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Research on Image Contour Edge Analysis Based on Canny Edge Detector

Linjun Zhao*, Ruisha Zhu

School of Computer Science and Information Engineering, Hubei University, Wuhan Hubei, 430062, China
**Corresponding author*

Abstract: *In this paper, aiming at the sub-pixel edge contour detection method, the sub-pixel edge contour extraction model and camera imaging geometric model are established step by step. Firstly, the improved anti-tangent function model based on canny operator is adopted. Firstly, the image is grayed out, then the edge of canny operator is detected by Gaussian filter, and a better method of edge detection after extended smoothing is proposed. Extract the sub-pixel edge outline of the target, then detect and fit lines, curves and circles, and mark them with different colors. Then for the correction of the image captured by the camera, this paper uses an image calibration model based on Zhang Zhengyou camera calibration method. The camera is calibrated by the calibration picture given, the internal and external parameters of the camera are obtained, and the unit matrix is calculated. Using the given definition of calibration board information, the number of pixels per millimeter pixel in the image is estimated. The research is helpful to improve the accuracy of sub-pixel edge contour detection and improve the image edge detection of industrial parts to a certain extent.*

Keywords: *Subpixel Edge Outline, Canny Edge Detector, Camera Calibration*

1. Introduction

With the development of science and technology, the measurement accuracy of various workpiece in modern industry is more and more demanding. The camera takes the image and calibrates it. According to the lattice or checkerboard characteristic information of the calibrated image, the image is corrected. Finally, the mapping relationship between the image coordinate space and the world coordinate space can be calculated.Therefore, for the calibration and feature extraction of workpiece, image edge detection technology is particularly important.

The edge of object is very important in image recognition and computer analysis.Image edge is a reflection of the discontinuity of local features. With the increasingly high requirements of modern industry on the measurement accuracy of various workpiece and parts, target detection for precision parts and high-precision measuring equipment is particularly important. PeterSussner, LisbethCorbachoCarazas et image detection based on interval value fuzzy mathematical morphology research [1] the mathematics method and the image detection together. At the same time, Hui Zhang et al. [2] also mentioned the application of computer vision to the detection and positioning of electric vehicle charging holes, proving that image pro-cessing is very necessary in the detection of industrial precision parts. We have learned two basic algorithms of Sobel and Canny for edge detection of target by reading relevant literature [3-4]. For sub-pixel edge detection technology, YosipY.Bylinskyetal. [5] Proposed the application of low-frequency filtering in sub-pixel edge detection, and Ming Liu etal. The purpose of contour extraction and contour tracking is to obtain the external contour features of the image. The application of certain methods to express contour features when necessary, in preparation for image shape analysis, has a significant impact on the performance of advanced processing such as feature description, recognition and understanding.

2. Based on Canny sub change tangent number type

The gray level distribution fitting the arctangent function is expressed as:

$$y = A\arctan(\omega x + \varphi) + h \tag{1}$$

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In this case, the zero of the second derivative $x=-\frac{\omega}{\varphi}$ is taken for research to obtain the sub-pixel edge position of the edge point.

$$\begin{cases} \frac{dy}{dx}=\frac{A\omega}{1+(\omega x+\varphi)^2} \\ \frac{d^2y}{dx^2}=-\frac{2A\omega^2(\omega x+\varphi)}{[1+(\omega x+\varphi)^2]^2} \end{cases} \tag{2}$$

According to the edge gray model theory, we need to make the areas of S_1, S_2 equal as much as possible to obtain the coordinate value of the segmentation point x more accurately.

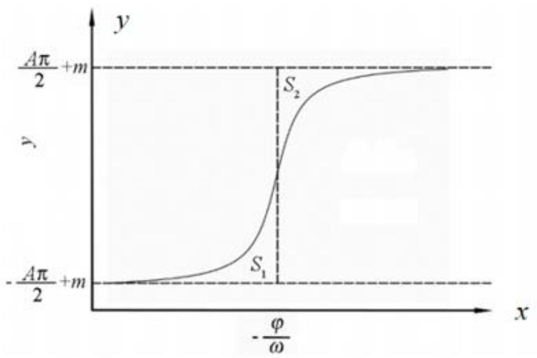

Figure 1: Gray function area segmentation diagram

Will function from x = 0 to x = xn (functions corresponding to the coordinate values of the upper bound) divided into infinitesimal section, record theory, theory of edge pixels (equinoctial edge point (point) coordinates for $P(x_p, y_p)$), in pixels in the image edge point method to take k points on each side, edge pixels around there is a transition point, the edge pixel edge points coordinates is P_{k+1} ,There are a total of $n=(2k+1)$ points, and the left and right sides of edge feature points are divided into k segments.

Suppose that the areas of the left and right sides of the pixel edge point are $S_1^{'}, S_2^{'}$ respectively by definite integration, and the area formula can be obtained by accumulative area:

$$\begin{cases} S_1^{'}=\sum_{i=1}^{k}S_{ii+1}=S_{12}+S_{23}+\ldots+S_{k(k+1)} \\ S_2^{'}=\sum_{i=k+1}^{n-1}S_{ii+1}=S_{(k+1)(k+2)}+S_{(k+2)(k+3)}+\ldots+S_{(n-1)n} \end{cases} \tag{3}$$

Definite integral is simultaneously performed on the functional segmentation regions on the left and right sides of theoretical edge point P, and the area formula of (definite integral form) is as follows:

$$\begin{cases} S_1^{'}=\int_{x_{p_1}}^{x_{p_{k+1}}}P(x)dx=\sum_{i=1}^{k}(y_i-y_1+y_{i+1}-y_i)\Delta x/2 \\ S_2^{'}=(x_n-x_{k+1})(y_n)-\int_{x_{p_{k+1}}}^{x_{p_n}}P(x)dx=\sum_{i=k+1}^{n-1}(y_i-y_1+y_{i+1}-y_i)\Delta x/2 \end{cases} \tag{4}$$

Due to the limited number of regions divided, there may be a case of $S_1^{'}, S_2^{'}$ is not equal. When $S_1^{'}>S_2^{'}$, the theoretical edge point will be located in the region between P_kP_{k+1};When $S_1^{'}<S_2^{'}$, the theoretical edge point will be in the region between $P_{k+1}P_{k+2}$.According to the coordinates of theoretical edge points explained above $P(x,y)$, then the equation is as follows:

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$$\left|S_1^{'} - S_{01}\right| = \left|S_2^{'} - S_{02}\right| \tag{5}$$

$$\begin{cases} x_p = x_{k+1} - \dfrac{S_{01} + S_{02}}{y_n - y_1} = x_{k+1} - \dfrac{S_1^{'} + S_2^{'}}{y_n - y_1} \\ x_p = x_{k+1} - \dfrac{\sum_{i=1}^{k}(y_i - y_1 + y_{i+1} - y_1)\Delta x - \sum_{i=k+1}^{n-1}(y_n - y_i + y_n - y_{i+1})\Delta x}{2(y_n - y_1)} \\ x_p = x_{k+1} + \dfrac{\Delta x}{2(y_n - y_1)}\left[2\sum_{i=1}^{n} y_i - (2k+1)(y_n + y_1)\right] \end{cases} \tag{6}$$

3. Subpixel edge extraction method solution

The output of the image results is the color edge contour image, and the detection result image is shown below (the detection result file is in PNG image format and named pic1_1.png,pic1_2.png,pic1_3.png) :

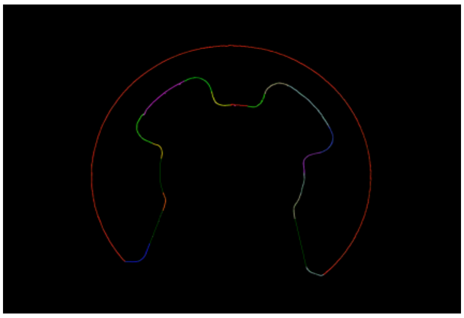

Figure 2: Pic1_1 color contour detection result diagram

Figure 3: Pic1_2 color contour detection result diagram

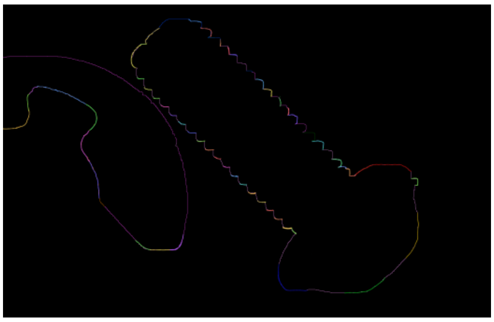

Figure 4: Pic1_3 color contour detection result diagram

From this, we can obtain the total number of contour curves on each image, as well as the number of points and length data on each curve.

For example:

Table 1: Pic1_1 Edge Contour Data Output Table

Total Edge Contours Count		5
Total Edge Contours Length		6805.15843
Edge Contour 1	Length	6.82843
	PointCount	5
Edge Contour 2	Length	4
	PointCount	2
Edge Contour 3	Length	4
	PointCount	2
Edge Contour 4	Length	3416.19
	PointCount	1474
Edge Contour 5	Length	3374.14
	PointCount	1457

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4. Camera imaging geometry model establishmment

A user-defined coordinate system for the three-dimensional world, introduced to describe the position of objects in the real world. The general coordinates are described as (unit: m):

$$P_w = (X_w, Y_w, Z_w) \tag{7}$$

camera coordinate system: The coordinate system established on the camera, defined for the purpose of describing the position of the object from the camera's point of view, as the middle ring of the communication between the world coordinate system and the image/pixel coordinate system (unit :m):

$$P_c = (X_c, Y_c, Z_c) \tag{8}$$

image coordinate system: It is introduced to describe the projection transmission relationship of objects from camera coordinate system to image coordinate system in the imaging process, so as to further obtain the coordinates in pixel coordinate system (unit: m):

$$p = (x, y, 1) \tag{9}$$

pixel coordinate system: Introduced to describe the coordinates of the image point of the object after imaging in the digital image (photo), is the coordinate system where we really read the infor-mation from the camera (unit: unit):

$$(u, v) \tag{10}$$

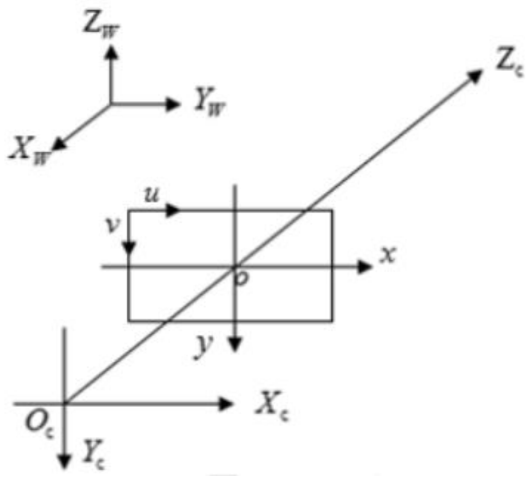

Figure 5: The relationship between the four coordinate systems

Where, the axis of the camera coordinate system coincides with the optical axis, and is perpendicular to the plane of the image coordinate system and passes through the origin of the image coordinate system. The distance between the camera coordinate system and the image coordinate system is focal length F (that is, the origin of the image coordinate system coincides with the focus).The pixel coordinate system plane u-v coincides with the image coordinate system plane x-y, but the origin of the pixel coordinate system is in the upper left corner of the image (defined so as to read and write from the initial address where the information is stored).

5. Corrective lens malformation

Combining camera coordinate system with pixel coordinate system, the internal parameter matrix can be obtained:

$$M = \begin{bmatrix} f_x & \gamma & u_o \\ 0 & f_y & v_o \\ 0 & 0 & 1 \end{bmatrix} \tag{11}$$

Here we introduce a new concept: Homography transform.It can be simply understood as it is used to describe the position mapping relationship between the world coordinate system and the pixel coordinate system. The corresponding transformation matrix is called the homography matrix.In the above formula, the homography matrix is defined as:

$$H = s\begin{bmatrix} f_x & \gamma & u_o \\ 0 & f_y & v_o \\ 0 & 0 & 1 \end{bmatrix}[r_1 \quad r_2 \quad t] = sM[r_1 \quad r_2 \quad t] \tag{12}$$

Where, M is the internal parameter matrix. From the definition of homography matrix, it includes both the internal and external parameters of the camera.

The conversion relationship from the world coordinate system to the pixel coordinate system is as follows:

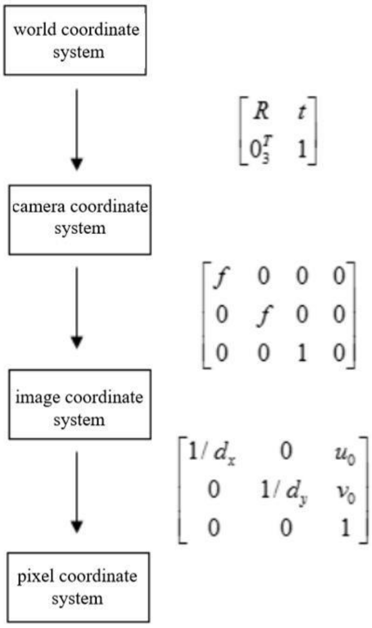

Figure 6: The conversion relationship from world to pixel coordinates

6. Take the image rim and calculate the profile

The contour of the object can be extracted by using the subpixel contour extraction method of model 1 again. However, the contour is divided into 6 parts and the length needs to be calculated separately. Therefore, the contour needs to be segmented first. Through threshold segmentation and shape screening, the 6 regions are segmented from the image:

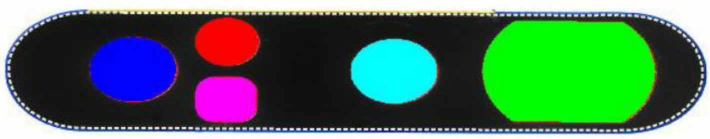

Figure 7: Each contour diagram after segmentation

After the region is screened, it must include its edge first. Only when the whole region is included, can the region edge be guaranteed to be inside.This paper first uses expansion, smoothes the area, and then cuts it out from the original image.After the segmentation, the Canny algorithm in Model 1 was used to extract the sub-pixel edge contours of the six regions, and then the contour was fitted.

7. Conclusion

With the development of science and technology, the measurement accuracy of various parts and workpieces in the industry is getting higher and higher, and the accuracy of measuring instruments is also getting higher and higher. Therefore, this paper first grays the image, then uses Gaussian filtering to detect the edge of the Canny operator, extracts the sub-pixel edge contour of the target, and then detects and fits lines, curves and circles, and marks them with different colors. Then the unit matrix is used to correct the image captured by the camera at the same height. After correction, the image contour is

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segmented. Using the given definition of calibration board information, the number of pixels per millimeter pixel in the image is estimated, and the pixel value of the profile to be measured is calculated.

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