Application of MOG Background Subtraction Algorithm in Automatic Measurement of Contact Angle

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Abstract. Contact angle measurement is very important in determining the liquid-solid affinity properties of materials. In recent years, many advances have been made in the research of contact angle automatic measurement algorithms, but most of the existing image processing and analysis algorithms are very sensitive to changes in the characteristics of the target, including the light source illumination angle, brightness, and the tangent of the camera lens axis to the target point. Factors such as error will affect the measured contact angle. This paper proposes a key improvement technique, using the MOG background subtraction technology to realize that only the edge of the morphology after the final stabilization of the droplet is reduced, which reduces the serious interference of the mirror image of the droplet on the smooth material surface on the measured value. This method has achieved accurate fitting of the droplet contour circle, avoiding the use of measurement parameters with large errors to calculate. The algorithm has many advantages, in particular, it has noise resistance to changes in the shape, size and position of the sample, has good robustness, and has low calculation cost and fast speed. The measurement results are very similar to the manual marking of manual optical measurement High consistency.

Keywords: Contact angle, image processing, MOG background subtraction, robustness.

1. Introduction

Contact angle parameters are very important in chemical, hydrophobic materials, mineral flotation, petroleum and other industrial production, and can respect the surface physical properties between gas-liquid-solid. Many studies have pointed out the importance of interface phenomena in different fields [1-4]. For example, Wu Chunzheng [5] found that the smaller the contact angle of alkanes on the mineral surface, the stronger the lipophilicity of the mineral and the higher the flotation recovery rate. Han, Chun [6] self-cleaning performance of TiO2 thin film is related its contact angle.

Research on the method of contact angle measurement is extensive in the field of surface physics. On the one hand, it can be divided into two categories from the measurement methods, manual
measurement marking method and automatic measurement method based on digital image processing. The new algorithm described in this article belongs to the image method. The core is to analyze the shape of the droplet, and use a special algorithm to process and analyze the digital image. On the other hand, the movement characteristics of the target droplet can be divided into static contact angle and dynamic contact angle. Lin Zhiyong [7] used the fitting derivation method to measure the contact angle in the phenomenon of droplet oscillation on the solid surface.

1.1. Research status
This study solves the problem based on image vision. Regarding the progress of this technology, the current special measuring instrument for measuring the contact angle of the surface has been fully developed for different application needs [8]. A high-temperature and high-vacuum contact angle measuring instrument has appeared on the international market [9, 10], which can not only measure the contact angle and surface tension of molten metal under high-temperature and high-vacuum or rare gas protection environment, but also by changing the position of the light source and install an injection system to achieve the measurement of contact angle and surface tension at room temperature, which can be widely used in aerospace materials, metallurgical industry, welding materials and other research fields. In addition, there is a handheld contact angle surface energy measuring instrument that can measure curved samples [11] on the market, which can automatically complete the titration of two different liquids, at the same time obtain all the relevant parameters of the contact angle, and automatically calculate the solid base. The composition of the surface free energy and energy component of the material is suitable for a variety of complex samples and measurement environments. It is not only suitable for measuring ordinary planes, but can also measure samples on vertical sides, ceilings and curved surfaces. The special measuring instruments that are currently available on the market are fully functional, but expensive. In the process of experimental research, in addition to expensive and fully functional special measuring equipment, some special simple measuring devices are also necessary to facilitate the rapid evaluation of the contact angle of the material surface at low cost, which is the experimental process. Provide reference basis for rapid and accurate adjustment of process parameters. The axisymmetric droplet shape analysis (ADSA) method is well known and is commonly used as contact angle measurement technology [12]. Other methods try to describe the shape of the sample with circles [13] or ellipses [14]. Similar to ADSA, they can only be used for symmetric droplets. In the past few years, many such methods have been proposed, including polynomial fitting [15], sub-pixel polynomial fitting [16], moving angle mask [17] and 3D analysis. Several such methods are reviewed, including secant one, polynomial edge fitting, contour analysis, and gradient intensity statistics [18].

2. Measurement of contact angle

2.1.1. Theoretical background. When the liquid wets the solid, as shown in Figure 1, the droplet spreads on the solid surface. When the measured droplet is very small, less than 6μL, gravity ignores the shape, and the droplet is considered to be part of a standard circle [8]. The surface of the droplet and the solid the intersection point of the surface and the gas surface is the measurement target point. The angle between the tangent line of the point along the liquid surface and the solid surface is defined as the contact angle. The tension relationship between the three interfaces meets the Young equation [19] γl-gcosθ=γs-g-γs-l. 90 degrees is the dividing point between hydrophilic and hydrophobic, greater than 90 test liquid and material surface hydrophobicity, otherwise it is called hydrophilic, and more than 150 is called super water less than 10 or even close to 0 is called hydrophilic material [20].
2.1.2. Test principle. The calibration of artificial optical instruments requires adjusting the focal length, focus, and manually rotating the lens scale to find the position of the droplet tangent. The operation error varies from person to person, and the average error is about 2 degrees [8]. Commonly used contact angle measurement algorithms for image automatic measurement include volumetric method [21], angular method [22], fitting method [23], L-Y method, etc. Among them, the volume height method, the angle method, and the fitting method are based on a certain mathematical model, that is, the droplet is approximated as a part of the sphere, and the contact angle is calculated by measuring the geometric parameters such as width, height, tangent slope, etc. as shown in Figure 2. The key of the automatic image measurement method is to obtain these parameters and perform automatic calculation. The principle is to drop a droplet on a solid sample stage, illuminate it with a light source, take a droplet image through a microscope head and a camera, and apply digital image processing technology and a corresponding measurement algorithm to calculate the contact angle.

2.2. Optimization and improvement

Based on the investigation of the above research situation, the author collected a large number of sample contact angles of the analysis and testing center of Central South University and found that the main interference affecting the results during the image method test has the following factors, and many studies have also summarized this:

(1) Uneven light intensity will cause underexposure or oversaturation of the image sensor [24], resulting in partial over-brightness or over-darkness of the image, loss of some details, and measurement errors.

(2) Accurately locate the solid-liquid-vapour three-phase intersection point, find the droplet boundary, the error is shown in Figure 1.

(3) When the surface of the test material is smooth, the mirror image of the lower edge of the droplet will seriously interfere with the search for the outline of the droplet, resulting in a larger h, as shown in Figure 3.

(4) The position error of the sample in the light source and camera will cause the change of the 2D histogram of the test image pixels. It is difficult to use a filter function to deal with various situations, and it is necessary to adaptively denoise.
For digital image measurement, the error of static droplets mainly comes from the light and shadow of the surface area of the material, and the resolution of the three boundary points. The high volume method determines the θ/2 method according to the ABC. To determine the outline of the droplet and find the points on the left and right sides, the two detections will obviously magnify the error. The circle fitting method also needs to detect feature points [25]. Therefore, this study uses micro syringe injection to ensure that the edge is part of the circle [25]. The MOG algorithm subtracts the pixels in the background area to obtain a clearer edge. The Hough Circle algorithm is used to fit the circle, and the radius of the circle is not affected by three. With the influence of phase point clarity, only the accurate H value and R value are needed to improve the calculation accuracy, the process is shown in Figure 4.

![Figure 4. Contact angle measure process.](image)

### 3. Experimental method

#### 3.1. Test system

![Figure 5. Test system.](image)

**3.2. Background removal**

Background detection is a very important step in many basic applications. For example, the number of detected targets in a specific scene, posture, etc. Therefore, the foreground object can be obtained by subtracting the background of the droplet that has not entered the camera capture area after the droplet shape is stable. So we need to make sure that the background is extracted before the droplet drops.

If the target in the image still has shadow or mirror image, this work is even more difficult. Just using subtraction will use shadow and mirror image as foreground, which is really a very complicated matter. In order to solve the problem, start from two directions. On the one hand, the device light
source uses all directions, similar to the use of shadowless lamps for surgery, and the BackgroundSubtractorMOG algorithm is used to further remove noise.

Figure 6. Source of error.

Use the length of time these colors (in the entire video) exist as the weight of the mix. The background color generally lasts the longest and is more static. How can a pixel be distributed? A pixel in the x, y plane is a pixel that is not distributed, but the background modeling we are talking about is based on time series, so the position of each pixel point will have many values in the entire time series, thus forming a distributed. When writing code, we need to use the function: cv2.createBackgroundSubtractorMOG ( ) to create a background object. This function has some optional parameters, such as the length of time to model the scene, the number of Gaussian mixture components, thresholds, etc. Set them all to default values. Then in the entire video we need to use backgroundsubtractor.apply ( ) to get the mask of the foreground.

Figure 7. Background subtraction algorithm processing.

3.3. Drop profile feature extraction
Everyone knows that three points can determine a circle. Using these three points to make circles of all radii must have a common intersection point. This intersection point is the center of the circle with three points as the circle. The principle of Hough transform for detecting a circle is the same as the principle for detecting a straight line. The expression of the circle is (x-a)²+(y-b)²=r² [26]. Transform the problem into solving the (a, b, r) parameter pair that passes the most pixels. Circle fitting and finding the smallest circumscribed rectangle using the Canny algorithm, there are two types of rectangle circumscribed, one is a positive rectangle and the other is the smallest rectangle, the error is, for example Put forward a set of data graphs to express. Reduce errors caused by uneven surface.
4. Experimental results and discussion

Figure 8 shows the influence of the measurement error of the crown height on the measurement error of the contact angle. The error of height h mainly depends on the error value of H in the figure. The selection of coordinates, according to a large number of experimental results of the test center, shows that different operators generally cause an error of 4 to 5 pixels in the ordinate of H. The background subtraction algorithm is used to extract the real liquid and solid contact surface. The earth improves the accuracy of the measurement. The figure shows the measurement results of the contact angle of pure water on the copper plate, and the comparative analysis is shown in Table 1.

![Figure 8. Test results and errors.](image)

4.1. Comparative analysis

After the data processing process, the contact angle between the water and the copper layer on the surface of the PCB board is 85.56 degree, and the relative error with multiple sets of manual measurements is about 1 degree. In order to test the versatility of equipment and algorithms, multiple sets of materials were selected for Height measurement method, Angle measurement method, Manual measurement, MOG-BSA measurement, the comparison results are shown in Table 1.

![Figure 9. Contact angle of different samples.](image)

|                  | Height measurement method (θ) | Angle measurement method (θ) | Manual measurement (θ) | MOG-BSA measurement (θ) |
|------------------|-------------------------------|-----------------------------|------------------------|-------------------------|
| Average angle error | 0.3~0.6°                     | 0.8~1.1°                    | 1~2°                   | 0.2~0.4°                |

Table 1. Measurement error of contact angle.
5. Conclusion
This paper presents a method of contact angle measurement based on computer vision, a new background detection algorithm was designed to remove the influence of the background and the surface mirror image of the material, and the height of the droplet. The error caused by the contact angle of the droplet was avoided. The equipment was less affected by the light source, shooting angle, and the picture Sharpness. The influence of the degree and droplet size is reduced. Compared with sophisticated commercial instruments, the device uses the MOG algorithm with low cost, simple and convenient, and is suitable for laboratory measurement of material contact angle.

Since the selection of key droplet boundary points is an important factor affecting the accuracy of contact angle measurement, manual selection of boundary points will increase the measurement error, and it will take a long time to face a large amount of data. Therefore, an automatic measurement method using the MOG background subtraction algorithm is proposed, and its specific processes are described, namely image preprocessing, edge automatic detection and positioning, and computer vision measurement (quantity height method + circle fitting method). 10 different hydrophilic materials were used for experiments to verify the accuracy of the method. The data showed that the maximum measurement error of the new algorithm was 0.9°, and the standard deviation was 0.49°. Faced with the rapid measurement of a large number of samples, the effect is better than manual measurement method. This method efficiently locates the solid-liquid-gas three-phase intersection point of droplets, and is especially suitable for qualitative analysis of a large number of samples. The cost is much lower than that of commercial instruments and has engineering value.

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