An Adaptive Method for Recognition of Dual-pointer Mechanical Instrument Based on Hough Transform

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Abstract. For automatic and efficient reading of dual-pointer mechanical instruments in petroleum engineering applications, an adaptive recognition method based on Hough transform is proposed. Firstly, the instrument dial is detected by Hough transform. Then the center of circle is located, as well as the pointer is recognized. Finally, the linear relationship between the dial scale and the pointer is adopted to calculate the pointer reading. The experimental results show that the algorithm achieves high application value for the dual-pointer mechanical instrument with uniform scales.

1. Introduction

Conventional mechanical instruments are manually identified in petroleum exploration, mine operation and other fields. There is a heavy and inefficient workload in manual recognition of pointers. When the working environment is in high temperature, high pressure or high radiation, it is not suitable for manual identification. Therefore, it is very important to realize the automatic identification of mechanical instruments.

The instrument automatic identification technology based on digital image processing technology can improve the efficiency of instrument detection and reduce error [1]. At present, there are many research results of a single pointer instrument recognition algorithm [2,3]. The mechanical instrument reading method based on visual saliency region detection [4,5] can effectively solve the problem of instrument pointer recognition accuracy caused by illumination. The automatic reading system of multi-pointer water meter developed by [6], it provides a reference basis for the research of double-pointer meter. The improved angle method proposed by [7]. It can determine different pointer positions, but the symmetric position scale of double-pointer cannot be recognized. The fast arc detection algorithm proposed by [8] can effectively detect circular arc, but the recognition efficiency of the "burr" arc with scale is poor. Therefore, the key to solving the problem of automatic reading recognition of dual-pointer mechanical instrument is to determine the pointers, detect and calibrate the position of different pointers, and determine the effective rotation radian of pointers in the instrument panel. Therefore, this paper proposes an automatic recognition algorithm based on the Hough transform.
2. Algorithm flow

In this paper, in order to recognize the dial quickly, several comparative experiments have been carried out in the image preprocessing process. Combining the adaptive threshold binarization algorithm with the Hough transform, this paper proposes a reading algorithm based on adaptive double-pointer instrument image recognition. The implementation flow of the algorithm is shown in Fig.1.

Step 1: After obtaining the original image of the instrument to be identified, it is converted into a gray image.

Step 2: Gaussian filtering, dilation and etching are used to obtain the binary image containing pointer information.

Step 3: The Canny operator edge detection calculation is carried out to extract the image contour.

Step 4: Hough line segment detection algorithm is used to detect all line segments and circles on the contour map with clear edge.

Step 5: select two-line segments with different colors as the pointer, and calculate the quadrant where the pointer is located.

Step 6: calculate the pointer angle and obtain the meter reading according to the angle and range.

![Figure 1. Flow chart of automatic reading recognition.](image)

2.1. Image preprocessing

2.1.1. Image binarization processing. Image gray-scale processing is the most basic way to simplify image data information. It compresses the information of each pixel of the original RGB image from 3 bytes to 1 byte, which can effectively reduce the image storage space. This paper adopts the average method.

2.1.2. Gaussian filtering denoising. The purpose of filtering is to remove the noise in the image and make the image information smooth, which is conducive to the follow-up work. In this paper, a two-dimensional Gaussian template is selected as the weighting coefficient template. The gray value of the central pixel is obtained by convolution formula (1)

\[ G(x, y) = F(x, y) * H(x, y, \delta) \]  

Where: \( F(x, y) \) is the gray level template of the pixel around the center pixel; \( H(x, y, \delta) \) is the Gaussian convolution template; \( G(x, y) \) is the gray value of the center pixel after filtering. The Gaussian convolution template \( H(x, y, \delta) \) can be obtained by the second-order Gaussian formula.

After a comparison of several groups of experiments, a Gaussian filter is selected to filter the dial. The mechanical instrument after Gaussian filtering is shown in Fig.2.
2.1.3. Expansion and corrosion treatment. After filtering, only the pointer is left in the area to be identified. But parts of the pointer are intermittent, which is not conducive to the subsequent recognition processing. So the expansion operation in morphology is used to reconnect the pointers with breakpoints. After expansion, the pointer image becomes thick, clear and continuous. Although the pointer is continuous, but the pointer is too thick, which will affect the accuracy of recognition. Therefore, it is necessary to refine it again, so that the pointer image becomes a straight line segment.

3. Identification the pointer and center of circle

3.1. Image edge detection

The image edge is one of the basic features of an image. In this paper, the Canny edge detection operator is used to detect the edge of the image. It is a kind of edge detection operator with good performance. The operator uses a Gaussian function to smooth the image that shows a strong ability to suppress noise. The processed image pointer has a single-pixel width, which makes the pointer recognition more accurate.

The processing flow of the Canny edge detection algorithm can be divided into the following five steps:

1. Gaussian filter is used to smooth the image and filter out the noise.
2. The gradient intensity and direction of each pixel in the image are calculated by formula (2) and (3). Where $G$ is the gradient intensity, $\theta$ is the gradient direction, and arctan is the arctangent function.
3. Non-maximum suppression is applied to eliminate the spurious response caused by edge detection.
4. Double threshold detection is applied to determine the real and potential edges. The specific selection of threshold depends on the content of the given input image. In this algorithm, the threshold is associated with the actual image pixels to complete the adaptive effect.
5. Finally, edge detection is completed by suppressing isolated weak edges. In order to track the edge connection, by looking at the weak edge pixels and their eight neighborhood pixels, as long as one of them is a strong edge pixel, the weak edge point can be retained as the real edge. The instrument image after edge detection is shown in Fig.3.

3.2. Recognition of dial and pointer by Hough transform
The identification of the instrument pointer is the most important step in the process of identifying the meter reading. In this paper, the Hough transform is used to detect the position and angle of the pointer. Based on the traditional Hough transform, the geometric characteristics of the pointer instrument and the relationship between the center of the dial and the pointer are used to improve the traditional Hough transform, which reduces the accumulation of Hough space, shortens the calculation time and improves the recognition efficiency.

It can be seen from Fig.4 that only two points in the cumulative graph of Hough transform meet the restriction conditions. Two points are accumulated, which greatly reduces the amount of computation. After positioning to the center of the circle, continue to distinguish with different color positioning pointers, as shown in Fig.5.

3.3. Angle recognition
Using the vector relationship and trigonometric function in mathematics, the pointer line detected by Hough transform is processed to obtain the angle \([9]\) between two pointers, and then the angle of different pointer is calculated. According to the analysis, there is a certain corresponding relationship between the pointer angle and the meter reading. Because the scale of the dial is uniform, the identified angle can be converted into the reading of the instrument. So the angle proportional relationship is shown in (4):

\[
\text{read} = \frac{\text{angle - start}}{\text{end - start}} * \text{total} \tag{4}
\]

Where \text{start} is the angle at which the scale begins, \text{end} is the angle at which the scale ends, and \text{total} is the range of the table.

4. Experimental results

![Figure 6. Test run data reading results.](image)

\[
G = \sqrt{Gx^2 + Gy^2} \tag{2}
\]

\[
\theta = \arctan(Gy/Gx) \tag{3}
\]
The algorithm proposed in this paper runs in Python environment. The recognition speed is measured, as shown in Fig.6, which meets the engineering application index.

Through the test experiment, it can be seen that the method can accurately read the instrument readings, the recognition accuracy is improved. The average treatment time is less than 0.5s. Compared with some existing processing methods, it is more in line with the requirements of real-time and accuracy in actual production.

5. Conclusion
Based on the Hough transform, the range of dial scale and the geometric relationship between a pointer and center of the circle are used to limit the search range and accumulation of Hough transform. An improved Hough transform is proposed, which improves the recognition speed, achieves good experimental results and has certain practical value. The disadvantage is that there will be an error of 0.1 to 0.2 degree in angle measurement. To achieve more accurate reading is the direction of further research in the future.

Acknowledgments
This work was financially supported by the National Science and Technology Major Project (Grants No. 2017ZX05069004), the Youth Science and Technology Innovation Fund Project of Xi’an Shiyou University and the Youth Innovation Team of Xi’an Shiyou University (No. 2019QNKYCXTD04). The authors would like to thank the editors and the reviewers for their careful review of this manuscript.

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