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A Novel Scale Recognition Method for Pointer Meters Adapted to Different Types and Shapes

by

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CONTENT

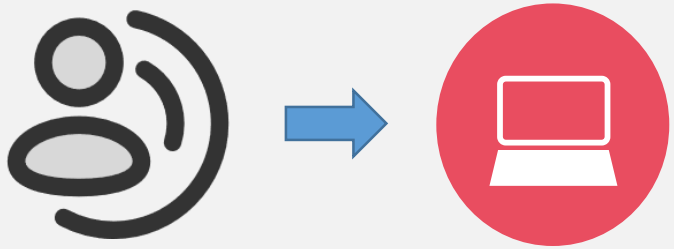
I. INTRODUCTION

Quantities of pointer meters are utilized in the field of chemical industry and electrical power system due to their **resistance to electromagnetic interference**, **simple structure** and **low maintenance cost**.

ammeter

pressure gauge

This paper proposes a novel method to read pointer meters of different types and shapes effectively.



Manually Computer Vision

I. INTRODUCTION – RELATED WORK

Angle-based: determining the meter center, the pointer and the lower limit scale. The reading is calculated through angle proportion. [Ref. 7-10]

Uniform scale

Non-uniform scale

Drawbacks:

1. not suitable for non-uniform scale meters
2. need to find meter center
3. prior information from database

- Meter center is hidden behind the panel
- Scales are non-uniformly distributed

[7]F. C. Alegria and A. C. Serra, “Automatic calibration of analog and digital measuring instruments using computer vision,” IEEE Transaction on Instrument and Measurement, 49(1), 2000, pp. 94-99.
[8]P. A. Belan, S.A. Araujo and A. F. H. Librantz, “Segmentation-free approach of computer vision for automatic calibration of digital and analog instruments,” Measurement, 46, 2013, pp. 177-184.
[9]F. Huo, D. Wang and Z. Li, “Improved recognition method of industrial linear pointer meter,” Journal of Jilin University: Information Science Edition, 36(4), 2018, pp. 423-429.
[10]J. Gao, H. Xie, L. Zuo and C. Zhang, “A robust pointer meter reading recognition method for substation inspection robot,” in: Proc. 2017 Int. Conf. on Robotics and Automation Sciences, IEEE 2017, pp. 43-47.

II. METHODOLOGY

This paper proposes a **distance-based** method to automatically read pointer meters of different types and shapes. It is independent from any prior information such as scale values.

A. The proposed method first recognizes the pointer using progressive probabilistic Hough transform(PPHT).
B. Then, a scale seeking method based on iterative moving and dynamic adjustment is proposed to find all scales on the meter panel.
C. Thereafter, scale values are recognized using connected domain(CD) analysis and convolution neural network(CNN).
D. Finally, the reading is obtained by a distance-based method.

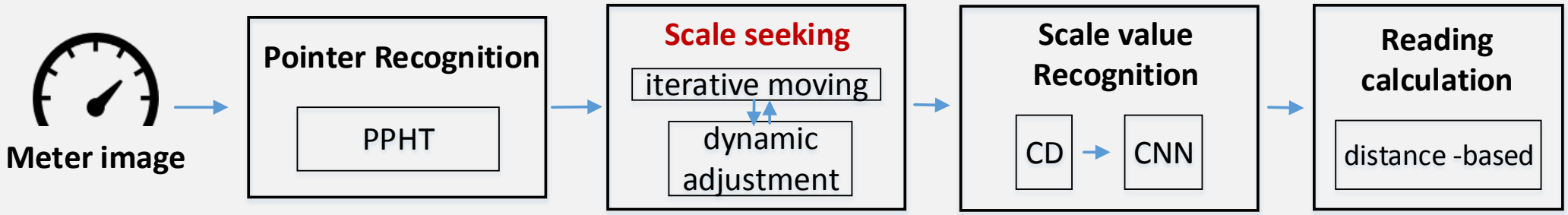


Fig 1. Flow chart of the proposed method

II. METHODOLOGY – POINTER RECOGNITION

A. Utilize PPHT to find all lines in the image.

B. Select the longest line as the pointer by:

$$l = \|p_1 - p_2\|_2 \quad (1)$$

where p_1 and p_2 are two points of the line.

C. Determine the start point p_s and end point p_e via:

$$[p_s, p_e] = \begin{cases} [p_1, p_2], & \text{if } \|p_1 - p_c\|_2 < \|p_2 - p_c\|_2 \\ [p_2, p_1], & \text{otherwise} \end{cases} \quad (2)$$

where p_c is the image center.

As shown in Fig. 3, the recognized pointer line does not completely coincide with the central line, but it does not affect the reading accuracy because only the end point is used in this method.

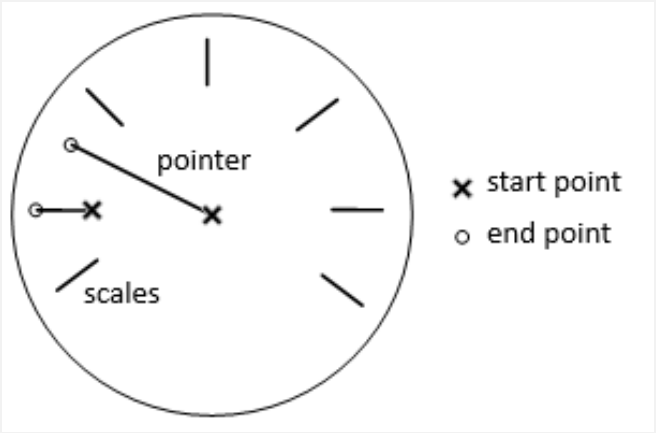


Fig 2. Start point and end point of the pointer

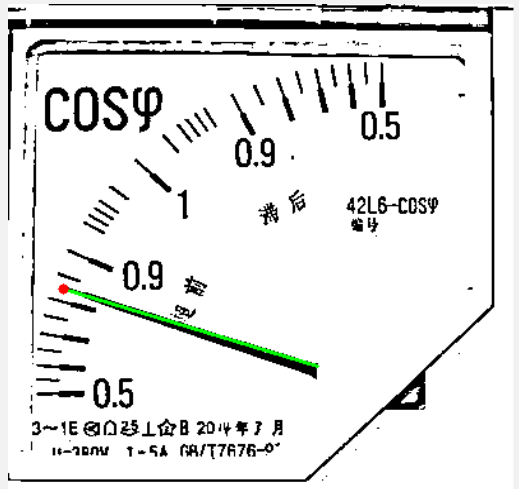


Fig 3. The recognized pointer

II. METHODOLOGY – SCALE SEEKING

The scale seeking algorithm is based on the fact that the inclination angle between two adjacent scales is approximately equal. The next scale can be recognized according to the one found previously.

As shown in Fig. 4, the searching box **moves iteratively** along the normal direction of the previous scale. The center of the searching box $c(x, y)$ is updated to (x', y') via:

$$\begin{cases} x' = x + s \cdot \cos\alpha \\ y' = y + s \cdot \sin\alpha \end{cases}, \quad dir = CW$$
$$\begin{cases} x' = x - s \cdot \cos\alpha \\ y' = y - s \cdot \sin\alpha \end{cases}, \quad dir = CCW \qquad (3)$$

Where s is the step length and *dir* is the searching direction flag .

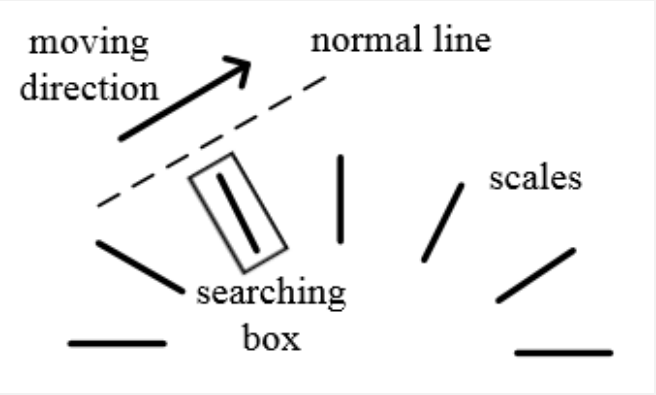


Fig 4. Movement of the searching box

II. METHODOLOGY – SCALE SEEKING

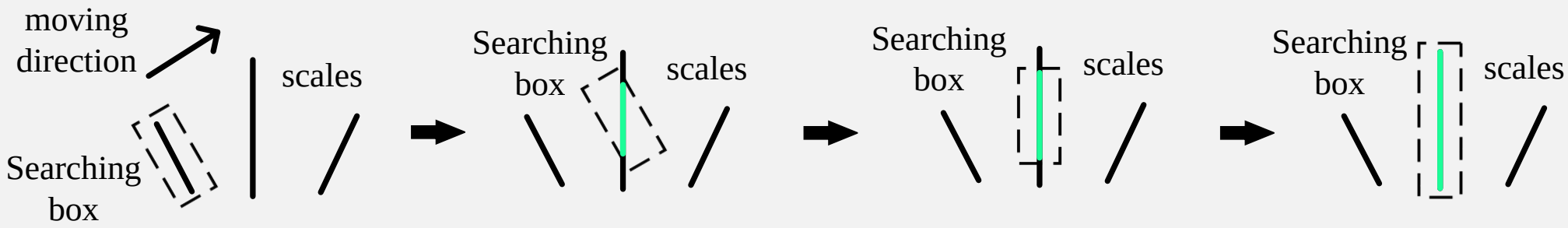


Fig 5. Dynamic adjustment of the searching box

To avoid incomplete recognition of a scale, the inclination angle and length of the searching box are adjusted dynamically to the current found scale during the seeking process. The inclination angle is calculated as:

$$\alpha = \begin{cases} \arctan\left(\frac{x_e - x_s}{y_s - y_e}\right), & y_e < y_s \\ sgn(x_e - x_s) \cdot 180° + \arctan\left(\frac{x_e - x_s}{y_s - y_e}\right), & y_e > y_s \\ sgn(x_e - x_s) \cdot 90°, & y_e = y_s \end{cases} \quad (4)$$

Where (x_s, y_s) is the start point and (x_e, y_e) is the end point.

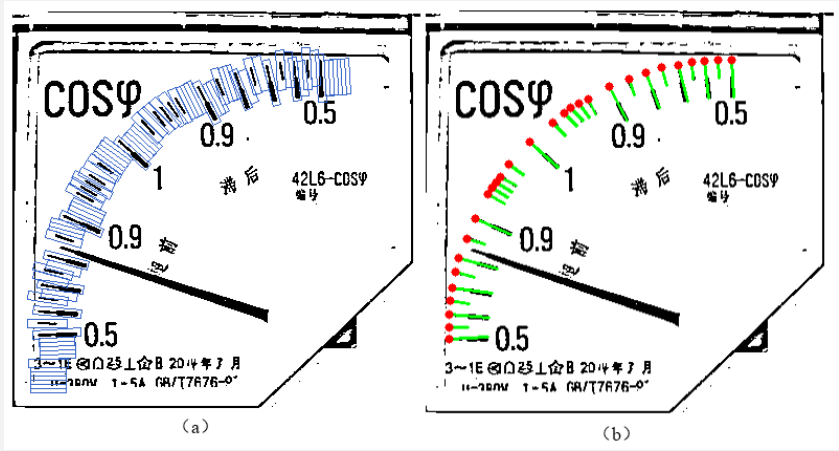


Fig 6. Scale seeking process and the result

II. METHODOLOGY – SCALE VALUE RECOGNITION

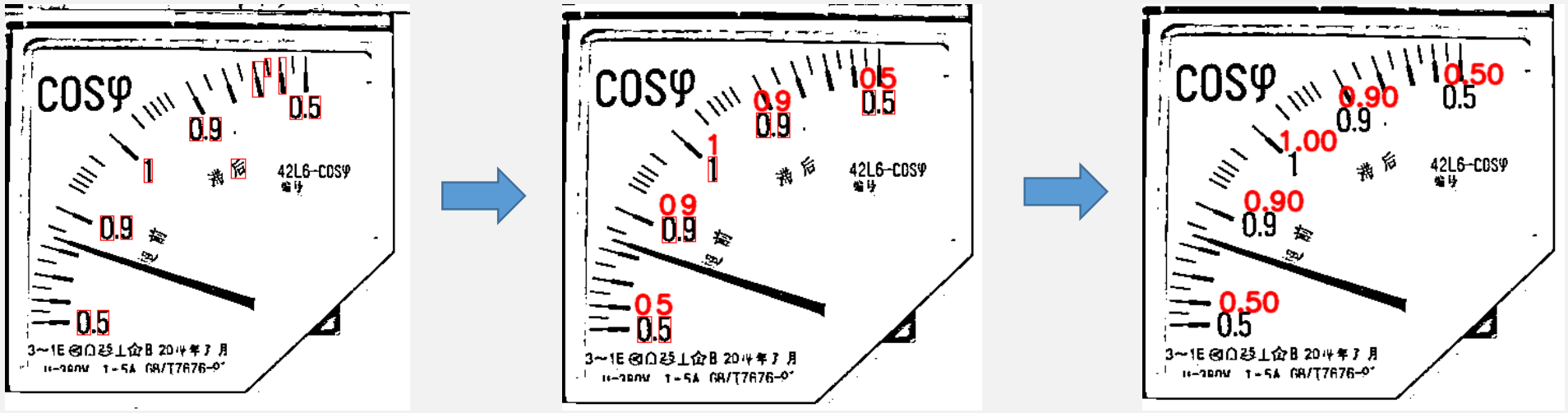


Fig 7. The process of scale value recognition

A. Determining number candidates. All elements found out by connected domain analysis are filtered by condition:

$$c_i \notin C \text{ if } \forall s_j \in S, \text{dist}\left(c_i, s_j\right) \leq d_{\min} \tag{5}$$

B. Single number identification. Convolution neural network is used to determine the exact number.

C. Number combination. Groups of single numbers are combined to an integer via

$$v = \sum_{i=0}^{n-1} d_i \times 10^i \tag{6}$$

Where number groups can be represented as $\overline{d_{n-1}d_{n-2},\ldots,d_1d_0}$. For decimals, the point is fixed behind the first number, i.e. $\overline{d_{n-1}.d_{n-2},\ldots,d_1d_0}$.

II. METHODOLOGY – READING CALCULATION

The distance-based method proposed in this paper calculates the reading of indication based on the relation of distances between the pointer and its nearest two scales. Hence no meter center or rotation angle is needed.

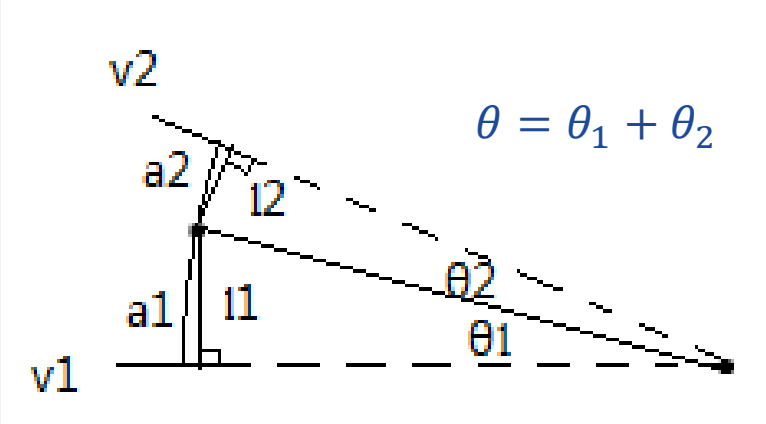


Fig 8. The distance-based reading method

When is θ small, we have the following approximate relation:

$$\frac{\theta_1}{\theta_1 + \theta_2} = \frac{a_1}{a_1 + a_2} \approx \frac{l_1}{l_1 + l_2} \tag{7}$$

According to the distance relation, the reading of indication is calculated via:

$$r = v_1 + \frac{l_1}{l_1 + l_2} \cdot (v_2 - v_1) \tag{8}$$

Where v_1 and v_2 are the scale values of the pointer's nearest two scales respectively, and l_1 and l_2 are the distances from the end point of the pointer to the scales.

III. EXPERIMENTS

Experiments

- Robustness and adaptability of scale seeking
- Accuracy and rapidity of reading

Hardware configuration

- Intel(R) Core(TM) i7-5500U CPU @2.4GHz ×4
- 8GB 1600MHz DDR3 memory
- 500GB 2.5 inches Samsung SSD hard disk

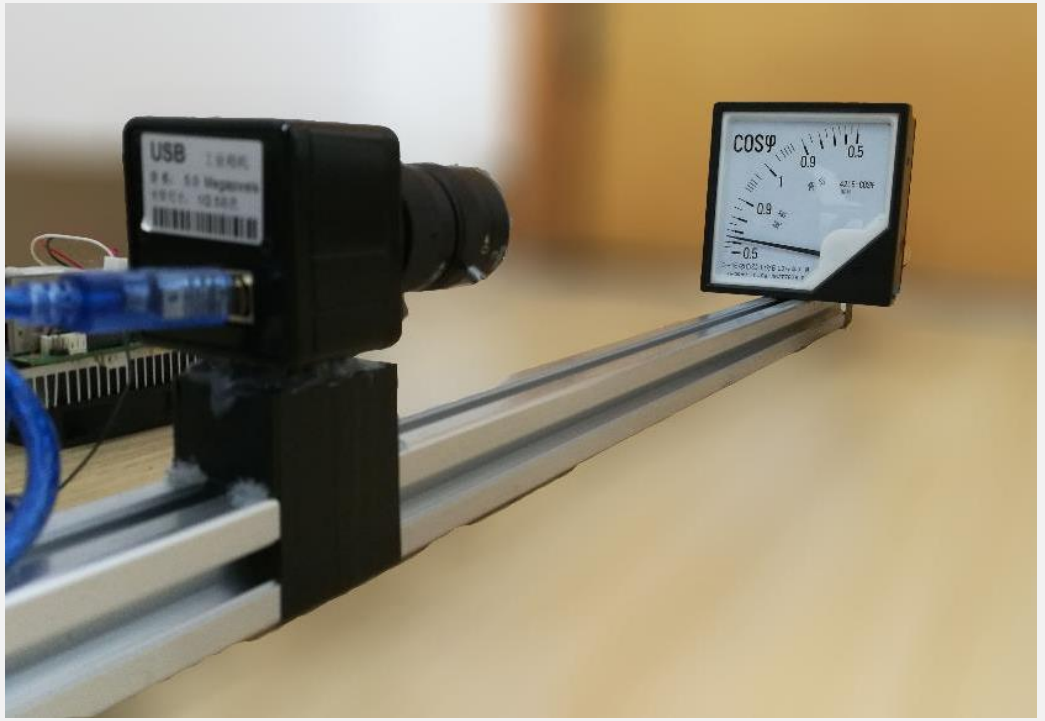
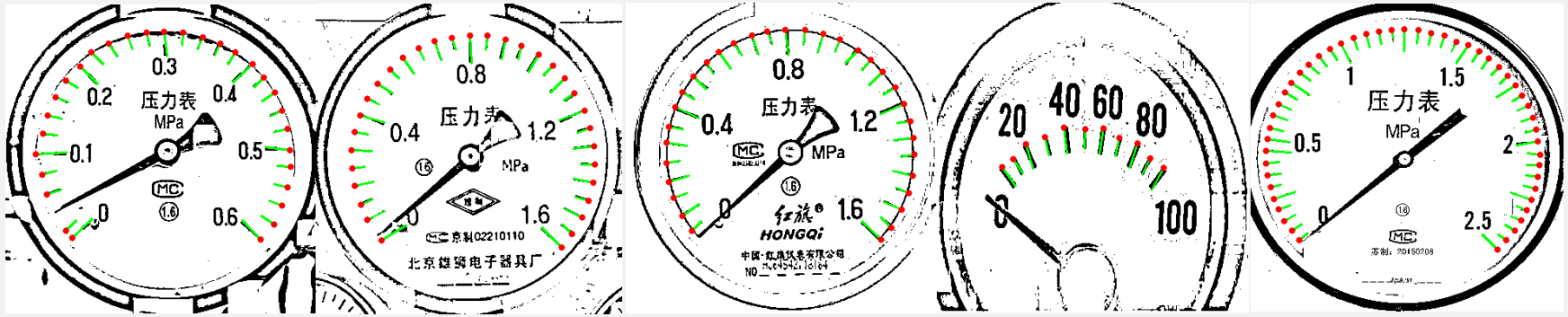


Fig 9. The meter reading system

III. EXPERIMENTS – SCALE SEEKING

circle meters, with uniform scales

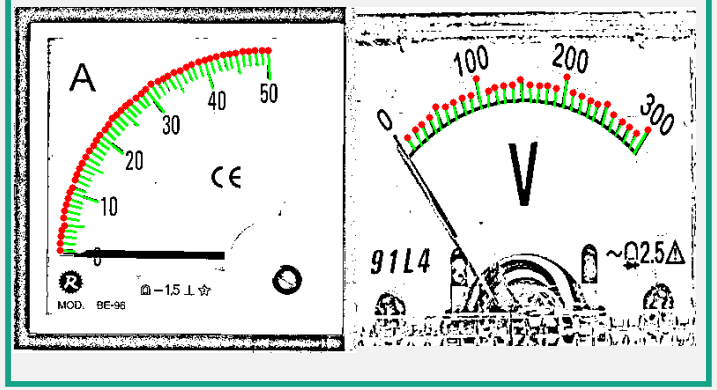


shapes and types

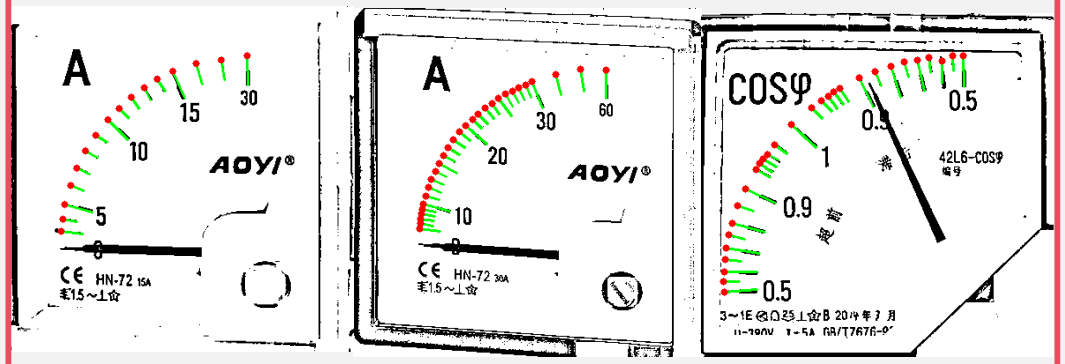
- Five **circle** meters and five **square** meters.
- Seven **uniform** scale meters and three **non-uniform** scale meters

square meters

uniform scales



non-uniform scales



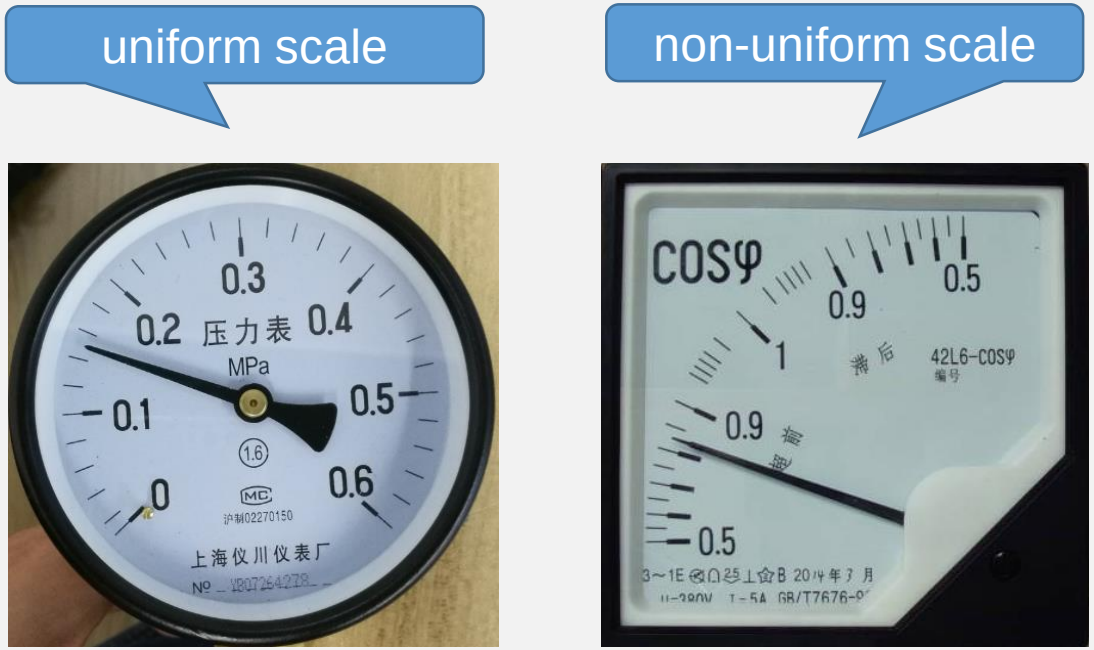
Adapted to different types and shapes.

III. EXPERIMENTS – ACCURACY AND RAPIDITY

The proposed method is tested on the pressure gauge and the power factor meter. For each meter, we test 10 cases whose indication is different.

Algorithm of [9] is also evaluated, but only for the pressure gauge because it cannot be used in non-uniform scale meters.

The reading process is in real time, and we record the **manual reading values**, the **algorithm reading values** and the **time** consumed for different indication.



(a) (b)

Fig 10. Meters tested in the experiment. (a) pressure gauge. (b) power factor meter

[9] F. Huo, D. Wang and Z. Li, “Improved recognition method of industrial linear pointer meter,” Journal of Jilin University: Information Science Edition, 36(4), 2018, pp. 423-429.

III. EXPERIMENTS – ACCURACY AND RAPIDITY

Fig. 11 shows the absolute error of our method and fig. 12 is the comparison of our method and ref. [9]. The results show that the proposed method performs well on both meters.

As shown in fig.12, the proposed method is **more stable** and achieves **less absolute error** than algorithm of [9]. A reasonable explanation for the higher time is that the our method includes additional steps such as scale value recognition.

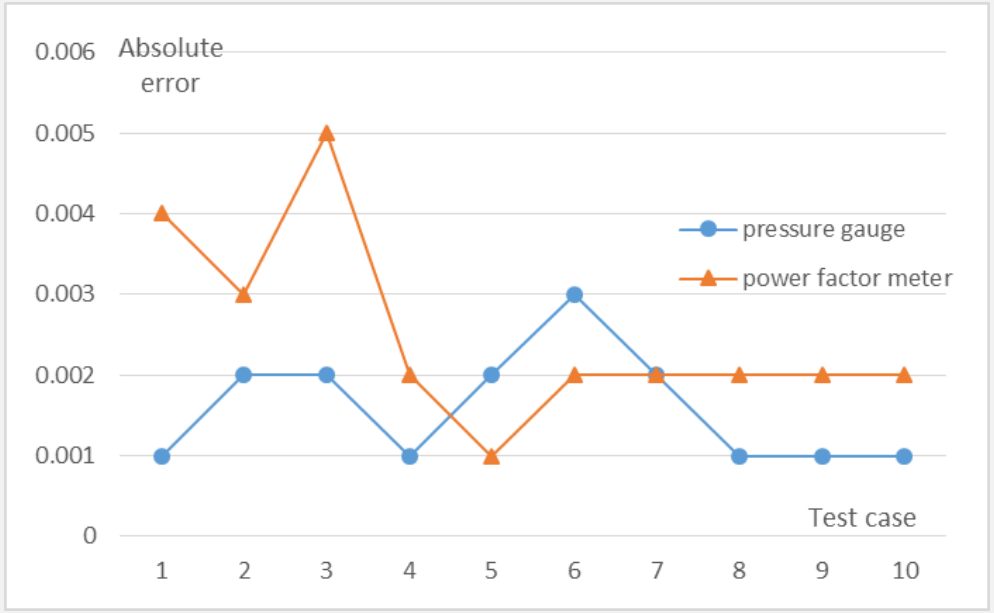


Fig 11. The absolute error

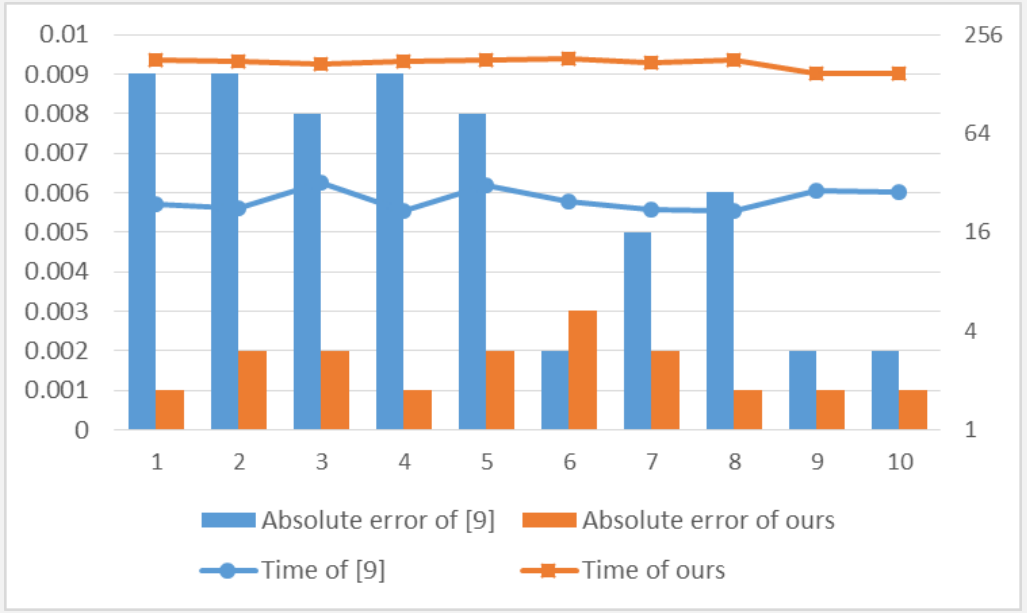


Fig 12. Comparison to the current method

IV. CONCLUSION

A. A novel automatic reading algorithm of pointer meter based on scale seeking is proposed, which can be applied to read both uniform and non-uniform scale meters.

B. Scale value recognition method is then presented, making it possible to get scale values printed on the meter panel automatically.

C. A distance-based reading calculation method is proposed. Only the peak of the pointer and its nearest two scales are utilized such that it is possible to read pointer meters of different shapes.

IV. Future Work

A. The current scale seeking algorithm uses fixed step length s for the searching box. A self-adaptive step length makes it more robust to different meters.

B. Sometimes scale values may be partly covered by the pointer, making it difficult to be recognized. This problem could be solved by improving the scale value recognition method to consider the values that have been recognized.

C. Some proven network learning methods (ref. [22]-[26]) should be tried to speed up the present training process in the future.

THANKS FOR YOUR ATTENTION !

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