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A Method to Improve the Precision of 2-Dimensioanl Size Measurement of Objects through Image Processing

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***Abstract*—Aiming at the problem of two-dimensional size measurement of objects , in this paper, an image-based measurement model with a reference object is first proposed. The bounding boxes of the target objects and the reference are obtained through image processing technology which give the lengths of edges in pixel of objects. The reference object with known length of the edge is used to calculate the pixel unit, the actual size of a pixel and then the size of the target objects are obtained accordingly. Further, a correction model with four small reference objects is proposed to improve the measurement precision. The experimental results show the validity of the proposed models.**

***Keywords*-size measurement; perspective projection; correction factor; horizontal and vertical scaling ratio;**

I. INTRODUCTION

In industry application and real life, there are many situations where one needs to know the geometric size of objects but the direct measurement is not possible. In these cases, image-based measurement technology is a good alternative. That is, acquiring the image of the target objects and measuring the size of the objects in the image by using image processing technology. This method can be used in many industry fields, for examples, industrial automation, target recognition and tracking, surveillance video, intelligent drivings [1], [2].

With the development of computer vision technology, image-based measurement technology attracts more and more attention from researchers. Qian Ying et al. [3] proposed a method for camera automatic calibration by photogrammetry. This method does not need to predict the internal and external parameters of the camera, instead, it looks for the feature points of the target object, and optimize the parameters to complete the height measurement of the target object. This method is easy and effective, but the distance of the calibration object to the camera will affect the measurement results. The farther the object is from the calibration object, the greater the error, and the increase of this error is not a linear relationship.

W. Sankowski et al. [4] proposed a simulation model and the mathematical formulation to accurately determine the errors of the stereo vision system with a standard calibration board and a general-purpose laser distance meter. The drawback of the method is that the data acquisition and analysis is time-consuming. Ashwini Bharade et al. [5] proposed a statistical method that scales the position of objects in pixels to the physical distance of the real world, translate the front view to a birds eye view which can remove the high uncertainty that exists in images. However, it is extremely sensitive to changes in environmental conditions and requires improved tolerance to changes in light intensity. Sang-Wook Park et al. [6] proposed a view-based framework for robust estimation of height and position of target objects. This method embeds the 2D features of the target object into a 3D scene space, whose coordinate system is given by a rectangular marker, and then estimates the position and height of the object in the 3D scene space. Kual-Zheng Lee et al. [7] proposed a simple height estimation calibration method based on the single-view metric. The calibration process is formulated as an optimization problem and a genetic algorithm with a Cauchy mutation operator is used to obtain the optimal parameters for estimating vanishing points.

In this paper, an image-based measurement model with a reference object is first proposed. The bounding boxes of the target objects and the reference are obtained through image processing technology which give the lengths of edges in pixel of objects. The reference object with known length of the edge is used to calculate the pixel unit, the actual size of a pixel and then the size of the target objects are obtained accordingly. Further, a correction model with four small reference objects is proposed to improve the measurement precision. The experimental results show the validity of the proposed models.

The rest of this paper is structured as follows: Section 2 gives a simple algorithm for 2D size measurement of objects through image process; Section 3 describes the model improvement to obtain high accuracy. Section 4 is the experiment and analysis, and finally the conclusion of the paper.

II. 2D SIZE MEASUREMENT THROUGH IMAGE PROCESSING

The traditional image-based geometric size measurement of target objects usually needs a professional camera with given internal and external parameters, which is difficult to use in daily life [8]. This paper hopes to simplify the measurement process and consider a measurement model suitable for most nonprofessional cameras such as mobile phones, without calculating the internal and external parameters of the camera.

However, the differences in the distance and angles of the camera shooting will affect the sizes of the target objects in the image, which are not able to directly reflect the actual sizes of the objects. In this paper, the influence of the camera position is eliminated by setting a reference object. The reference object is an object with known size and put at the upper left of the group of target objects to be measured in the same plane. An image is obtained by setting the optical axis direction of the camera vertical to the plane when taking pictures. Using the reference object, we can calculate the actual size corresponding to a pixel, and then, the actual size of the target object can be obtained. In this case, the internal and external parameters of the camera are not necessary.

Algorithm 1 presents the detailed process of image-based 2D measurement.

Algorithm 1 Image-based 2D measurement

Initialization: Prepare the square reference object with the length of the side l and the threshold H for detecting noise points.

Step1: Taking a picture, denoted as image I_C. Ensure that the target objects to be measured and the reference object are on the same plane, and the reference object is located in the upper left corner of a color image I_C.

Step2: Image preprocessing. The color image I_C is transferred to the grayscale image and then smoothed by using the two-dimensional Gaussian function .The final result is denoted image I.

Step3: Edge detection. The Canny edge detection algorithm is used to detect the edge of image I. Mathematical morphology is used to smooth and connect the cracked edges. The final result is denoted image I_E.

Step4: Contour detection. The contours of the objects can be obtained by using the function find-contour() of OPENCV. If the area contained in the contour is less than H, the object contained in the contour may be considered as a noise area and be discarded. The final object ranges are denoted as $\xi_i i = 1, ..., n$, where n is the number of objects in the image.

Step5: Bounding box. The minimum circumscribed rectangle of every object range, called bounding box, $\Omega_i, i = 1, ..., n$ can be obtained by using the function BoxPoint() of OPENCV. For each $i = 1, ..., n$ the four vertices of Ω_i are denoted as $\lambda_{ij}, j = 1, ..., 4$ and the four edges are $e_{ij}, j = 1, ..., 4$. The distances of parallel edges are L_i, H_i which are the lengths of edges in pixel of the corresponding object. For simplicity, just suppose $H_i \leq L_i$.

Step6: Pixel unit. Find the bounding box Ω corresponding to the reference object (which is on the upper left) and its lengths of edges L_1, H_1.The pixel units can be calculated as $K_1 = \frac{l}{L_1}, \quad K_2 = \frac{l}{H_1}$.

Step7: Actual size of target objects. With the pixel unit K , the actual size of every object can be calculated:

$$l_{oi} = L_{oi} K_1, \quad h_{oi} = H_{oi} K_2. \tag{1}$$

III. Model correction

Algorithm 1 gives a simple image-based measurement of target objects. Due to the assumption of verticality of shooting angle which is not always satisfied, the precision of the measurement is not high. According to the Equation 1, the errors may be induced by the lengths of edges in pixel, or the pixel unit. Inspired by the traditional edge detection operator [9]–[11], in this paper, a correction model with 4 reference objects is proposed to improve the measurement accuracy. Four small objects with the same size bounding box (for examples, same size squares, or same coins) are placed at the four corners of a large rectangle as a calibration template, depicted in Figure 1.

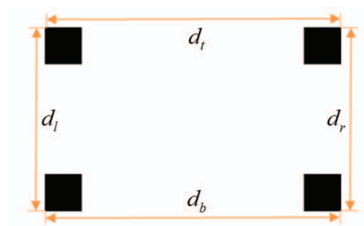


Figure 1. Calibration template

A. Correction of edge lengths in pixel

In the first part we perform edge length correction in pixels, i.e. correct L_{i1}, L_{i2} in Equation 1. Taking the ratio of the horizontal and vertical pixel width of the reference object to the horizontal and vertical pixel widths of the four small squares in the calibration template as the correction coefficient, and the relationship between the distance from the center of the bounding rectangle frame of the object to be measured to the center of each small square and the total distance as the weight, carry out weighted summation to obtain the edge pixel width of the corrected object.

Suppose L_j represents the horizontal pixel width of the jth small square, and H_j represents the vertical pixel width of the jth small square, and the 1th small square is reference object. d_{xj} and d_{yj} respectively represent the distance between the horizontal and vertical coordinates of the center of the target object to the jth small square. ω_{xj} and ω_{yj} represent the horizontal and vertical weights, e_{lj} and e_{hj} represent the horizontal and vertical correction coefficients respectively. $L_{oi}^{'}$ and $H_{oi}^{'}$ respectively represent the corrected horizontal and vertical pixel width for the ith target object. The specific equation is as follows:

$$\text{Ł}_{oi}^{'} = \sum_{j=1}^{4} \omega_{xj} e_{lj} L_j, \ \omega_{xj} = \frac{0.5 - d_{xj}}{\sum\limits_{j=1}^{4} d_{xj}}, \ e_{lj} = \frac{L_1}{L_j}. \tag{2}$$

$$H_{oi}^{'} = \sum_{j=1}^{4} \omega_{yj} e_{hj} H_j ,\ \omega_{yj} = \frac{0.5 - d_{yj}}{\sum\limits_{j=1}^{4} d_{yj}} ,\ e_{hj} = \frac{H_1}{H_j} . \quad (3)$$

B. Correction of pixel units

In the second part, we perform pixel-unit correction, that is, correct K_1, K_2 in Equation 1. The vertices in the four directions of the four small rectangles of the calibration template form a large rectangle, and the lengths of the four sides of the large rectangle are marked in Figure 1. The correction of the pixel unit starts from the large rectangle, and corrects K_1, K_2 by calculating the horizontal and vertical scaling ratio. Taking the top and left sides of the large rectangle as the reference standard, according to the idea of slicing, the large rectangle is cross-cut and longitudinally cut based on the center pixel point. Assuming that the length changes linearly, the lengths of the transverse and longitudinal edges can be calculated, and the horizontal expansion ratio of the center pixel of the target is defined as the ratio of the pixel width of the top side of the large rectangle to the pixel width of the transverse edge, and the vertical expansion The ratio is the ratio of the pixel width of the left side of the large rectangle to the pixel width of the vertical cut edge.

Suppose dox and doy represent the horizontal and vertical expansion ratios, respectively, and d_t, d_b, d_l and d_r represent the lengths of the top, bottom, left, and right edges of the large rectangle, respectively. h_o and w_o represent the ordinate and abscissa of the center pixel, h_t and h_b represent the ordinate of the midpoint of the top and bottom edges of the large rectangle, and w_l and w_r represent the abscissa of the midpoint of the left and right edges of the large rectangle. The mathematical expression is as follows:

$$dox = \frac{d_t}{d_t + \frac{(d_b - d_t)(h_o - h_t)}{h_b - h_t}} . \quad (4)$$

$$doy = \frac{d_l}{d_l + \frac{(d_r - d_l)(w_o - w_l)}{w_r - w_l}} . \quad (5)$$

Finally, the corrected horizontal and vertical pixel width of the target object can be obtained by:

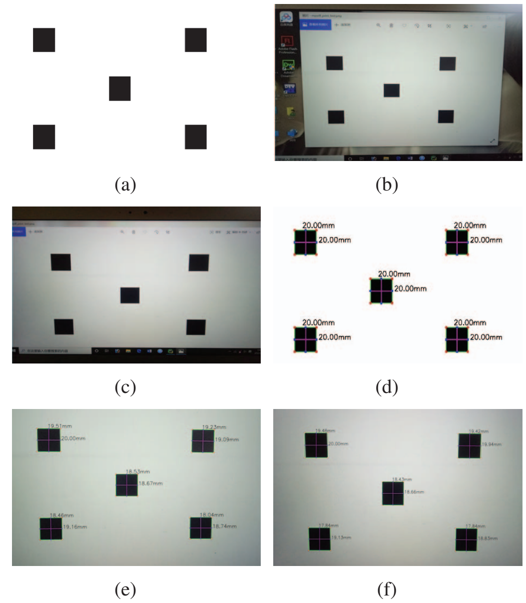
$$l_{oi}^{'} = L_{oi}^{'} dox K_1 , \quad h_{oi}^{'} = H_{oi}^{'} doy K_2 . \quad (6)$$

IV. Experiments

Experimental environment: We conduct experiments under the window 10 operating system, using the Python-Open CV computer vision library for image processing, and the code is written in python.

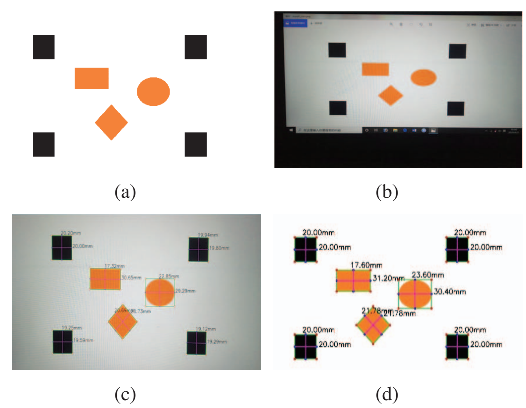
Experimental data: The original image data of the experiment is drawn from the drawing tool in the Windows accessory. The test shot image is obtained by directly adjusting the shooting angle of the mobile phone and shooting it against the computer screen.

Figure 2 depicts the test results of the first group, including original design graphics, shot images, original design graphics size, and test results.Figure 3 depicts the test results of the second group, including original design graphics, shot images, original design graphics size, and test results.



(a) (b) (c) (d) (e) (f)

Figure 2. The first group of test results, (a) original design graphics 1; (b) test shot image 1; (c) test shot image 2; (d) original design graphic 1 size; (e) test image 1 results; (f) test image 2 results.



(a) (b) (c) (d)

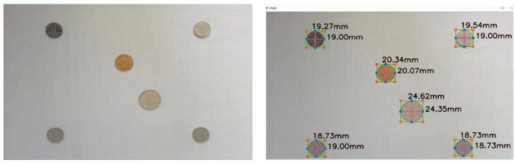
Figure 3. The second group of test results, (a) original design graphics 2; (b) test shot image 3; (c) test image 3 results; (d) original design graphic 2 size.

The actual width of the final corrected target can be calculated according to the horizontal and vertical pixel widths of the final corrected target. The corrected results, actual results, original errors, and corrected errors of the target object in the test chart are shown in Table I:

Table I
CORRECTION, ACTUAL RESULTS, ORIGINAL AND CORRECTED ERRORS OF THE TARGET OBJECT

Number	A3		B3		D1		D2		D3	
Corrected width	19.73mm	19.96mm	19.64mm	19.90mm	31.37mm	17.56mm	21.44mm	21.42mm	30.21mm	23.37mm
Actual width	20.00mm	20.00mm	20.00mm	20.00mm	31.20mm	17.60mm	21.78mm	21.78mm	30.40mm	23.60mm
Original error	6.65%	7.35%	6.70%	7.85%	1.76%	1.59%	4.82%	5.00%	3.65%	3.18%
Correction error	1.35%	0.20%	1.80%	0.50%	0.54%	0.23%	1.56%	1.65%	0.63%	0.97%

It can be seen that the maximum original error is



(a) (b)

Figure 4. Coin size measurement, (a) original shot image; (b) coin measurement result.

7.85%, the original average error is 4.86%, the maximum corrected error after correction is 2.57%, and the corrected average error is 0.94%. Therefore, the correction model proposed in this study has certain validity for the detection of image size in two-dimensional planes. In this example, the coins in the fifth set of RMB are used as measurement objects. The specifications of the coins [12]: one-cent coin (round, diameter 19.00mm, thickness 1.67mm), five-point coin (round, diameter 20.50mm, thickness 1.65mm), one yuan coin (round, diameter 25.00mm, thickness 1.85mm). The test result of the coin obtained by the algorithm is shown in Figure 4 as follows:

The actual width of the final corrected target can be calculated according to the horizontal and vertical pixel widths of the final corrected target. The corrected results, actual results, original errors and corrected errors of the 5-cent and 1-yuan coins are shown in Table II:

Table II
CORRECTION, ACTUAL RESULTS, ORIGINAL AND CORRECTED ERRORS FOR 5-CENT AND 1-YUAN COINS

Coin	Corrected width	Actual width	Original error	Correction error
5-cent	20.23mm	20.50mm	2.10%	1.31%
	20.18mm	20.50mm	0.78%	1.56%
1-yuan	24.68mm	25.00mm	2.60%	1.28%
	24.74mm	25.00mm	1.52%	1.04%

It can be seen that the maximum original error is 2.60%, the original average error is 1.75%, the maximum corrected error after correction is 1.56%, and the corrected average error is 1.29%. This result is an increase compared to the average error when validating the model. The reason is that the thickness of the 1 cent, 5 cent, and 1 yuan coins is different, but the increase in error is also within an acceptable range. Therefore, four coins of the same specification can also be selected for the calibration template in the future, which provides certain convenience for the surveyor.

V. CONCLUSION

In this paper, the problem of size detection of two-dimensional plane graphics images is studied. Through the perspective projection relationship and triangular geometry knowledge, it is proved that the ratio of the pixel width of the object to the actual width of the object is invariant, and the length and width of the minimum circumscribed rectangle of the image captured by the graphics are calculated, and then obtain the size of the plane figure. In the process of research and experiment, it is found that the problem of shooting angle will have a greater impact on the measurement results. In order to ensure the accuracy of the measurement, a correction model is proposed to correct the pixel width of the object calculated in the first stage. After the model is revised, the error of image size detection has been greatly improved, and the average error has been reduced from 4.86% to 0.94%, which verifies the effectiveness of the model proposed in this study. Finally, by measuring the size of coins for example analysis, the previously designed calibration template can also be replaced by four coins with the same specifications, which is convenient for the measurer.

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