# A New Digit Positioning Method for Analog Measuring Instruments

[1]Zhenhua Wei, [1]Le Zhang, [1]Jie Lin and [2]Shibo Song
[1]North China Electric Power University, Beijing 102206, China
[2]Harbin Colleges, Harbin 150080, China

**Abstract:** For the automatic digit positioning of analogy measuring instruments, a positioning method based on coordinate transformation which has practical application is brought forward. And for the present, the mostly used ways for this field are method based on Hough transform and method based on circle scanning. But they have some defects such as time-consuming and complex or low accuracy rate. The method in this study is proposed to solve the above problems. It is primarily based on the coordinate transformation and projection operation to realize the object of digit positioning. By experiment, the validity and feasibility of the positioning method based on coordinate transformation are confirmed. It is shown that the average accuracy is improved by 5.4% and average positioning efficiency is improved by 8.73% compared to the present methods.

**Keywords:** Computer vision, coordinate transformation, digit positioning, pattern recognition

## INTRODUCTION

Analog measuring instruments have been used widely in various kinds of industry fields. The main reason is that they have advantages of simple structures, high reliability and low price. And the analog measuring instruments cannot produce digit signals which can be captured and then put into the computer system. Also the traditional way of reading those instruments is by human beings. That is full of great labor intensity and great errors. So how to automatically read analog measuring instruments has become an urgent issue in the some fields of automation control. Especially in those perilous situations, it is dire need of automatic recognition about dial instruments (Wen and Wen, 2005). For those situations, such as high temperature and high voltage and high radiation and so on, are too harsh for workers to work in. By the means of system based on computer vision, those problems can be avoided so as to reduce the accident rates. However, the key to automatic reading is just this: digit location on the dial plate.

Digit positioning is a key branch of pattern recognition. And for now, Hough transform and circle scanning are two commonly used methods in digit location. The positioning method based on circle scanning has high speed, but is not very effective when there are lots of font discrepancy, font slant, font defilement and stroke connection due to the environment or the instrument. The positioning method based on Hough transform has a relatively better performance in improving the location effect by the way of more calculation. But the side effect is that the

speed of the whole system definitely gets much slower due to its computational complexity.

Some related works have been reported in recent years (Chuang *et al.*, 2001; Ashida *et al.*, 2005; Ezaki *et al.*, 2004; Shiku *et al.*, 2005; Muls *et al.*, 2003) and many initiative contributions have been made. Some achievements obtained in Ref. (Chuang *et al.*, 2001) from the aspects of edge detection and color quantization. But it is of worst performance when the natural scene is complex. In most applications, character isolation is performed by projections or connected region analyses of a binarized analog measuring instruments image.

To develop the best appropriate positioning method for analog measuring instruments, a novel method was proposed that can locate digit on the plate more precisely. In the proposed method, digit regions were located by coordinate transformation and projection. Moreover in this process, the characteristics that the graduation lines are perpendicular to the abscissa after coordinate transformation were fully used. Then the abscissas of each digit were obtained on the way of vertical and horizontal projection. So the nearest abscissa of number from the pointer comes out and it's located. That is the very point we desire in the study.

In this study, we propose a method to solve the defects such as time-consuming and complex or low accuracy rate. It is primarily based on the coordinate transformation and projection operation to realize the object of digit positioning. By experiment, the validity and feasibility of the positioning method based on coordinate transformation are confirmed. It is shown that the average accuracy is improved by 5.4% and

**Corresponding Author:** Le Zhang, School of Control and Computer Engineering, North China Electric Power University, Beijing 102206, China

average positioning efficiency is improved by 8.73% compared to the present methods.

## POSITIONING METHOD BASED ON COORDINATE TRANSFORMATION

**Calculate the rotation center of pointer:** In the location process, frame difference is first used after getting the position of an original image $I_0(x, y)$. Then rotate pointer in large angle and capture the image $I(x, y)$. If the pointers in two images mentioned above are so close that least square method can hardly calculate equations of the two lines, then the subtraction is made on the corresponding pixels in the two different images. It means that those pixels in different gray scale are set as 1 and naturally those with same gray scale are set as zero. Therefore, after this operation, only changed parts could be left by subtract background, including graduation lines and digits and other information on the plate. At late, the gray difference image can be figured out, that is:

$$\Delta I(x, y) = |I(x, y) - I_0(x, y)| \tag{1}$$

So we can detect the existence of pointer and get the position information of rotation center.

Duo to some interferences, such as lighting conditions, beside the image $\Delta I(x, y)$, there are also other pixels which might be changed and contribute to noises, disturbing the pointer detection. In order to solve this problem, corrosion operation can be a good choice which can get a better performance of eliminating noises. According to coordinate points $(x_i, y_i)$, $(i = 1, 2, …, n)$ calculate the pointer equation $y = ax+b$ and get the minimum of $\delta$:

$$\sum_{i=1}^{n} \delta^2 = F(a,b) = \sum_{i=1}^{n} \left[ y_i - (ax_i + b) \right]^2 \tag{2}$$

If we want to get the minimum of $F(a, b)$, then $\frac{\partial F}{\partial a} = \frac{\partial F}{\partial b}$ and get the formula:

$$\begin{cases} \sum_{i=1}^{n} \left[ y_i - (ax_i + b) \right] x_i = 0 \\ \sum_{i=1}^{n} \left[ y_i - (ax_i + b) \right] = 0 \end{cases} \tag{3}$$

Then the coefficients $a$ and $b$ can be determined as well as the pointer equation. The intersection point $(X, Y)$ is the rotation center we desired.

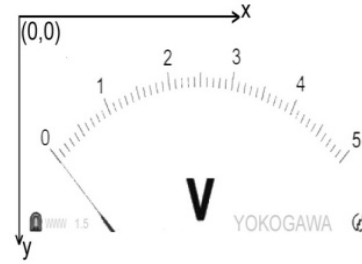**Line searching:** The key to automatic recognition for analog measuring instruments lies in locating the
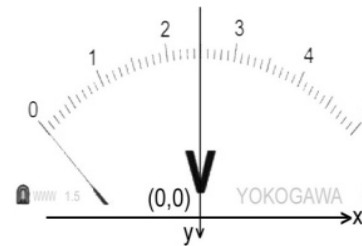


Fig. 1: Original image I(x, y)



Fig. 2: Image I'(x–X, y–Y)

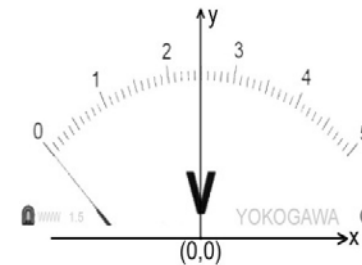

Fig. 3: Image I''(– (x–X), y–Y)

pointer and digits on the plate. In other words, it's extracting the linear equation of pointer and digits between it. The traditional way is circle scanning that the key is to determine rotation center before location. But there are inevitable errors for some reasons. First, pixels' coordinate values are integers. Second, in order to thin the pointer to one pixel width, operations such as thinning and corrosion are adopted in preprocessing. All these might introduce errors into experiment to some extent and cannot get the precise data. So, in this study, line scanning is used.

Analog measuring images are stored as form of matrix which is represented as $I(x, y)$ in rectangular coordinate system. And according to the features of plate, it needs to transform images from rectangular coordinate system to polar coordinates.

In the first step, moves coordinate origin to rotation center $(X, Y)$ and after coordinate translation $I(x, y)$ becomes $I'(x–X, y–Y)$. It's showed in Fig. 2.

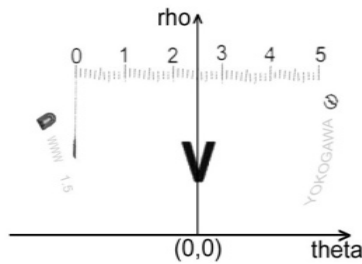Then turnover the image $I'(x–X, y–Y, y)$ and get image $I''(– (x–X), y–Y)$ as Fig. 3 represents.

Fig. 4: Image $I'''(\theta, \rho)$



Fig. 5: Digits' region

In the end, on the basis of formula (4), get image $I''(\theta, \rho)$ in polar coordinates through coordinate system transformation as Fig. 4 showed. Fig. 1 shows the original image $I(x, y)$. Fig. 2 shows the image $I'(x–X, y–Y)$:

$$\begin{cases} \theta = \arctan\left(\dfrac{y-Y}{-(x-X)}\right) \\ \rho = \sqrt{(x-X)^2 + (y-Y)^2} \end{cases} \tag{4}$$

**Digit positioning:** From the analysis of Fig. 4, it is clear that graduation lines are always perpendicular to axis of abscissa. So we can get precise graduation lines' information through line scanning from up to down in image $I'''(\theta, \rho)$. That is to draw lines from up to down and record coincident parts and then compare them with mounts of graduation line pixels.

According to the range of ordinate of pointer, abscissa $X_p$ can be determined.

Commonly, analog measuring instruments have some outstanding characteristics. Most of background on their plate is white or other light colors and regions of interest such as graduation line, pointer and digits are black as well as well distributed. In some small regions, there are obvious differences among them. Therefore, there is significant bimodal distribution in vertical projection. Then choose this best threshold $T$ and based on it to extract digit region. Fig. 5 shows the result.

At the same time, calculate each abscissa $(cx_j)$ of digit's center point. At last and the most important step is to compare each $(cx_j)$ with $X_p$ and find out the near $(cx_j)$ from $X_p$. It means digit is located.

## EXPERIMENT AND ANALYSIS

In order to demonstrate the validation of the dial instrument's digit positioning method, compare to the classical methods based on Hough Transformation and Circle Scanning, various kinds of original images from different firms were tested. The total amount of images is 500 and the general results are listed as follows (Table 1):

In the experiment, the whole 500 images are divided into 5 groups, which means that the whole recognition process is consist of five stages; and after each stage is completed, record the cost time of each identification algorithm. The details are showed in Fig. 6.

Though analyzing the Fig. 6, it clearly shows that the accuracy rate of positioning method based on Hough transform is better than method based on circle scanning and the positioning method based on coordinate transformation has the best performance. Besides, during the stage 2 and 4, there are more errors in the all three methods and oppositely in other three stages there are smaller amount of errors.

For the main reason is that: during the two stages (stage 2 and stage 4), processed images are so slur, reflect phenomenon resulted from irregular light, there are some dirt on the platform or irregular array of digits that interferes preprocessing effect terribly. Then, we cannot get the nature of structure which would greatly help methods succeed in locating quickly and efficiently. And it is known for us that positioning method based on Hough transform has strong anti-noise capability which can rectify those errors resulted by those interferes mentioned above and so the accuracy rate is higher than methods based on circle scanning. Also, fast processing speed is what the positioning method based on circle scanning is known for. But the price is losing higher accuracy rate. This point is also clearly demonstrated in Fig. 6, during stage 2 and 4, that smaller amount of time was used by method based on circle scanning, compared with method based on Hough transform.

As for the positioning method based on coordinate transformation, it fully takes advantages of the important and key feature that the line of pointer is upright to the coordinate. Therefore, though there are larger amounts of images with lower quality, we can also use this feature to get the right position of pointer and then measure the distance from the nearest digit. At

Table 1: Result data

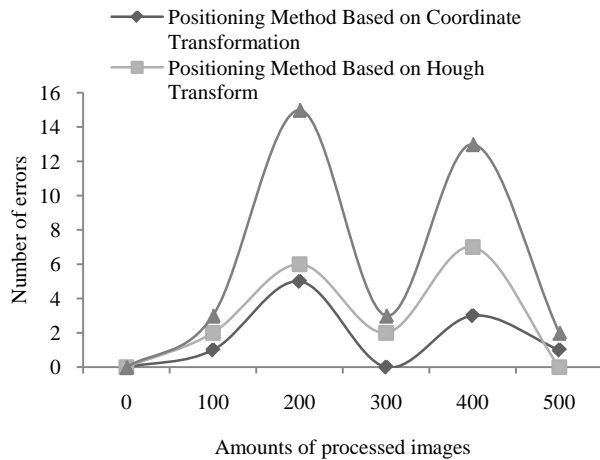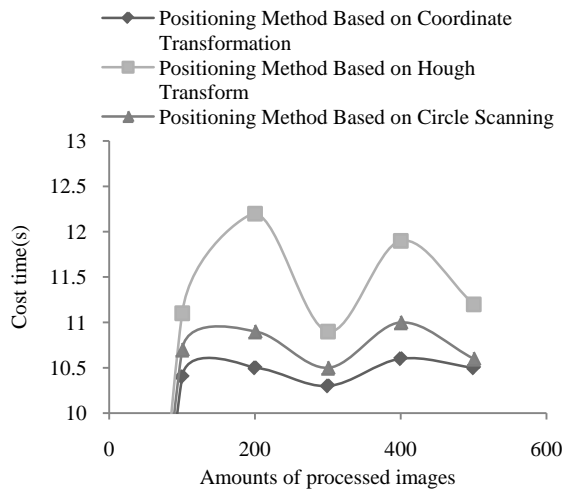| Method | Correct numbers | Accuracy rate (%) | Average time (ms) |
|---|---|---|---|
| Positioning method based on coordinate transformation | 490 | 98.0 | 106.60 |
| Positioning method based on Hough transform | 483 | 96.6 | 114.6 |
| Positioning method based on circle scanning | 463 | 92.6 | 107.4 |

Fig. 6: Error rates



Fig. 7: Cost time

Table 2: The details in stage 2 and 4

| Method | Average time (ms) | Average accuracy rate (%) |
|---|---|---|
| Positioning method based on coordinate transformation | 105.5 | 96.0 |
| Positioning method based on Hough transform | 120.5 | 93.5 |
| Positioning method based on circle scanning | 109.5 | 86.0 |

last, we can locate the digit. Back to the Fig. 6, the position method based on coordinate transformation owns the advantages of other two methods that it's fast speed with higher accuracy rate. Moreover, in all stages, its performance is highly better than other two methods. For the reason that during those stages images' definition is better. And obviously, for those high quality images with good preprocessing, the accuracy rate almost near 100%!

At the same time, for validating the processing rate of these three methods, we also do sampling five times

during identification process. And the details are listed in Fig. 7.

The analysis of Fig. 6 is highly proven by the information showed in Fig. 7. For the interferes resulted by the lower definition images, positioning method based on Hough transform needs more time to determine the curve equation, especially in stage 2 and 4 in which there are lots of images with lower quality.

More valuable information would come out by the way of further analysis of Fig. 6 and 7. Table 2 shows the details in stage 2 and 4.

In the two stages the cost time of positioning method based on Hough transform is nearly more 12.5% of positioning method based on coordinate transformation, but the accuracy rate is greatly lower by 2.5%. The above all mean that in some production environment longing for real-time capability the more cost time is not deserved.

The result definitely shows that positioning method based on coordinate transformation has strong stability, high accuracy and rapid response. And non-uniform illumination leading to reflection phenomenon, some damages or filth resulting occlusion and messy distribution of digits on the plate are the main reasons causing errors that seriously affect the accuracy rate and the correct feature extraction.

But in practice, when all equipments are in good condition, there would no such low definition images processed in stage 2 and 4. So, for the consideration of efficiency or accuracy rate, positioning method based on coordinate transformation has strong stable, high accuracy rate and fast corresponding speed.

## CONCLUSION

In this study a new positioning method for dial instruments was proposed. It's based on the simple operation of coordinate transformation and the advantages are listed as follows:

- Compared with positioning method based on Hough transform with plenty of complex calculation and other methods full of location errors, it is simple and there is no need of bulk storage memory.
- It is faster with low complexity and high accuracy rate.
- It is well compatible with low performance processors' running environment.

## ACKNOWLEDGMENT

## REFERENCES

Ashida, K., H. Nagai, M. Okamoto, H. Miyao and H. Yamamoto, 2005. Extraction of characters from scene images. Technical Report of IEICE, PRMU, J88-D-II, 9: 1817-1824.

Chuang, L., D. Xiaoqing and W. Youshou, 2001. Automatic text location in natural scene images: Document analysis and recognition. Proceedings of the 6th International Conference, Sep. 10-13, pp: 1069-1073.

Ezaki, N., M. Bulacu and L. Schomaker, 2004. Text detection from natural scene images: Towards a system for visually impaired persons. Proceedings of the 17th International Pattern Recognition, 2: 683-686.

Muls, F., C. Thillou and B. Gosselin, 2003. From picture to speech: An innovative OCR application for embedded environment. 17th Proceeding of RISC, Veldhoven.

Shiku, O., X. Yi and Y. Hong, 2005. A method for character string extraction from natural scene image. Res. Rep. Sasebo Natl. Coll. Technol., 42: 31-36.

Wen, J.X. and L.H. Wen, 2005. The history and outlook of intelligent residences and housing districts [J]. Chongqing Archit., 9: 9-13.