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Research on Distortion Algorithm of Panoramic Image Unfolding Map

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Abstract: **For an in-depth study of the aberration correction of the panoramic camera image unfolding map, a distortion correction method based on the panoramic image unfolding map inside the pipe is proposed for the aberration correction of the panoramic image unfolding map captured by the panoramic camera. The Hoff transform is used to select the part of the panoramic image captured by the panoramic camera with regular distortion and intercept it into a circle, expand the circle into a rectangular map, identify the black frame outline in the rectangular map, and derive the distortion correction formula for the distortion existing in the rectangular map by using the parameters of the radius and focal length of the panoramic camera lens combined with the pipe diameter. The results show that the distortion processed by the correction formula conforms to the original characteristics of the panoramic image unfolding map with an error of less than 0.2%.**

Keyword: panoramic unfolding; Hough transform; image recognition; distortion correction

I. Introduction

With the development of industry, the processing accuracy of pipeline has reached micron level or even nanometer level, and the measurement of internal defects of pipeline has also put forward higher requirements. For the internal detection of the pipeline is initially used contact measurement, in most universities and enterprises to measure the inner wall of the pipeline is a combination of contact measurement and visual inspection method, contact measurement method for the inner wall of the pipeline is generally used long rod gauge, plug gauge, internal diameter percentage table, micrometer, comparator and other measuring devices, generally with a certain measuring force between the contact surface of the measurement target, with a high degree of measurement Reliability, but the manual use of contact measurement of the inner wall of the pipe will be affected by the length of the pipe, pipe diameter and other factors, increasing the difficulty of measurement and work intensity, so the contact measurement of the inner wall of the pipe in the detection efficiency, accuracy, repeatability and other aspects have great limitations. This shows that the contact measurement of the inner wall of the pipe not only has a large measurement error, but also has an impact on the stability of the use of the pipe.

After the development of modern industrial technology, automation, photoelectric detection, computer vision and other disciplines have also been enhanced, in terms of non-contact measurement, with the rapid development of measuring instruments, the emergence of high-precision measuring instruments such as laser technology, ultrasonic technology and other measurement accuracy and high pixel CCD device pixels have also been improved, these emerging measurement technologies have the advantages of fast measurement speed, high detection accuracy, non- Contact measurement can avoid direct contact with the inner wall of the pipe, the current mainstream body tube inner wall measurement system using laser detection, visual peephole method, etc.At present, the rotary peeping method and panoramic peeping method are used for the acquisition of the internal image of the pipeline peeping method. And the rotary peeping method is mounted on the rotating mechanism to rotate the camera to take pictures of the peeping, but this method for calculating the location of defects inside the pipe will cause errors due to the centrifugal rotation of the rotating mechanism on the judgment of the location of defects. The panoramic view method does not require rotation to photograph the inner wall of the pipe to compensate for the error caused by the eccentric rotation movement, but the image taken by the camera in the panoramic view method will have aberrations, so the aberrations need to be corrected.

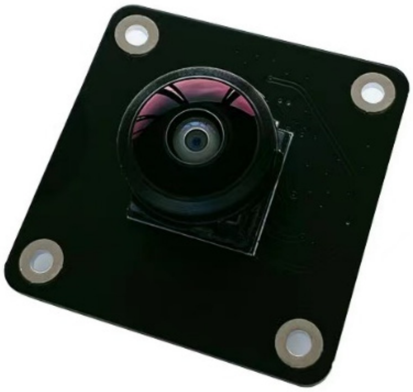
The problems that existed in the image distortion captured by the panoramic camera currently are pillow distortion, barrel distortion, and trapezoidal distortion of the unfolded map[1]. Xu Dingtian et al. proposed a 360° hovering display system based on human eye tracking[2]. The multi-camera human eye tracking algorithm is used to obtain the viewpoint position of the observer in real time, and OpenGL is used to generate the corresponding viewpoint screen. Yang Fan et al. quantitatively analyzed the amount of image distortion and proposed a divergence scan mode OCT image correction and reconstruction algorithm[3]. Lu Lijun et al. proposed a new method to correct the image aberrations of the fisheye lens. By tracing the main light of the optical system, the relationship curve between its radial position on the projection plane and its position on the image plane is obtained[4]. Then the relationship curve is fitted with the Fourier series, and the inverse function of the series is derived[5]. As a result, the image without aberration can be recovered according to the aberrated image[6].

In summary, this paper intercepts the part of the pipe inner wall image taken by the panoramic camera with the Hough transform where the distortion exists regularly[7], expands the intercepted circle, identifies the contour of the black frame in the expanded image, derives the relevant distortion correction formula, corrects the contour of the black frame, and compares it with the original image[8].

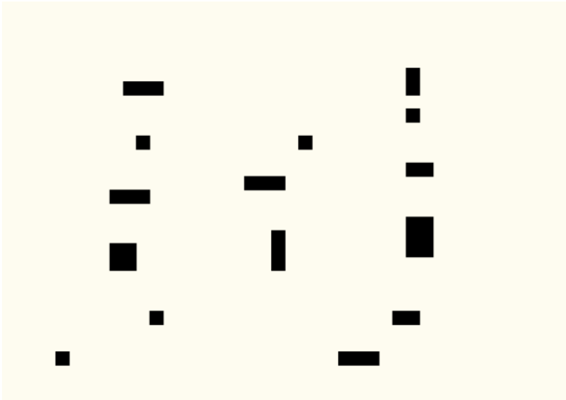
II. Panoramic image processing and defect recognition

The Raspberry Pi panoramic camera with IMX-378 sensor chip model is selected as the experimental object, as shown in Figure 1(a). The panoramic camera field of view is 190°, the pixels are 12.3 million (4056*3040), the aberration is <58%, the focal length is 6.5mm, the CMOS size is 1/2.3 inch, the aperture is F2.4, and the focusing method is fixed focus[9].

In this paper, the diagram with black grids is attached to the inner wall of the cylinder as the experimental object[10], as shown in Figure 1(b). The minimum grid is 10*10 mm, the size of the grid diagram is 210*297 mm, and the black grids are randomly distributed to form rectangles of different areas.



(a) IMX-378 panoramic camera



(b) Plan view of the black grid

Figure 1 Experimental subjects

The Raspberry Pi 4B+ is selected as the experimental control module, and the images captured by the Raspberry Pi-controlled panoramic camera are shown in Figure 2(a). It can be seen that the distortion becomes more serious as the image goes to the center. In addition, the distortion in the center part of the panoramic image and the part near the edge also show serious distortion[11], but the transition part from the center to the edge in the panoramic graph shows regular distortion, so the Hough transform is applied to the image captured by the panoramic camera.

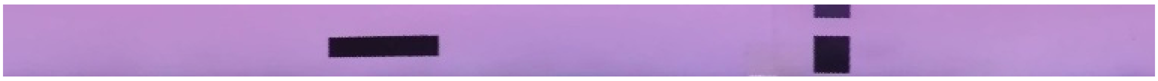
The panoramic image is cropped using the Hough transform as in Figure 2(b) to intercept the circular part that presents regular aberrations. When the edge map of the whole image is traversed, if it is an edge point, then this point is taken to vote on the parameter space because the normal at a point on the circle is fixed over the center of the circle. In light of this[12], only the normal direction, such as the gradient direction, is considered here. And the quantization of the parameter space is mainly to reduce the computational effort while expanding the voting space to make the result more controllable. The pixels of the panoramic image is 640*480, and the radius of the outer circle of the intercepted circle is 195 pixels with a width of 130 pixels. In the Hough transform the circle you need three parameters (x, y, r). x, y denote the coordinates, r denotes the radius of the circle, and the Hall circle calculation formula is shown in Equation (1).

$$\begin{cases} x = x \pm step\,, y = y \pm step \times tan\theta \\ r = r \pm \sqrt{x^2 + y^2} \end{cases} \tag{1}$$

The intercepted circle is expanded as in Figure 2 (c).

(a) Panoramic camera captures Heggigram images

(b) Hoff transformation of the acquired image to intercept the circle



(c) Circle image expanded into a rectangle

Figure 2 Panoramic camera shooting image processing

From Figure 1(b) and Figure 2(c), we can see that the image captured by the Raspberry Pi-controlled panoramic camera has a serious distortion compared with the original image after expansion. And this distortion needs to be corrected to restore its shape to Figure 1(b). The distorted black frame outline is identified using Python for the expanded image in Figure 2(c), and the identified image is shown in Figure 3. All units in the figure are pixels.

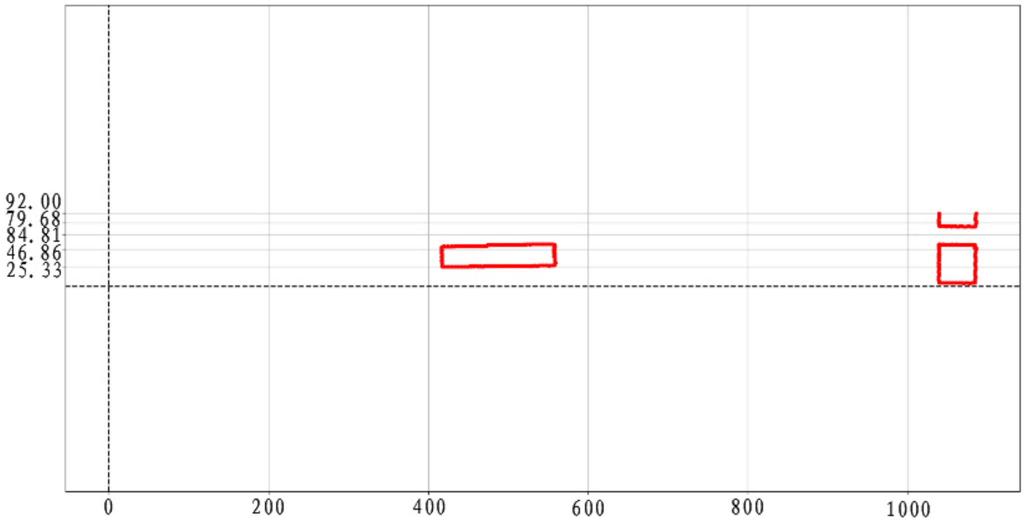


Figure 3 Black grid outline recognition

III. Correction of identified black grid contours

Since the recognized black grid outline is captured by the panoramic camera, the schematic diagram of the panoramic camera correction parameters is shown in Figure 4.

This contour for correction restoration needs to consider this panoramic camera by using this panoramic camera focal length, the field of view angle, size, and other parameters to derive the correction formula for Figure 3 aberration correction formula for coordinate values such as Formulas (2) and (3).

$$\text{Y-axis:} \begin{cases} \theta_i = \left(\tan^{-1}\left(\frac{c+i\times y}{R}\right) - \tan^{-1}\left(\frac{c+(i-1)\times y}{R}\right)\right), i = 1 \cdots n \\ l = 2r \times \sin\left(\frac{\theta_i}{2}\right) \end{cases} \tag{2}$$

Where, y is the value of y coordinate in the corrected coordinate system, and l is the arc length corresponding to θi in the panoramic camera lens circle. R=52.5 mm is the cylinder radius, r=30.1 mm is the camera diameter, and c=23.8 mm is a constant.

X-axis:

$$x = \frac{2\pi R}{360} \times \beta_i \tag{3}$$

Where, x is denoted as the corrected coordinate system x coordinate value, and βi denotes the circular equal division angle.

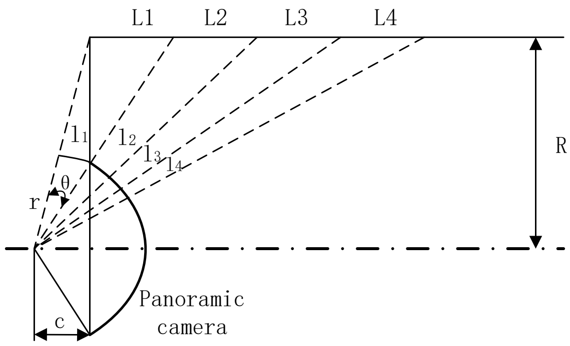


Figure 4 Schematic diagram of the correction parameters of the panoramic camera

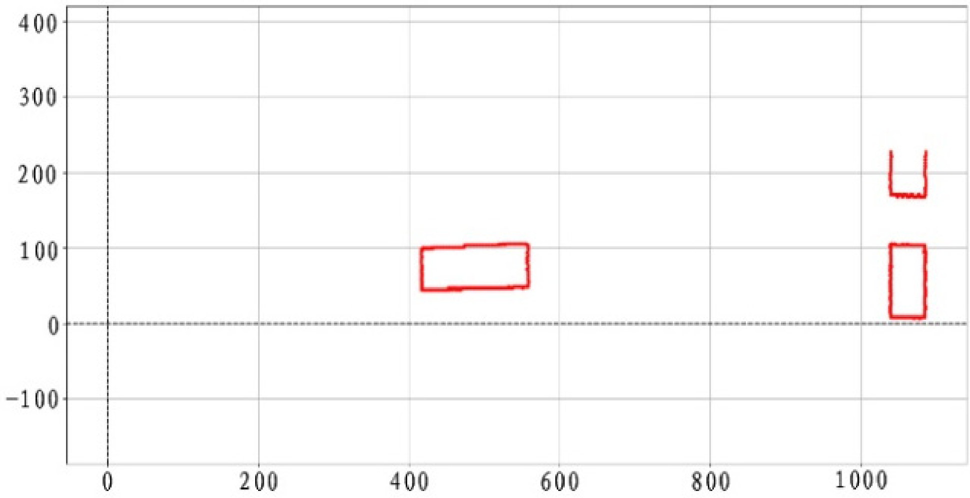


Figure 5 Distortion correction effect

The coordinate values derived from Equations (2) and (3) are mm. However, the units of the image are pixels, so the conversion of mm and pixels is required. From Figure 1(b) and Figure 2(c), the conversion multiplier of image mm and pixel is calculated by using the image pixel and size after distortion, and the conversion multiplier = image expanded pixel width/(2×π×R) = 1507/(π×105) = 4.5685.

The contour map obtained from Figure 3 is corrected and calculated by Equation (2) and Equation (3). The corrected result is obtained by using the pixel conversion multiplier as shown in Figure 5.

IV. Experimental verification of image distortion correction

Data verification of the correction results of Figure 5. Taking the midpoint of the distortion grid brought into the correction Equation (2), Equation (3) is used to obtain the corrected effect in Figures 6 and 7 and Table 1 before and after correction data comparison. The results show that the coordinate values calculated by the correction formula are still at the midpoint of the grid, and the error is less than 0.2%. So this correction formula is calculated accurately.

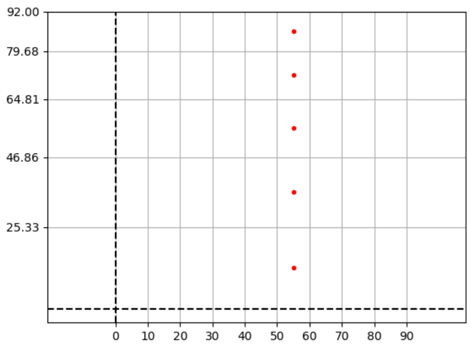


Figure 6 Map of distortion point data

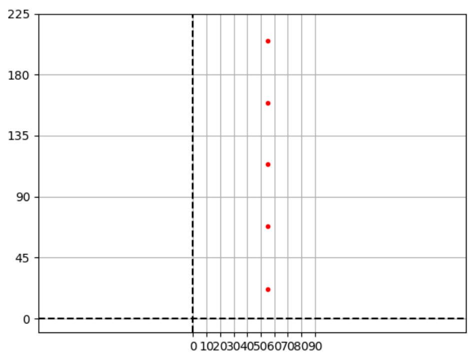


Figure 7 Correction point data graph

Table 1 Comparison of points before and after correction

Serial number	1	2	3	4	5
Aberration point	（55，12.665）	（55，36.095）	（55，55.835）	（55，72.245）	（55，85.84）
After correction	（55，22.501）	（55，67.497）	（55，112.509）	（55，157.51）	（55，202.519）

V. Conclusions

In this paper, we study the aberration correction of the internal image of the pipe taken by the panoramic camera, which is based on the Raspberry Pi 4B+ control platform using the IMX-378 Raspberry Pi camera as the experimental object. The black lattice map of the inner wall of the pipe used the Hough circle to identify the center point of the inner wall of the pipe. And the Hough transform is used to select the regular part of the panoramic image to be cropped and expanded into a rectangular The black lattice contour in the rectangular image is identified, and the black lattice contour is corrected by using the distortion correction formula derived from IMX-378 camera. The experimental results show that the error between the corrected point and the original image is less than 0.2%, and the corrected result is close to the original image data.

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