

A Method of Hole Center Positioning in Building Steel Plate Image

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Abstract. Detection technology research about the steel plate of high-rise buildings has practical application value in building survey. In order to obtain center positions of circular holes in steel plate, Close-range Photogrammetry with advantages of non-contact, high accuracy is employed. According to the coordinate of control points, regions of interest of holes in steel plate image are confirmed. Then the holes' edge is detected by Sobel operator after binarization in respective regions of interest. Finally, the center coordinates of each hole are localized precisely by ellipse best fitting, and the space coordinates of holes are calculated by bundle adjustment. Test results show that the method can meet the requirement of accuracy.

Introduction

In recent years, many measurement technologies based on image, such as Close-range Photogrammetry, Vision Measurement, Vision Inspection, have been widely used in many fields[1, 2]. Measurement technologies based on image have the advantages of non-contact, high-speed, appropriate precision and strong anti-interference. As for the detection of hole in steel plate, it's necessary to confirm the precise location of circular hole's center in image for qualifying the identification of circular hole. According to the intrinsic characteristics of perspective projection, circular target is transformed into elliptic through lens imaging. There are several research methods for identifying ellipse center, such as gray square method[3], perimeter averaging method[3], and Hough transform[4] etc. These methods are usually used in the images with uniform distribution of gray level, and are unavailable in noisy and complex measuring environment. In order to obtain the precise coordinates of the ellipse center, many researchers have done a lot of related research. In Reference [5], circle targets are made from retro-reflective material, some classic algorithm and gradient amplitude average method are used to extract the sub-pixel edge of circle targets, then the coordinates of hole center is determined in sub-pixel. Under the premise of good measuring environment, a good measuring precision is gotten using above method. Once the measuring environment becomes complex, the precision advantage does not exist.

In this paper, images of building steel plate with circular holes taken in workshop are served as research objects. Under such circumstance, the following method is adopted in order to achieve precise center coordinates of circular hole. First of all, the rough center position of circular hole in image is calculated through Two-Dimensional direct linear transformation, thereby the regions of interest (ROI) of each hole are determined. Then binarization processing is executed in each region of interest, and ellipse edge of hole image is detected by Sobel operator. Thirdly, ellipse curve is fitted according to ellipse edge points by least-squares algorithm. The center of the fitted ellipse is regarded as the accurate position of the hole center in steel plate image. Finally, object space coordinates of each hole are calculated using bundle adjustment.

Image Preprocessing

When human visual system deal with complex scenes, its visual attention focuses on a few objects, which are prior processed in order to obtain main information of the scene in the shortest time. This

process is called Visual Attention Process, and region of these objects in the scene is called Region of Interest (ROI). Not only the amount of calculation is decreased in ROI, but also the difficulty of next processing steps is reduced on account of complex background in image. Therefore, ROI plays an extremely important role in circular hole measurement under complicated background.

There are two steps to determine ROI of each hole.

1) Calculating the approximate coordinates of circular hole center.

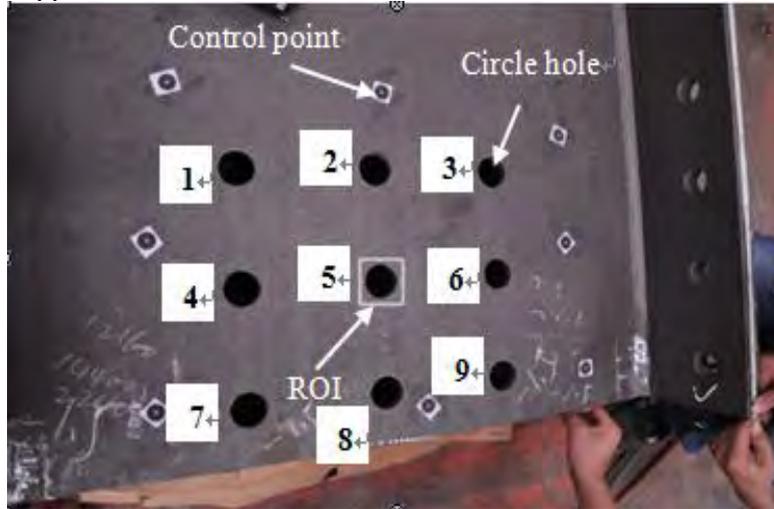


Fig. 1 Images For ROI

Artificial targets are placed on the steel plate, as shown in Fig.1, which are regarded as control points. Their object space coordinates(X, Y, Z) are measured by total station. After extracting the image coordinates(x, y) of control points, 8 coefficients($l_1, l_2...l_8$) in Equation (1) could be calculated.

$$\begin{cases} x + \frac{l_1 X + l_2 Y + l_3}{l_7 X + l_8 Y + 1} = 0 \\ y + \frac{l_4 X + l_5 Y + l_6}{l_7 X + l_8 Y + 1} = 0 \end{cases} \quad (1)$$

According to the designed distances among circular hole centers and the relative position relationship between circular holes and artificial targets in object space coordinate system, the initial values of object space coordinates(X^0, Y^0, Z^0) of circular hole center are estimated. The initial values of object space coordinates(X^0, Y^0, Z^0) of circular hole center and 8 coefficients($l_1, l_2...l_8$) are regarded as known values and taken into Equation (1), then the approximate image coordinates (x_0, y_0) of hole center could be calculated[6, 7].

2) Determining ROI of each hole.

Each circular hole in image has nearly same size, so the size of ROI of each hole can be set as the same size. The approximate coordinates (x_0, y_0) of circular hole center are regarded as the center of ROI, around which square could be drawn as ROI, as shown in Fig.1.

In order to extract the edge more effectively, binarization processing is executed by Otsu algorithm[8] in ROI. This algorithm has strong anti-noise ability and could achieve good binarization results. Due to the uncertainty of the measurement environment, there are a few independent noise points in binarization image of ROI. So median filtering method[9] is employed to remove those noise points.

Detecting Edge

There are some traditional edge detection algorithms, such as Roberts, Prewitt, LOG[10, 11], etc. These operators are simple and easy to implement, however they are more sensitive to noise. By contrast, Sobel operator has the advantage of a large SNR and high detection accuracy.

The Sobel operator performs a 2-D spatial gradient measurement on an image and so emphasizes regions of high spatial frequency that correspond to edges. Typically it is used to find the approximate absolute gradient magnitude at each point in an input grayscale image [12].

The operator uses two 3×3 kernels which are convolved with the original image to calculate approximations of the derivatives - one for horizontal changes, and one for vertical [13], as shown in Fig.2.

-1	0	1
-2	0	2
-1	0	1

1	2	1
0	0	0
-1	-2	-1

(a) Horizontal direction kernel (b) Vertical direction kernel

Fig. 2 Sobel Edge Operator

In the process, Sobel operator is used for the convolution operation of horizontal and vertical directions, and the magnitude of the gradient is obtained. According to the magnitude, the edge of the circle hole could be detected. The effect noise has on the extraction of edge has been greatly reduced after been preprocessed. However, few clutters still might be detected. An area threshold, whose value is defined tenth of the total area of ROI, is employed to avoid this phenomenon. When the area of edge contour is less than the threshold value, the clutters will be filtered out. The result images of threshold limits before and after been processed are shown in Fig. 3.

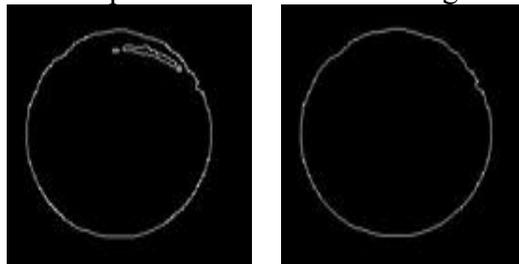


Fig. 3 Images before and after Area Threshold Limits

Fitting Ellipse and Determining Center Position

In computer vision, quadratic curve, just like points, lines, is considered as the basic image feature. In real life, when the target is a round or oval, its perspective projection is ellipse.

To determine the center position and spindle orientation of these ellipses, we can fit the set of edge points obtained by the previous as an ellipse by the least squares method. The general equation for an ellipse:

$$x^2 + 2Bxy + Cy^2 + 2Dx + 2Ey + F = 0 \tag{2}$$

The center coordinates of ellipse can be obtained based on five ellipse parameters (B, C, D, E, F). The center coordinates is shown in Equation (3).

$$\begin{cases} x_c = \frac{BE - CD}{C - B^2} \\ y_c = \frac{BD - E}{C - B^2} \end{cases} \tag{3}$$

In order to reduce the influence of image noise and improve the positioning accuracy, quadratic fitting can be carried out on the edge. After we calculate the residuals of each edge point obtained in the first fitting, the residual of the point is large, get rid of it, the remaining points are used for the second ellipse fitting. By this calculation method, we achieve the ellipse best fitting and improve the accuracy of the calculation of the center.

Experimental Results and Analysis

Three building steel plate images are taken in messy environment by digital camera, which is Nikon D90 SLR camera with 18mm lens. Images are shown in Fig.4. So it is obvious that there are some noise in these images.

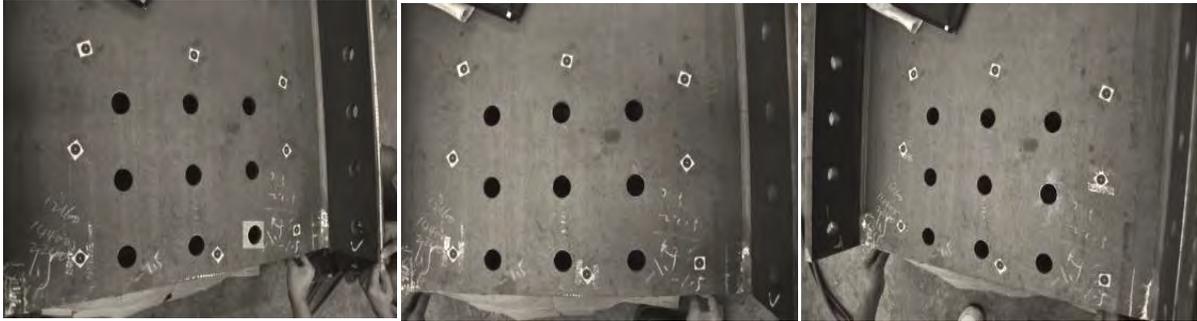
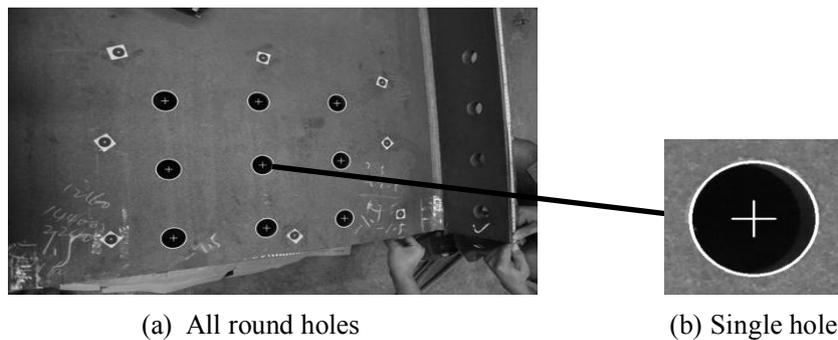


Fig. 4 Images of Steel Plate

The extracted and positioned result image is shown in Fig.5 (a). This image illustrates that this method could ensure accuracy and robustness. One of ellipse fitting images is shown in Fig.5(b), and the cross mark displays the center of the hole. Apparently the elliptical edge fits nicely the actual edge, the center position is also very reasonable.



(a) All round holes

(b) Single hole

Fig. 5 Ellipse Fitting Image

The object space coordinates of all holes are calculated by bundle adjustment [1], while the accuracy is computed. The tolerance of quality inspection is $\pm 0.5\text{mm}$ for plane point accuracy and $\pm 0.7\text{mm}$ for plane distance accuracy between two adjacent holes. Table 1 displays the theoretical accuracy of plane coordinates of 9 holes, where m_X , m_Y represent X , Y coordinates accuracy and m_{XY} represents plane point accuracy. Table 2 displays the distances of two adjacent holes. The designed distances between two adjacent holes in X , Y direction are 180.0mm and 150.0mm respectively. The results prove that the above method could meet the accuracy requirement.

Tab. 1 the Position Error of Circle Hole Center [mm]

Tab. 2 the Distance of Circle Holes [mm]

No.	m_X	m_Y	m_{XY}	No.	m_X	m_Y	m_{XY}
1	0.06	0.10	0.11	6	0.13	0.11	0.17
2	0.08	0.09	0.12	7	0.13	0.13	0.18
3	0.09	0.03	0.10	8	0.07	0.11	0.13
4	0.10	0.09	0.13	9	0.10	0.09	0.13
5	0.10	0.11	0.15				

Line No.	Distance	Line No.	Distance
1-2	180.02	1-4	149.93
2-3	180.12	2-5	150.70
4-5	180.09	3-6	150.22
5-6	180.23	4-7	150.31
7-8	179.98	5-8	150.66
8-9	180.12	6-9	150.39

Conclusion

This paper analyzes the complexity of the test image data. In order to avoid the effect of noise on the center hole location, regionalizing holes, binarization image processing, Sobel operator which has strong anti-noise capability and extract edge with good effect is selected, the center of the circle holes is determined by using least squares method to fit ellipse. The object space coordinates of holes are calculated by using bundle adjustment. Results indicate that this method could achieve good center positioning accuracy and meet accuracy requirement of quality inspection. This method effectively solves the problem of center positioning of holes in close-range images, ensures the accuracy and lay a good foundation for future relevant work.

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References

- [1]W. H. Feng, Close-range photogrammetry, Wuhan University Press, Wuhan, 2002.
- [2]Y. D. Jia, Machine vision, Science Press, Beijing, 2000.
- [3]B. X. Yan, N. G. Lv, W. Y. Deng, et al, Comparison of several calculating methods of target image center in digital photogrammetry, J. Optics and precision engineering, 2004, vol. 12(4): 171-175.
- [4]Y. X. Chen, F. H. Qi, A new ellipse detection method using randomized hough transform, J. Journal of Infrared and Millimeter Waves, 2000, vol. 19(1): 43-47.
- [5]G. P. Huang, Center subpixel localization of circular retro-reflective targets, J. Geomatics and Information Science of Wuhan University, 2005, vol. 30(5): 388-391.
- [6]X. Li, S. W. Li, X. Shen, Automatic measurement of circular artificial targets in digital image, C. 2009 International Conference on Information Engineering and Computer Science, ICIECS, Wuhan, 2009, vol.1: 417-420.
- [7]X. Li, C. X. Chen, X. L. WANG, Deformation measurement of mine similar material model based on multi-intersection photography, J. Geomatics and Information Science of Wuhan University, 2012, vol. 37(11): 1294-1298.
- [8]N. OTSU, A threshold selection method from gray-level histograms, J. IEEE Transactions on Systems, Man, and Cybernetics, 1979, vol. SMC (9): 62-66.
- [9]T.S.Huang, G.J.Yang, G.Y.Tang. A fast two-dimensional median filtering algorithm, J. IEEE Transactions on Acoustics, Speech, and Signal Processing, 1979, vol. ASSO(27): 13-18.
- [10]G. P. Yan, R. Y. Dai, Q. Pan, et al. Adaptive approach to image by Laplacian of Gaussian operator, J. Journal of Huazhong University of Science and Technology: Natural Science Edition, 2008, vol. 36(3): 85-102.
- [11]D. Marr, E. Hildreth. Theory of edge detection, C. Proceedings of the royal society of London. London, 1980, vol. 207(1167): 187-217.
- [12]Information on <http://homepages.inf.ed.ac.uk/rbf/HIPR2/sobel.htm>.
- [13]Information on http://en.wikipedia.org/wiki/Sobel_operator.