images couldn't be too small.
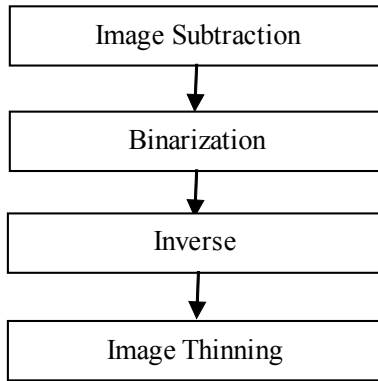

Figure 7.   Image preprocessing before the extraction

Before extract the radius and the rotating center of pointer, image preprocessing is necessary. The steps of algorithm of image preprocessing are shown in Figure 7. The feature of the image would be more obvious after the image preprocessing, and it is helpful in the image processing of Hough Transform while detecting the two pointers. The results of every step of algorithm are shown in Figure 8.
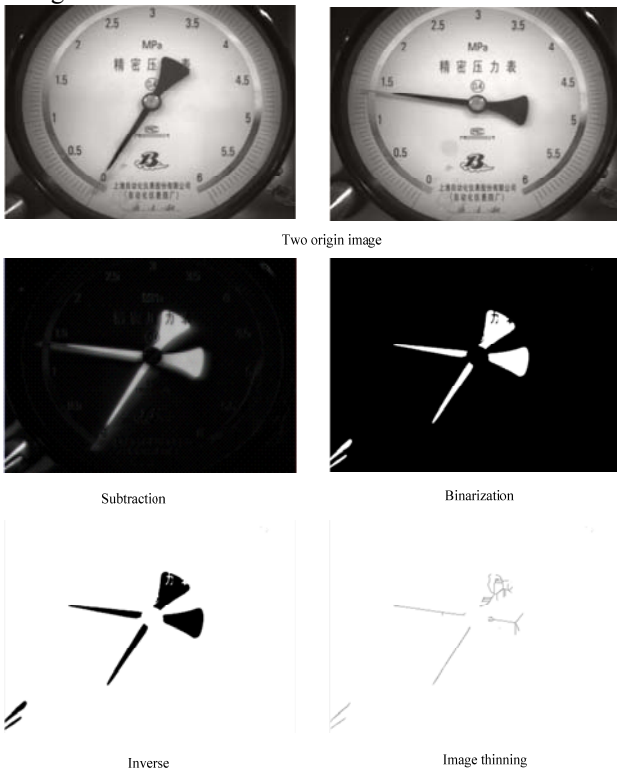

Figure 8.   Extract the rotating center of pointer

After the image preprocessing, Hough transformation is applied to detect the two pointers. Two largest values have been given in the transformation domain after the image processing by using Hough transformation. The linear equation about two pointers can be obtained. The rotating center of the pressure gauge is the intersection of two lines. Find the point which belongs to the line and has the longest

distance with the center point. This longest distance is the radius of the pointer.

B. Detect the Pointer in a Single Image

The steps of algorithm of image preprocessing before detecting the pointer in a single image are shown in Figure 9.
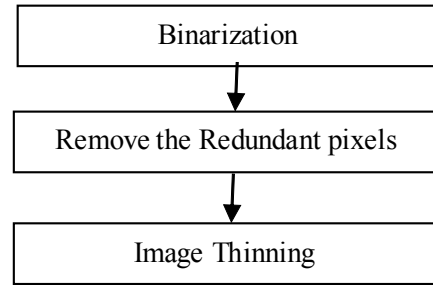

Figure 9.   Image preprocessing before detecting the pointer

First, remove the pixels data outside of the circumference of the pointer to reduce data of the following steps. The linear equation is obtained through Hough transformation after the image being processed by the algorithms of binarization and Hilditch [10]. The results of every step before detecting the pointer in a single image are shown as follows:
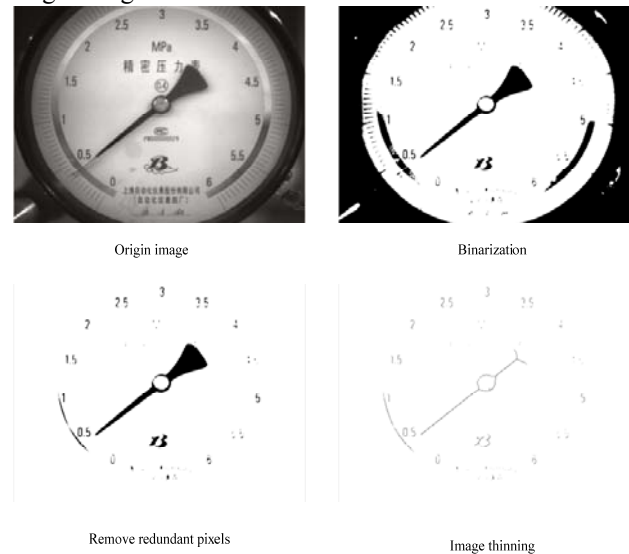

Figure 10. Detect the pointer in single image

Each pixel in this line is compared with the rotating center to determine which quadrant it belongs to. An accumulator is established to calculate the numbers of pixels in different quadrants. The largest value in the accumulator is the quadrants which the pointer belongs to. Then the angle of the pointer in the Cartesian coordinates is calculated.

C. Calculate the Value of Gauge

Some mistakes may occur if the values of gauge are calculated through comparison of the angle between zero scale in the image and the pointer in the target image, especially when the scales are not uniform. The longer

scales should be calibrated to reduce these mistakes. The angles of these longer scales can be obtained by the method in B of this section through processing the pictures of the pointer point to the longer scales.

Through analyzing of which two longer scales the pointer is between, the angle of the pointer in the target image can be calculated by:

$$p = p_1 + \frac{M * (\theta - \theta_1)}{(\theta_2 - \theta_1)} \qquad (6)$$

where p is the value of gauge; p_1 is the value of previous longer scale; M is the value between two longer scales; $\theta, \theta_1, \theta_2$ are the angles of the target pointer, the previous longer scale and the latter scale respectively.

The experiments are carried out on a pressure calibration system. A pressure gauge, made by the Shanghai Automation Instrumentation Company with the measurement range of 6 MPa and 0.5 MPa between two longer scales, is selected as the testing gauge. The experimental results are shown in Table 1.

TABLE I.
EXPERIMENTAL RESULTS

Human Reading Values (MPa)	Identified Values (MPa)
0.02	0.020
0.10	0.103
0.39	0.399
0.88	0.888
1.36	1.363
2.45	2.449
3.69	3.687
4.55	4.554
5.32	5.316

D. Error Analysis

There are some factors which may affect the accuracy of this system. The main factors are as follows:
- The condition of the light around the camera and the panel.
- Small angle between the field of camera's view and the panel's surface.
- Reflective of the glass surface.
- The shadow of the pointer

The quality of gauge panel images would be affected by these factors and make some pixels become the noise points .They would decrease the accuracy when the pointer equation is detected with Hough transformation. But these influence caused by these factors could be reduced after appropriate image preprocessing. The

comparison error between identified values and human reading values are shown in Figure11.

From the Figure.11 knows that the maximum between identified values and human reading values is smaller than 0.01 MPa while the value between two smallest scale lines is 0.05 MPa .

The results indicate that this method is reliable. In fact, people couldn't judge the value accurately when the pointer locates between two smallest scale lines. Therefore, the identified values are more accurate than human reading values in most cases.
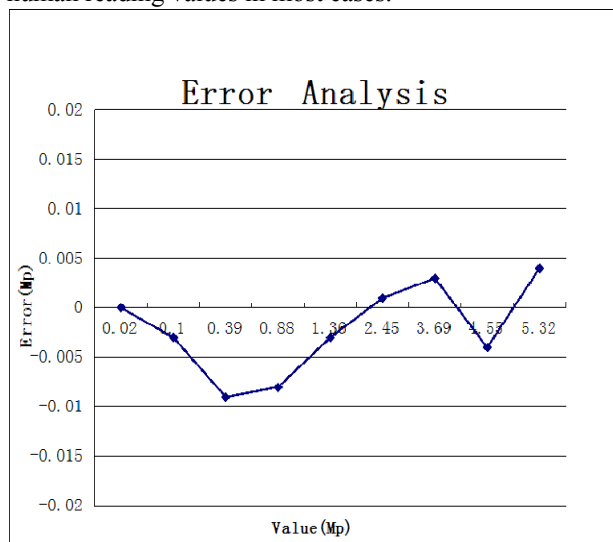

Figure 11. The comparison error between identified values and human reading values

V. CONCLUSION

This paper use image subtraction, binarization, image thinning to make the feature of the image more obvious. Hough transformation is used to detect the lines in the processing of extracting the radius and the rotating center of pointer and detect the pointer in single image. Removing the pixels data outside of the circumference of the Pointer before Hough transformation when detecting the angle of pointer in a single image greatly reduce the impact of the unrelated pixels.

The appropriate image processing eliminate the redundant pixels to decrease the influence of the noise pixels. The experimental results show that this machine vision method of reading the pressure values on the gauge panel automatically is reliable and more accurate. The accuracy and speed of values identification is increased when the equation of the line is calculated by the presented algorithm. A method is employed to contribute to reduce the non uniform errors. Compared with the methods introduced in thesis[1,2,3,4] , the testing results show that the method is more effective and reliable.

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