Automatic Reading Recognition System for Analog Measuring Instruments Base on Digital Image Processing

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Abstract: Pointer instrument has been widely used in the electric power, chemical industry and other industrial fields, because of the advantages such as low price, high reliability, easy installation, replacement and so forth. The traditional manual reading method has its drawbacks for example process trivial, big workload, lack of accuracy. This article, based on digital image processing techniques, studies the automatic reading recognition method for analog measuring instruments. After pretreatment of original image on the instrument dial, the pointer information will be split by binarization; The Hough transform is the main idea for line detection and then by the pointer straight line parameters and calculating the image pixel the angle and direction of the pointer can be got; Angle method is used to determine the reading of the meter pointer which is simple but effective. At the same time template matching method is used to recognize the range of pointer instrument automatically. The system software is designed by matlab on the platform of windows. By using MATLAB (gui) simulation, pointer meter reading recognition system can be constructed which includes control interface.

Key words: Digital image processing, hough transform, matlab (gui) simulation, template matching, method

INTRODUCTION

As is known to all, analog measuring instrument has many advantages, such as easy to use, convenient maintenance, less susceptible to electromagnetic interference and low price. It can also display the tendency of the measured values intuitively. Domestic and international scholars who researched pointer instrument had obtained many achievements by using digital image processing technology. Alegria and Serra (2000) obtained the instrument pointer through the subtraction method. Thus by Hough transform he identified pointer deflection angle. Chen and Jin (2005) used the center projection method to detect instrument pointer (He et al., 2006). Fan et al. (2007) achieved instrument pointer and scale line fitted by least squares method, furthermore utilized the distance method to get meter readings but the recognition time of this method is 3.78 see. The above algorithms are relatively complex. In addition to this, the recognition time of those methods is much longer. In this study, the main algorithms involved in the extraction of feature parameter in the image processing are analyzed carefully. The first step the pointer image is preprocessed and after that pointer line is positioned. Thus, achieving readings recognition in the angle method. In this way, the algorithm is simplified and the calculating time also become shorter. Moreover the precision of recognition is much higher.

This study introduces the method that how to realize automatic recognition of pointer instrument readings based on digital image processing.

IMAGE PREPROCESSING

Now-a-days, in the field of automatic reading recognition for analog measuring instruments, the main idea is digital image processing technology which includes edge detection operator realizing image preprocessing, instrument pointer positioning, using angle or distance method gets pointer value. The realization of the system process is shown in Fig. 1.

Image binarization: It will be better to separate the pointer from dial background through the image binarization method.

In the MATLAB, utilizing the “im2bw” function can convert a gray scale image to a binary image, it is necessary to set an appropriate threshold. This article uses the Otsu method to get a [0, 1] range threshold (Qi et al., 2006). This method is better to transform a
Importing pictures ➔ Images binarization ➔ Invert binarization ➔ Image thinning
Display meter readings ➔ Get pointer deflection angle ➔ Position the pointer ➔ Hough transform line detection

Fig. 1: Flow chart of system design

Fig. 2: Original dial image

![Original dial image](image)

Fig. 3: Get binarized image with Otsu method

Grayscale image into a binary image than the method artificial setting. After binarization, it can filter out some noise. Compared with Fig. 2, the image after binarization processing as shown in the Fig. 3 which performed better in contrast ratio and clarity.

**Image thinning:** Binary image after thinning processing often leaves a “skeleton” (Gonzalez, et al., 2009), useless information is excluded. In this study, the image has been thinning using “bwmorph” function in MATLAB, until the pixel is 1, the image does not change. After thinning treatment the image lines become clearer, facilitating subsequent Hough transform processing. The image after thinning is shown in Fig. 4.

![Binarized image](image)

Fig. 4: Image after thinning

**Reading Identification:** The major advantage of the Hough transform (Duda and Hart, 1972) to extract straight lines is less affected by collinear point gap and noise and

![Hough transform](image)

Fig. 5: Hough transform peak detection

which has strong robustness. In this study, using “houghlines” function extracts line segments and determines the longest line in the image after thinning. Hough transform peak detection and the pointer position images are respectively shown in Fig. 5 and 6.

A corresponding relationship between the pointer angle and instrument reading has been artificially set in front of the image processing. The pointer instrument value is received by putting the pointer deflection angle into the equation. Equation is shown as Eq 1.

\[ \theta = -1 \times \frac{6\theta_{max} - \theta_{min}}{\theta_{max} - \theta_{min}} \]  

(1)
where, $\omega$ is the value of the pointer instrument, $l$ is the maximum range of the instrument ($l$ can be received by automatic identification or manual input), $\theta$ is the angle of Pointer instrument (The pointer slope $k$ identified by the Hough transform can calculate recognition angle), $\theta_{\min}$, $\theta_{\max}$ are the minimum deflection angle and the maximum deflection angle.

Firstly, calculating the image size by the “size” function. After that we can get the image size which is $M$ rows and $N$ columns. The instrumentation pointer parameter is obtained by Hough transform and finally gets the start and the end of the pointer line, thus the direction of the pointer is determined (Fig. 7).

$$\frac{(xy(1, 2)+xy(2, 1))}{2}\times N/2$$  \hspace{1cm} (2)

Note: $xy(1, 1)$ as the starting point abscissa, $xy(2, 1)$ for the end of the absissa.

If the calculation result meets the Eq. 2, the pointer points to the range of $0-45^\circ$. On the contrary, the instrument points range of $45-90^\circ$. While the angle is not within the normal range, the system will automatically identify errors and pop up errors window. This method is able to determine the pointer deflection direction accurately (Fig. 8).

Range identification: In this study, template matching method (Chenle and Wancheng, 2009) is used to realize the recognition of the instrument range. Template matching method is matching the character templates and the character image after normalization (Li, 2012). It has the advantages of high precision and easy to implement, less affected by noise. Template for matching characters are shown in Fig. 9.

The recognition range of the instrument is achieved, by positioning range area of the instrument, range area binarization, median filtering (Li et al., 2004), image segmentation, character image normalization processing and other operations. The character segmentation result is shown in Fig. 10.

This article will split out three images normalized to the size of $40\times 20$ pixels in size. Then the three digital pictures are subtracted following with ten character templates. When the matching error is smallest, the corresponding number of the template is the identification number.

**SYSTEM CREATION**

System functions: The system is developed in MATLAB2012a GUIDE (Higham et al., 2005) platform, with M language programming. Based on digital image processing technology, the pointer instrument automatic identification system’s main interface is shown in Fig. 11.
The system will read and display images according to the path of users select. If the user select "Display reading" button in the menu, the system will identify and display the pointer straight line based on the principle of Hough transform. At the same time, the recognition angle, readings and computing time will also are displayed. System will automatically save data to the “Operation records.txt”. This system also has a real time display, image preprocessing, batch processing, voice reading, manual data storage functions and so on. Visual interface enhances the human-computer interaction which makes the operation become more simple and convenient.

**System stability test:** Salt and pepper noise are added in the picture of the parameters from 0-0.32 which can simulate the pointer dial blurred situation. It is shown in Table 1.

From the Table 1 we can see that the dial is very vague but when adding salt and pepper noise parameter is 0.3, the system will also be able to accurately identify pointer readings. Which shown stability of the system performance is very good.

**System experimental results:** This experimental subject is a DC voltmeter which range is 450 V and the accuracy class is 1.5. Multiple dial images are analyzed. Experimental data is shown in Table 2.

From the experimental data we can see that the system can get the pointer instrument readings correctly and quickly. The readings can be accurate to four decimal places, whose accuracy is above 99%. According to “Phase-frequency single-phase meter testing procedures” experimental error is within the scope of permit.
CONCLUSION

Digital image processing technology and image analysis algorithms are used to automatically determine the instrument reading. In the detection of pointer angle, strong anti-interference Hough transform is adopted, this method has good robustness. By extracting the end of the pointer line, calculating pixels, the pointer deflection direction can be got. The range of the instrument recognition is realized by template matching method. Furthermore, using angle method the readings can be calculated exactly. In the end, the use of matlab (gui) realizes the simulation of the system. The detection method proposed in this study is simple and effective. Construction of pointer meter reading recognition system has great practical value. This system has the advantages of simple designment, advanced software algorithm, stable performance and high accuracy.

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REFERENCES