Research on the Verification Method of Capillary Viscometer Based on Connected Domain

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Abstract. In order to solve the problem that the dust in the insulation cabinet is mistakenly identified as the liquid level in the process of automatic verification of the capillary viscometer, this paper studied the verification method of the capillary viscometer based on connected domain. On the basis of the common automatic verification system of capillary viscometer based on computer vision, the dust recognition method based on connected domain is added. Industrial cameras are used to acquire viscometer video images in real-time. In order to make the images clearer and improve the processing speed of the images, the following preprocessing is carried out on the acquired images first, including the ROI region selection, frame difference method to capture moving targets, binarization, corrosion, and expansion. Then, the preprocessed image is marked with connected domain. The parameter difference of the connected domain combining liquid level and dust, the problem of misidentified dust as liquid level is solved. The experimental results show that the time repeatability and constant reproducibility of the verification results of the proposed method are better than those of the ordinary verification method based on computer vision, which reduces the probability of misidentified dust as the liquid level and improves the accuracy and efficiency of the verification of capillary viscometer.

Keywords: Connected domain · Liquid level · Dust · Capillary viscometer · Verification

1 Introduction

Viscosity is the resistance of a fluid to flow. Accurate measurement of viscosity is of great significance in many scientific research fields [1, 2]. The traditional measurement methods are mainly the capillary method, rotation method and vibration method. Among them, the capillary method has become the most widely used method for liquid viscosity measurement because of its high accuracy and simple structure.

In order to ensure the measurement accuracy of the capillary viscometer, it is necessary to pass the verification process stipulated by the state to judge whether the capillary

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viscometer is qualified. Under constant temperature conditions, a certain amount of standard fluid with known kinematic viscosity fell from the upper scale line to the lower scale line under gravity, and the duration of liquid level fell from the upper scale line to the lower scale line of the standard fluid is measured. The verification of the viscometer can be completed according to the requirements of JJG 155-2016 verification regulations for working capillary viscometer.

At present, the verification of capillary viscometers usually uses a method based on computer vision to detect the liquid level of the standard liquid [3], and an external timer is used to measure the time for the level of the standard liquid fell from the upper scale line to the lower scale line. However, the verification of the viscometer needs to be carried out under constant temperature, so the viscometer is placed in the insulation cabinet. However, there is a lot of dust in the insulation cabinet, which will affect the detection of the liquid level, and the dust will be misidentified as the liquid level. Therefore, the capillary viscometer verification and dust identification system based on connected domain is studied in this paper. On the basis of the traditional automatic verification system of capillary viscometer based on computer vision, the connected domain is added to eliminate the influence of dust on liquid level detection, which improves the efficiency and accuracy of viscometer verification.

2 Liquid Level and Dust Detection Based on Connected Domain

2.1 Basic Principles of Connected Domain

The connected domain refers to the area composed of adjacent pixels with the same pixel value in the image. Generally, a connected domain contains only one kind of pixel value, so in order to prevent the influence of pixel value fluctuations on the extraction of different connected domains, connected domain analysis usually deals with the image after binarization. There can be multiply connected domains in a binary image, and any two connected domains are neither overlapping nor adjacent.

There are two traditional connected domain labelling algorithms, which are four neighbourhood connected domain labelling and eight neighbourhood connected domain labelling. Four neighbourhood connected domain labelling determines the connected relation according to four neighbourhood directions (up, down, left, and right). Eight neighbourhood connected domain labelling identifies the connectivity relationship based on eight neighbourhood directions (up, down, left, right, upper left, lower left, upper right, lower right). As shown in Fig. 1, if any pixel labelled b, d, e, g has the same pixel value as the pixel labelled 1, it is considered to be connected with 1. As shown in Fig. 2, if any pixel labelled a, b, c, d, e, f, g, h has the same pixel value as the pixel labelled 2, it is considered to be connected with 2.

	b	
d	1	e
	g	

Fig. 1. Four neighbourhood connected domain labelling

a	b	c
d	2	e
f	g	h

Fig. 2. Eight neighbourhood connected domain labelling

In the binary image, the regions composed of the pixels that conform to the four neighbourhood connected domain labelling and the eight neighbourhood connected domain labelling are marked with different labels, which are called the labelling of the connected domain. Therefore, multiple target regions in the binary image are assigned unique markers. Then, the relevant parameters of the region corresponding to each marker number are calculated.

As shown in Fig. 3 below, it is the image before the connected domain label. There are seven white areas in the image, and they are not connected. As shown in Fig. 4 are the images marked with connected domains. Seven white areas are marked with "1, 2,

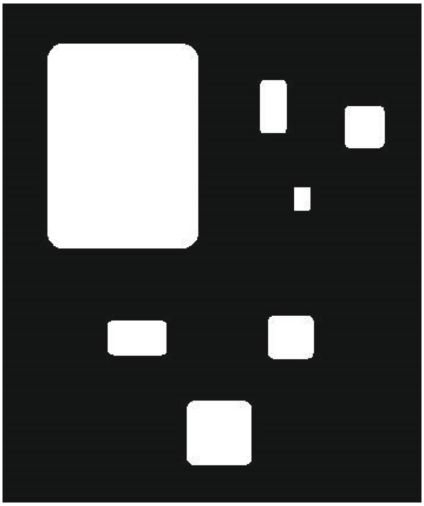

Fig. 3. Before mark

3, 4, 5, 6, 7" and seven different marks, respectively. Through these seven marks, it is convenient to calculate the different characteristics of the seven regions: the area of the connected domain, the width and height of the outer rectangle of the connected domain, the y coordinates of the upper left corner of the connected domain and the x and y coordinates of the central point of the connected domain. By analyzing this information, we can judge the size, position, and so on of the objects in the image.

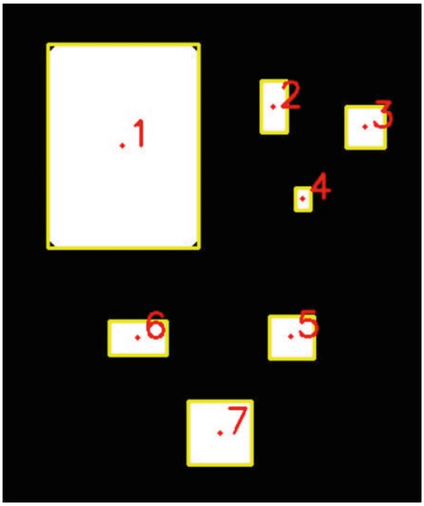

Fig. 4. After mark

2.2 Image Preprocessing

This system uses Hikvision industrial camera to collect images. The collected images will have noise, which will increase the amount of calculation and reduce the accuracy of the image analysis. Therefore, the collected images are preprocessed. Pretreatment mainly includes the ROI region selection, frame difference method to capture moving targets, binarization, corrosion, and expansion.

First, the ROI region at the scale line of the viscometer is selected, as shown in Fig. 5. This can reduce the amount of calculation and improve the speed of calculation.

Then, the frame difference method [4, 5] was used to capture the moving targets, as shown in Fig. 6, to capture the liquid level.

However, the acquired image is very unclear, so the image is made clearer by binarization [6, 7], with only 0 and 255 pixel values, as shown in Fig. 7.

Finally, the excess image at the edge is removed by corrosion, and the image edge is expanded by expansion so that the internal defects are filled, and the liquid level becomes clearer, as shown in Fig. 8.

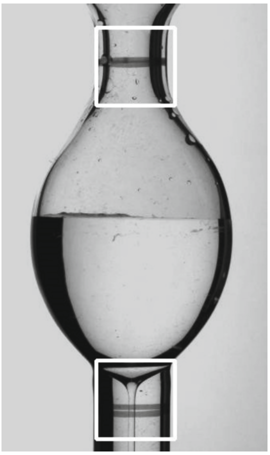

Fig. 5. The ROI region selection

Fig. 6. Liquid level capture

Fig. 7. Image after binarization

2.3 Use the Connected Domain to Mark the Liquid Level and Dust

The verification of the viscometer needs to be carried out under constant temperature conditions, so the viscometer needs to be put into a special insulation cabinet. However, due to the long term use of the insulation cabinet, a large amount of dust is accumulated, which will affect the verification of the viscometer. Using the frame difference method, the liquid level and dust will be detected as moving targets at the same time, and the

Fig. 8. Image after corrosion expansion

dust passed through the scale line will be mistakenly identified as the liquid level passed through the scale line. In order to eliminate the influence of dust, the system marked the connected domain of the preprocessed image and distinguished whether the moving target is the liquid level or not according to the different connected domain parameters of the liquid level and dust. The liquid level after the connected domain label is shown in Fig. 9.

Fig. 9. Image after connected domain mark

It is mainly distinguished by the following parameters:

1. The y coordinate of the upper left corner of the connected domain. When the liquid level rises, the y coordinate of the upper left corner of the connected domain changes from large to small, and when the liquid level falls, the y coordinate of the upper left corner of the connected domain changes from small to large. The y coordinate of the upper left corner of the connected domain of dust has been changing irregularly.
2. The x coordinate of the centre point of the connected domain. Near the scale line, the x coordinate of the centre point of the connected domain of the liquid level changes within a certain range without significant changes. The x coordinate of the centre point of dust connected domain changes greatly.
3. Area of connected domain. The area of the liquid level connected domain is usually relatively large, while the area of the dust connected domain is often relatively small.

3 Experimental Results and Analysis

In order to test the effectiveness of the capillary viscometer verification and dust recognition system based on the connected domain, under the requirements of the national regulations and standards, the Pinkevitch capillary viscometer is used for verification, and the following two systems are compared. The experimental requirements are as follows:

1. The temperature of the water bath is maintained stable, and the temperature of the water bath is set at 20 °C, and the temperature fluctuates within 0.01 °C;
2. The inner diameter of the Pinkevitch capillary viscometer to be verified is appropriate;
3. Design repeated experiments and calculate repeatability.

According to the experimental requirements, the comparison experiments are designed, which are the ordinary automatic verification system, that is, the automatic verification system based on computer vision and the ordinary automatic verification system added to the dust identification system in this paper. A Pinkevitch capillary viscometer with an inner diameter of 0.8 mm was verified by using standard fluids with kinematic viscosity of 10.10 $mm^2 \cdot s^{-1}$ and 20.94 $mm^2 \cdot s^{-1}$. The repeatability of outflow time and the reproducibility of the viscometer constant were taken as comparison parameters. The verification results are shown in Table 1.

Table 1. Comparison of experimental results

Experimental parameters		Added dust identification		General automatic verification	
		Group 1	Group 2	Group 1	Group 2
Kinematic viscosity of standard liquid ($mm^2 \cdot s^{-1}$)		10.10	20.94	10.10	20.94
Outflow time t_i(s)	1st	282.06	584.72	282.07	584.67
	2nd	282.03	584.70	261.05	530.13
	3rd	282.00	584.64	282.03	584.63
	4th	282.10	584.62	282.01	584.65
Mean value of the outflow time $\bar{t}$ (s)		282.05	584.67	276.79	571.02
Time repeatability δ_i		0.04%	0.02%	7.59%	9.55%
Viscometer constant C_i ($mm^2 \cdot s^{-2}$)		0.035809	0.035815	0.036490	0.036671
Constant reproducibility δ_C		0.02%		0.49%	
Viscometer constant C ($mm^2 \cdot s^{-2}$)		0.03581		0.03658	

It can be seen from the experimental data that the time measurement data after the addition of the dust recognition system is relatively uniform and does not fluctuate greatly. However, due to the interference of dust in liquid level detection in the ordinary automatic verification system, the dust passed the scale line will be mistakenly identified as liquid level passed the scale line, resulting in a large difference between the start and end timing. Through analysis and calculation, the time repeatability and constant reproducibility parameters of the capillary viscometer verification and dust recognition system based on the connected domain are superior to the ordinary automatic verification system and meet the requirements of the regulation on time repeatability and constant reproducibility, thus verifying the feasibility and effectiveness of the dust recognition system, and can effectively eliminate the interference of dust on liquid level recognition.

In conclusion, the stability and accuracy of the capillary viscometer verification and dust identification system based on the connected domain in this paper are better than that of the ordinary automatic verification system, and the interference of dust on liquid level recognition is basically eliminated in the verification process, greatly reduced the probability of misidentified dust as liquid level.

4 Conclusion

In order to eliminate the influence of dust on liquid level detection in capillary viscometer verification, the capillary viscometer verification and dust recognition system based on connected domain is studied in this paper. The dust recognition system based on connected domain was added to the ordinary automatic verification method of capillary viscometer based on computer vision. The verification results show that the capillary viscometer verification and dust recognition system based on connected domain in this paper is superior to the ordinary automatic verification method of capillary viscometer based on computer vision, and the measurement results meet the requirements of JJG 155-2016 verification regulations for working capillary viscometer. At the same time, the capillary viscometer verification and dust recognition system based on connected domain can greatly reduce the probability of misidentified dust as liquid level and greatly improve the accuracy and efficiency of verification.

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