An Automatic Calibration System for Multiple Pointer Water Meters using Image Processing Technology

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Abstract **— Most Chinese water meter factories products are calibrated manually, which is efficient and labor intensive. In this paper, the system is re-designed using image processing technology for pointer meter automatic calibration, as follows: i) a camera is used to obtain water meter image, ii) image processing techniques acquire water meter data, iii) the system calculates water meter random errors, iv) an automatic system is developed to judge whether the water meter is qualified, v) the calibration results are automatically stored in database. Experimental tests show the system to be easy to use and automatic, it has high accuracy and can completely replace the manual system.**

Key words - Water meter calibration; VB.NET; Hough transform

I. INTRODUCTION

Water meters need to be calibrated before they are dispatched from the factory and only the qualified water meter can be launched into market. At present, most Chinese meter factories calibrate meters by manual work, the operators copy the meter data and calculate random errors in front of inspecting device, the verification efficiency is very low, while the workload is big and the calculation of water meter will be influenced by human. The water meter factory usually owns large scale of outputs, so meter calibration is an important part, which large amount of labor and cost should be needed. So an automatic calibration system is needed in order to reduce cost. This paper designs a model based on image processing technology of pointer meter automatic calibration system, the camera is used to obtain water meter image and image processing techniques is identified for water meter figures, to determine whether a water meter is qualified and to complete timing process automatically. Compared with traditional manual calibration, it greatly improves the work efficiency, and also overcome the human random errors.

II. OVERRALL DESIGNOFTHE CALIBRATIONSYSTEM

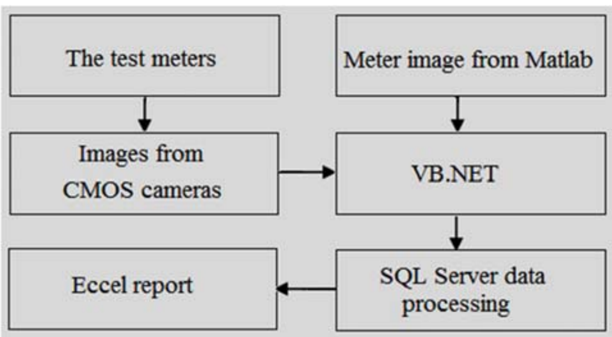

Figure 1 Calibration system block diagram.

The total flow chart of the calibration system is shown in figure 1. This system is developed based on VB.NET and the application mainly includes image acquisition, image processing and data processing. The CMOS camera is smaller and cheaper with a higher image taking speed than CCD camera at the same time and is more appropriate to be used to acquire digital images in this system. The application calls CMOS camera dynamic link library (DLL) for water meter images. According to special feature of water meter dial's images, the reading is automatically read through a series of processing procedure, such as color space transformation, gray-scale transformation, dilation and erosion and so on by calling Matlab image processing dynamic link library, so as to recognize the reading and judge the product defect or not. The obtained calibration data are saved to SQL Server database. At the same time, The Excel report can be exported based on meter calibration data for the convenience of the data audit and processing. This paper mainly introduces the system core content meter data recognition part.

III. IMAGE PROCESSING OF THE WATER METER

A. Image Pretreatment of the Water Meter

The recognition accuracy of Water meters is influenced by many stochastic factors such as light intensity. As a result, the pretreatment is imposed on the sampled real-time image sequence to enhance image quality. The main steps in that image preprocessing technique includes the color space transformation, gray-scale transformation, decreasing noise by corrosion and expansion algorithm, binarization, edge processing and roughening treatment, etc. As is shown in Figure 2.

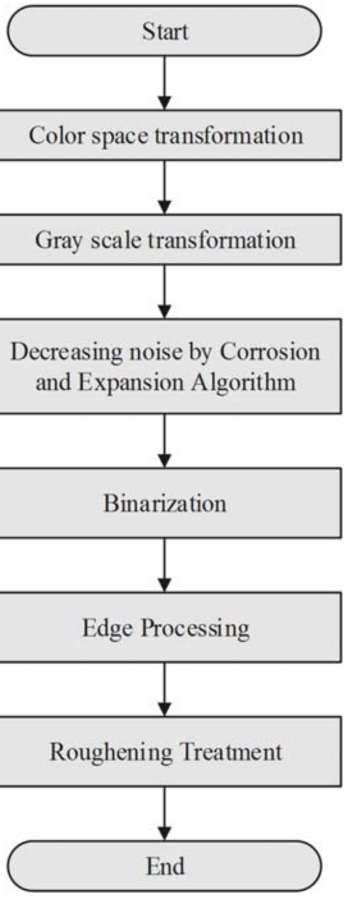

Figure 2 The flow chart of water meter image pretreatment

We have to adopt some methods separating target image, the red accented hands, of interest from the background. It is essential that RGB color space be converted into YCbCr space in image processing of water meters because RGB images which achieved through CMOS camera are established by hue, saturation and intensity and the level of correlation between these elements is rather high, therefore, it is really hard to identify red Pointers in the RGB image. YCbCr is an effective descriptive format of color image and in the YCbCr color space, the luminance information is contained in Y component while the chrominance information is in Cb and Cr. Conversion relationship between these two colors is defined as shown below.

$$\begin{aligned} Y &= 0.299 * R + 0.587 * G + 0.114 * B \\ Cb &= -0.1687 * R - 0.3313 * G + 0.5 * B + 128 \\ Cr &= 0.5 * R - 0.4187 * G - 0.0813 * B + 128 \end{aligned} \quad (1)$$

Figure 3 shows the R component map of a RGB image and the Cr component of YCbCr image, and it could be seen that the YCbCr image is obviously more easily distinguished.

Figure 3 R components.

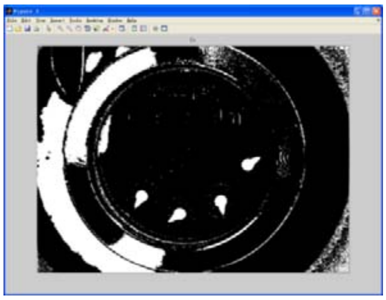

Figure 4 Cr components.

To get the binary image, we used a method of converting Cr Component to Gray-scale images and set threshold of parameter in a certain range between 0 and 1, as shown in the figure 4. Features between a background graphic and an image of water meter were easily distinguishable, but there were so many noisy point that the analysis of the result was yet not so reliable.

Figure 5 Grayscale.

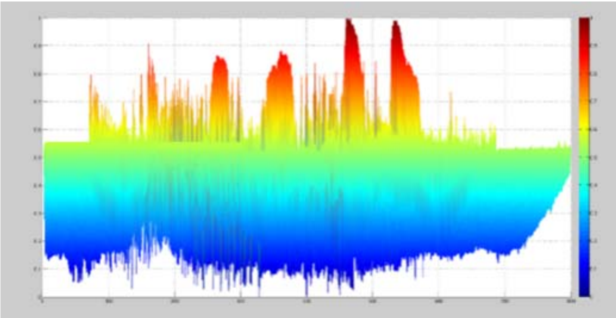

Figure 6 Cr X - Z floor plan after grayscale transformation.

So we should deal with the noise. The gray image segmentation is mainly carried out by using a group of 3*3 pixels square structural elements. After that, the image should do corrosion operation firstly, and then do the expansion operation to remove noise. After adding lost elements, we get figure 5(a), and pointer image is shown in figure 6. You can see the image noise interference is almost non-existent.

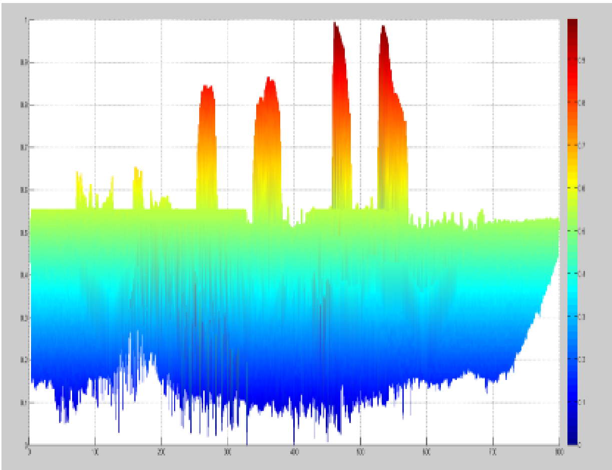

Figure 7 Cr X - Z floor plan after corrosion.

Figure 8 Pointer figure after corrosion expansion

Then, binary images by following formula:

$$g(x,y)=\begin{cases}1, & f(x,y)\geq t\\ 0, & f(x,y)<t\end{cases} \qquad (2)$$

$f(x,y)$is eager to be solved, $g(x,y)$ is the image which have been binary, it is selected by the method of corresponding threshold value of the target area. Pending the grayscale image which is greater or equal to the threshold of the pixels were set to 1, actually white, and the less are set to black. Then, we got two binarization images as is shown in figure 7. We usedMatlab to image edge extraction, and canny calculate was utilized to extract edge figure as shown in figure 8. The some part would be weak in the pointer, the pointerwould influence the circle number when we do center extraction. This had a great influence in the result. So, it was necessary to increase the edge pixels to coarsening pointer edge. As a result, the move cleared the edge, and reduced the influence of the following conduct.

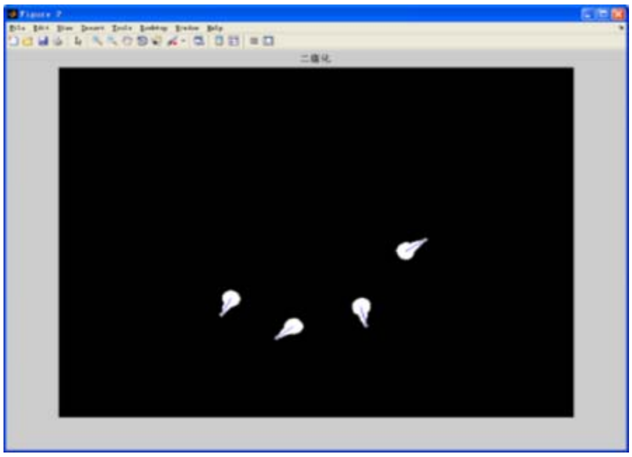

Figure 9 Brinarization image.

Figure 10 Edge Image of Extraction Pointer.

B. To Determine the Vertex Coordinate and Location for the Center of the Circle

Through the Hough Transform, the edge points of original image space was mapped to parameter space. As known to us all, parameter expression of a circle is$(x_i-a)^2+(y_i-b)^2=r^2$. There is a mapping relationship

DOI 10.5013/IJSSST.a.17.47.33

ISSN: 1473-804x online, 1473-8031 print

between (x_i,y_i) parameter in original image space and (a,b,r) parameter in parameter space. Infect, all the points in the same circle can only be mapped to the same (a,b,r) parameter in parameter space. The largest number of (a,b,r) is the center. Instead of using traditional Hough Transform to receive the center coordinate which is not unique, we improves the algorithm to ensure uniqueness and to improve accuracy. After the blocking on center coordinate, it is compared and analyzed to identify which one are belongs to the same pointers on the basis of what difference between different center coordinates, and adjacent coordinates belongs to the same pointers have to be summed and averaged, thereby unique center coordinate corresponding to every edge of different pointers can be obtained. There is a custom range in Hough Transform for searching without a certain query scope. It can overcomes the irregularity radius of pointers, making the algorithm used for this system more adaptive obviously. Since both the position of cameras and water meters are unlikely to be accurate, the water meters dial's images what we received are different sizes, so was the radius of pointers.

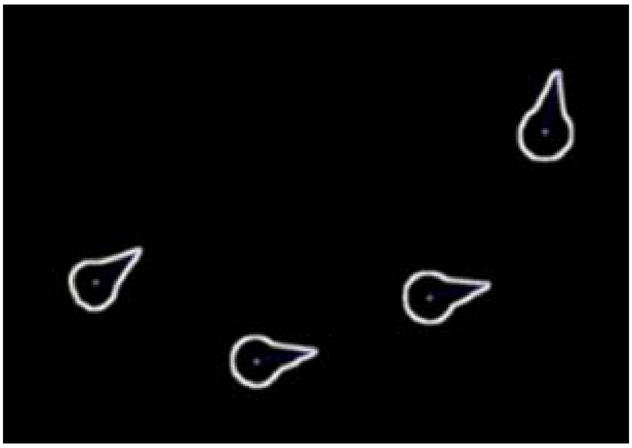

Figure 11 Center Calculated by Hough transform

The determination of flow chart is shown in figure 10. The maximum distance method is the simplest solution to the determination of the vertex coordinate. The process is that distance between the center and other points are recorded for identifying vertex coordinate because the longest distance is the stretch from origin to peak of the pointer, this is more evident than ever. Tag connected region of binary image. The connected region is topped by the coordinates of center. Researchers calculated vertex coordinate by analyzing the distance between the center and every edge pixel, according to the theory that the point where a pixel is at the greatest distance from the center coordinates was seemed to be the really tip of the pointer.

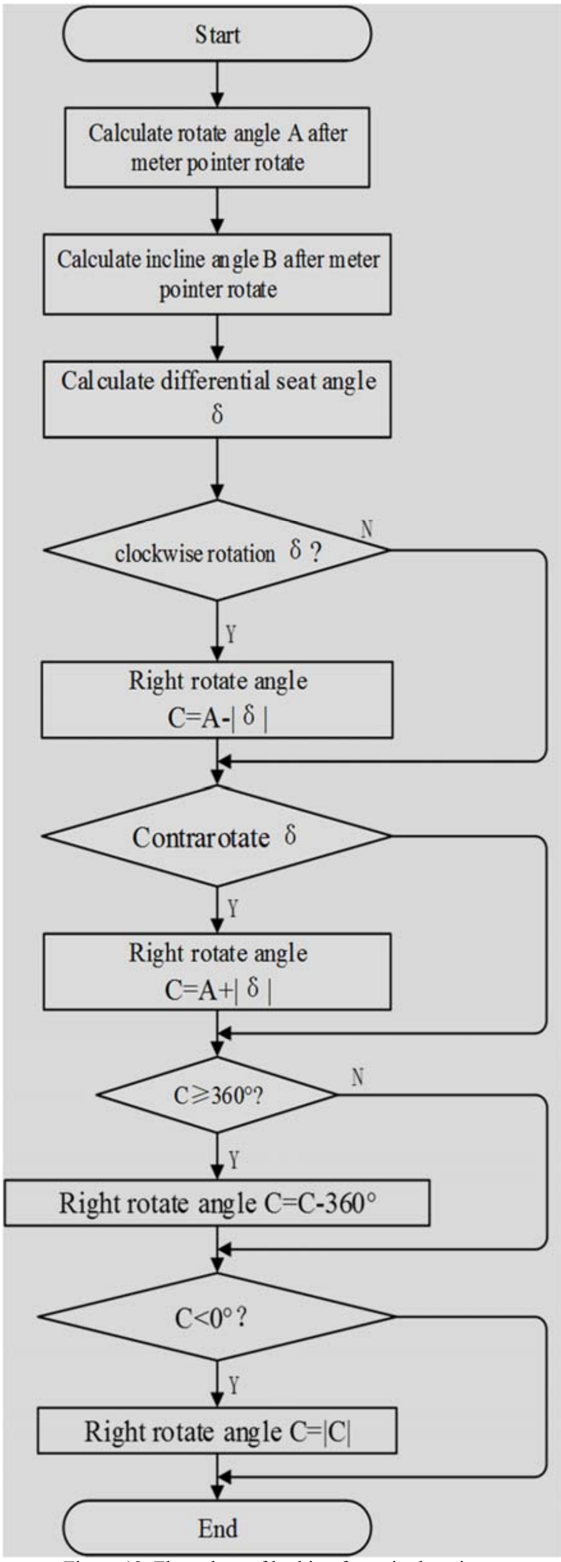

Figure 12. Flow chart of looking for a single pointer.

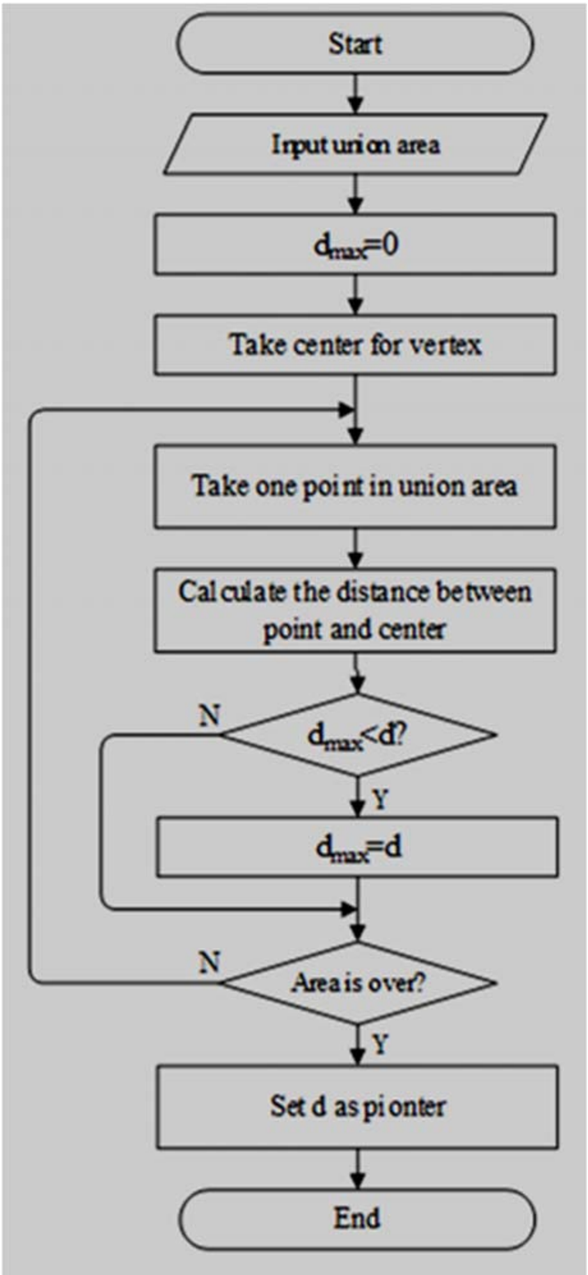

Figure 13. Flow chart of check dial pointer value.

C. To Determine the Reading of Pointers

Rotation angle of the pointer are easily computed after receiving coordinates about vertex and center of the circle. When compared rotation angle to scale value in table1, it's easy to get this reading directly from the correspondence between vertex and center of the circle. The flow chart is shown in figure 11.But when practically detecting water meters, we are confronted with random error because they look like kind of randomly placed. The meters will have some angle. We have to correct the picture according to following process to eliminate the random rotating angle. Starting with a calculation that computes the angle between line connecting the two leftmost circle center and horizontal axle. The angle between line connecting the two leftmost circle center and horizontal axle in this experiment is tilted 22.9 degrees. I compare these to the default baseline and modified the eventual rotation angle of the pointer to get a true reading. The accuracy of this system is affected because of calculating error of the rotation angle, especially at the demarcation line between critical angels. In order to reduce the measuring error, it is needed to adjust the error for this automatic detection system.

TABLE i. THE CORRESPONDING RELATION OF POINTER ROTATION ANGLE AND SCALE VALUE

Rotate angle(degree)	Corresponding numeric	Rotate angle(degree)	corresponding numeric
0 ~ 36	0	180 ~ 216	5
36 ~ 72	1	216 ~ 252	6
72 ~ 108	2	252 ~ 288	7
108 ~ 144	3	288 ~ 324	8
144 ~ 180	4	324 ~ 360	9

Since a pointer of high data is at the demarcation line, the real so must be a pointer of low data at the zero or nine graduation. With the pointer of low data at zero graduation, the result were obtained from a series of ordered operations to determine if the result of this reading is credible or not. Well, as is mentioned above, to tell right from wrong on this reading, the recognized adjacent high data reading is multiplied by 36and then reduce real reading based on the newly garnered value. If the absolute value of above reading is greater than5, the result is wrong and another 1 should be added to the reading; otherwise, the reading is accurate enough. A similar correction method of readings also needs to be applied in cases where a pointer of low data at nine graduation, as shown in the above process.

IV. TESTAND PERFORMANCE ANALYSIS OF CALIBRATIONSYSTEM.

The first step what have to do is match the work number of technicians with the data table we'll gather in advance. Applications should be approved only if the work number of technicians is correct; otherwise, they should re-enter for security purposes until the test passes. Then with only a click on the Snapshot button, administrators can see a small text box in which they can read the reading.

Each reading sampling 3 times from 3 different images what we received, with different volume levels (100L/10L) error, and compered to 4% and 1.5%, make out the right meters. The test result data can be stored into database.

Various practical factors contribute to the calibration result so it must be conducted under different light intensity, rotation angle, bubble content to ensure the accuracy.The present study calibrated the water meter in three light conditions: the dim interior scene, normal illumination interior scene, and light interior scene. In each case, intensity of light had little effect on calibration result because the result, 155L, was consistent with reading through entirely artificial means, as is shown in table 2.

TABLEII TESTS UNDER DIFFERNET LIGHT INTENSITY

Condition	**dim interior scene**	**normal interior scene**	**light interior scene**
Manual reading /L	155		
Process reading/L	155	155	155

As is shown in table 3, similar to the approach taken in the proceed paragraph, the water meter was calibrated in extreme rotation angle with the same normal illumination interior scene. The result, 155L, was also consistent with reading through entirely artificial means, ruling out the idea that a little rotation angle would impact the experimental result as a potential affecting factor in a practical application. Therefore, the rotation angle within a certain range does not much affect the precision in this calibration system.

TABLE III THE TEST UNDER DIFFERENT ROTATION ANGLE

Condition	**Normal rotate angle**	**Clockwise angle**	**Anticlockwise angle**
Manual reading/L	155		
Process reading/L	155	155	155

TABLE IV THE TEST UNDER DIFFERNET CONDITIONS OF BUBBLES

Condition	**No bubble**		**Some bubble**
Manual reading /L		155	
Process reading /L	155		155

As is shown in table 4, the reading is consistent with the truth, under different bubble content scene but the same other conditions, have further proved the theory that few of bobbles doesn't affect the test result greatly.

Such analyses indicate that this automatic calibration system has a better adaptability with strong anti-interference capacity. Having conducted 100 experiments over several days, we calculate all the experimental data. It shows that the identify rate can reach 98%, and fit for design requirements completely.

V. CONCLISION

This paper presents an automatic calibration system for multi-pointer water meter based on image processing technologies. The system usesVB.NET as the design platform and obtains the meter image through CMOS cameras, simultaneously through the processing of color space transformation, gray-scale transformation, decreasing noise by corrosion and expansion algorithm, binarization, edge processing and roughening treatment for the preliminary image. Then it obtains the center coordinate by the improved Hough Transform and identify the water meter reading automatically. Finally, it draw a conclusion whether the water meter for qualified products. The final results are stored in the database. Extensive research under various conditions has led to a better understanding of availability and stability of the automatic calibration system. Practical running shows this calibration system can replace traditional manual reading method completely because of its simple operation and high accuracy

ACKNOWLEDGMENT

This work is supported by the National Natural Science Foundation of China (nos. 61473174, 61573213, and 51376110), the Specialized Research Fund for the Doctoral Program of Higher Education (no. 20130131130006), a project funded by the China Postdoctoral Science Foundation (no. 2014M551907), and the Independent Innovation Foundation of Shandong University (no. 2013ZRQP002).

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