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Comparison and Research of Fisheye Image Correction Algorithms in Coal Mine Survey

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Abstract. Fisheye lenses are widely used in scene surveillance, robot navigation and engineering measurement due to their wide field of view and short focal length. However, the image taken by the fisheye lens has a large degree of distortion, so image correction is the key point of research. In this paper based on the distortion of fisheye image in coal mine underground video surveillance system, the latitude and longitude coordinate method, spherical perspective projection method and panoramic stitching method commonly used in fisheye correction are compared and given an improved algorithm. In the actual survey image correction, preprocessing is an important process, that is, to find the center and radius of the fisheye image. The advantages and disadvantages of the algorithm for finding a circle are also compared.

Keywords: Coal mine monitoring image; Fisheye image; Latitude and longitude coordinate method; Spherical perspective projection; Bilinear interpolation.

1. Introduction

The fisheye camera has the advantages of short focal length and large field of view. Many fisheye cameras have a viewing angle of more than 180º, which can be used to record the entire horizontal or vertical 360o scene in the field of view very conveniently and quickly. The "all-round" and "real-time" information is widely used in scene surveillance, satellite positioning, robot navigation, micro-intelligent systems and engineering measurement.

This paper mainly discusses the overall process of fisheye correction algorithm and correction algorithm application. The survey image of fisheye correction consists of three processes: corrective pretreatment (Ie finding the center and radius), fisheye correction, and post-treatment. Thus, a brief introduction to the fisheye correction algorithm is very necessary.

2. Fisheye Panoramic Correction Algorithm

The fisheye lens is a hemispherical shape with a convex shape. Due to the nonlinear structure, the distortion of the image edge is large, so the fisheye picture is more severely deformed, which is not conducive to direct observation and information acquisition. However, in some application fields, such as three-dimensional reconstruction, face recognition, etc., it is necessary to accurately identify an object in an image or restore a real scene, and it is necessary to effectively perform a correction algorithm on the fisheye image to restore it to a normal picture [1]. After correction, the fisheye image is transformed into one or more ordinary images covering the entire fisheye image field of view from different angles,

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and the geometric distortion of the image features is removed, so that the difficulty of human eye viewing and computer recognition is greatly reduced.

In the fisheye image, except for the center image, the other vertical and horizontal images have offset distortion. The essence of fisheye correction is the spatial transformation of image processing (geometric transformation, geometric operation), which only copies the points on the image without modification. The spatial transformation is seen as moving the image point within the image, ie the point A(x,y) on the fisheye image to the point Al(u,v) on the corrected image.

At present, many scholars at home and abroad have studied the fisheye image correction method and proposed some effective correction algorithms, such as correction algorithm that is based on Scaramuzza's theory, latitude and longitude coordinate method, spherical perspective projection, fast uniform expansion, circular segmentation algorithm, etc., although fisheye image distortion is divided into barrel shape and pincushion shape, in reality, barrel distortion is changed. This paper selects the latitude and longitude coordinate method and the spherical perspective projection algorithm for comparative study.

2.1. Latitude And Longitude Coordinate Method

The fisheye image is a distorted circular image. The larger the angle of view of the fisheye lens is, the larger the barrel bending distortion will be, and only the partial line at the center of the lens can maintain its original state. The latitude and longitude image correction are to restore the abscissa ("long" axis) of the pixel of the fisheye image to the original position, while the ordinate ("width" axis) remains unchanged, that is, the distortion of the fisheye image is mapped to normal. The image of the rectangle, that is, the degree of distortion of the fisheye image is reduced by mapping [2].

The principle of this correction method is to approximate the deformation of the scene in the fisheye image by the latitude and longitude line of the spherical surface. The different pixels in each longitude have the same column coordinate value in the corrected image, and the greater the longitude is , the more the distortion will be. Big. The pixel points of the original fisheye image are represented by A(X, Y), and the corresponding corrected image pixels are represented by Al(U, V), and the relationship between them is as follows:

Implementation steps of the latitude and longitude coordinate method:

$$X = X_0 + (U - X_0)\sqrt{R^2 - Y^2}/R\ ,$$
$$Y = V\ .$$

1) Find the effective information area of the fisheye image, extract the useful image to find the center of the circle, and determine the radius of the fisheye image circle;

2) Apply the method of latitude and longitude mapping, change the coordinate system, and find the correspondence between the coordinates;

3) According to the coordinate mapping relationship found in step 2, the pixel information of the source image is assigned to the point on the target image to obtain the expected correction map.

By analyzing this correction algorithm, we can find that the mapping relationship between the distortion point and the corresponding correction point is only the best on the outermost meridian; otherwise, the closer the distortion point is to the center of the circle, the worse the effect of the fitting of the mapping function will be.

2.2. Spherical perspective projection method

Spherical perspective projection method, using the fisheye deformation correction model with deformation correction parameters, maps the points on the fisheye projection curve of the spatial line to the area, and then uses the spherical distance from the spherical point to the large circle to fit the large circle to restore the correction parameters. To achieve correction of the fisheye image.

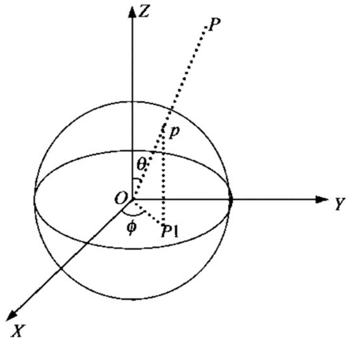

Figure 1. Spherical projection model

Assuming that the P coordinate of any point in the space is (x, y, z), the origin O and the space point P are connected to obtain the ray OP. This ray intersects the spherical surface x2 + y2 + z2 = R2 at the point p, and the point p is projected to the fisheye lens. The imaging point P1 of the fisheye image is obtained on the XOY plane perpendicular to the z-axis of the optical axis, and the coordinates are assumed to be (u, v). As shown in FIG. 3, the relationship between the coordinates is as follows:

$$\frac{x}{u} = \frac{y}{v} = \frac{z}{\sqrt{R^2 - u^2 - v^2}} = \frac{\sqrt{x^2 + y^2 + z^2}}{R}$$

$$u = \frac{R \times x}{\sqrt{x^2 + y^2 + z^2}}, v = \frac{R \times y}{\sqrt{x^2 + y^2 + z^2}},$$

It can be seen from the above conclusion that if the pixel of the original fisheye image on the XOY plane is represented by A(X, Y), the corresponding corrected image pixel is represented by Al(U, V), and the relationship between them should be as follows:

$$X = X_0 + R \times (U - X_0) / \sqrt{z^2 + (U - X_0)^2 + (V - Y_0)^2}, (z \geqslant R) ,$$

$$Y = Y_0 + R \times (V - Y_0) / \sqrt{z^2 + (U - X_0)^2 + (V - Y_0)^2}, (z \geqslant R) .$$

The expanded image point and the fisheye distortion image point are one-to-one mapped, and the RGB color value of the fisheye distortion image point is mapped to the RGB color value of the expanded image. However, the coordinate point corrected by the spherical perspective projection model is not necessarily an integer value, and the interpolation algorithm is used to calculate the non-integer point coordinates according to the calculation of the adjacent pixel point information. A more efficient bilinear interpolation algorithm is recommended here.

2.3. Comparison of The Two Ways

The latitude and longitude map correction algorithm converts the nonlinear fisheye image storage into linear latitude and longitude storage to realize image correction. Based on the spherical perspective projection correction algorithm, the corresponding mathematical model is first established, and then the camera internal and external and correction parameters are solved. It can be seen from the comparison of the above figure that the spherical perspective projection method is more ornamental after the correction, but the edge field of view is lost.

Figure 2. Fisheye original

Figure 3. After spherical coordinate positioning correction

Figure 4. After spherical perspective projection correction

2.4. Panoramic expansion method

The main principle of fisheye panoramic stitching is to use the self-owned information in the image to correct the geometric distortion in the fisheye image to restore it to the perspective projection image of the ordinary lens [3]. Then find the overlapping area between each image and the adjacent image, restore the position and spatial transformation relationship between the images, project each image into a unified coordinate system, and complete the image mosaic [4].

The panoramic expansion method is mainly adopted to obtain a 360° panoramic view. The expanded model is as follows:

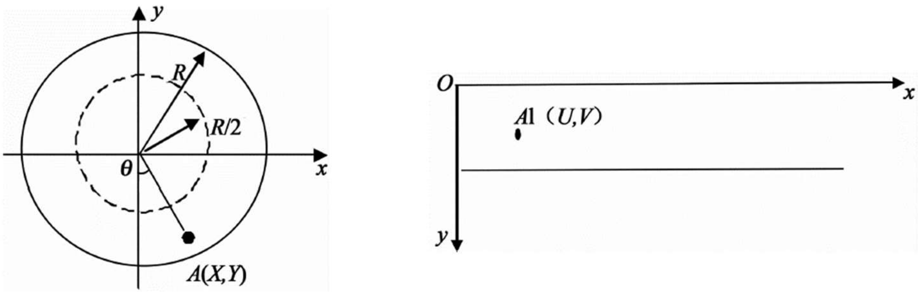

Figure 5. Panoramic expansion model

It can be explained as follows:

It is known that the fisheye image radius is R and the center of the circle is (X0, Y0). Draw a concentric circle with a radius of R/2 on the fisheye image. If any pixel on the fisheye image is P (X, Y), connect the image point P and the center of the circle to get the line segment OP, and the angle with the Y axis is θ. . In order to obtain a satisfactory unfolding result, the corrected panorama length is a concentric circumference length (R×π) with a radius of R/2, and the width is a radius R. At this time, a panoramic development map corresponding to A (X, Y) is obtained. The correction point pixel A1 (U, Y) on the upper side must satisfy the following relationship:

$$\theta = 2U/R$$

$$X = X_0 + V \times \cos\theta$$

$$Y = Y_0 + V \times \sin\theta$$

One point: This method can be used in top and floor. The difference between top and floor is that the image is rotated by 180°.

Look at the comparison of the two figures:

Figure 6. Fisheye original

Figure 7. Panoramic correction

It can be seen that the part of the edge is distorted and curved. For the effect to be viewed, it is necessary to trim the unsuitable edges.

3. Pretreatment And Post Treatment of Fisheye Correction

3.1. Pretreatment

In practical engineering applications, preprocessing is an important process, that is, to accurately find the center and radius of the fisheye image. It is conceivable that only when the center and radius are accurate, then the corrected image will be accurate. But in practice, finding a circle is affected by two important factors:

1> Imaging effect of actual image

2> camera individual difference size, or mass production consistency

The first factor is the imaging effect of the actual image, specifically the image resolution, whether the boundary between the black area of the fisheye and the effective area is obvious. If the image resolution is too small, the error of the algorithm is pixel-level, and the effect will be enlarged accordingly. Therefore, the fisheye image is generally better than 1080P. If the boundary between the black area and the image effective area is not clear, there is a certain gray scale, which will affect the accuracy of finding a circle. The reason for this phenomenon is generally that the structural lens holder is not tightly sealed, resulting in an image "light leakage", which is generally solved by structural sealing.

The second factor is the key to determining whether a fisheye camera is successfully commercialized. Because of various objective factors such as structural process/generation process/material differences, the relative center and radius of each camera will be different. Therefore, controlling the consistency of mass production is the best way to solve such problems. The following focuses on the advantages and disadvantages of the circle finding algorithm.

Method 1: The solidification structure method is to uniformly treat according to a fixed center and radius. Artificially solidify the black areas. The advantage of such method is that the processing is simple, and the final consistency is high, avoiding the error floating caused by the algorithm to individual differences. The disadvantage is that the engineering consistency requirements are very high.

Method 2: Contour tangent method. That is, after grading the image, four straight lines are used to find the four tangent lines of the circle, and then the center and radius are found. The disadvantage of this method is that the error is large and the imaging effect on the image is high.

Method three: Hough transform synthesis method. This method combines the characteristics of the first two, adding Hough transform and fault-tolerant processing. The flow chart is as follows:

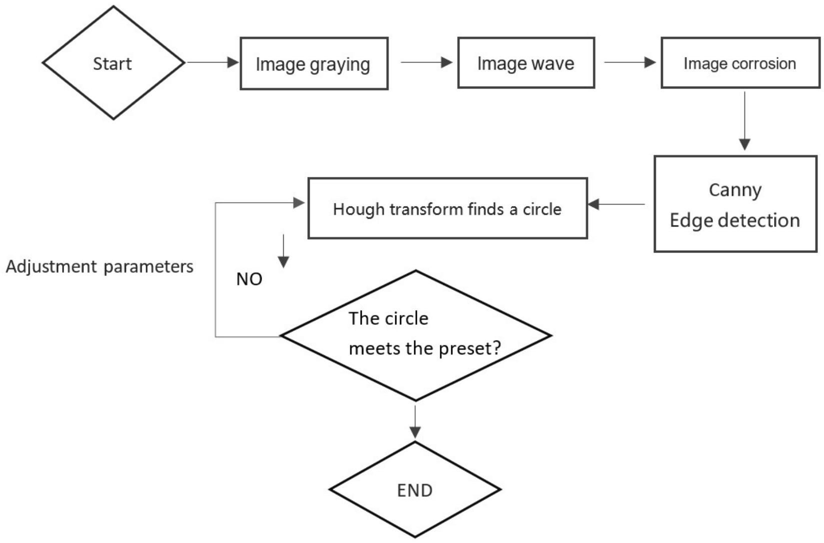

Figure 8. Hough transform flow chart

The condition that the circle found by the Hough transform meets is the range of the position and radius of the preset according to the actual application. From the actual effect, the third method is more adaptable and accurate.

3.2. Corrective Treatment

Post-correction processing is mainly the choice of interpolation method. When the calculation power is not limited, the polynomial interpolation can be selected with high precision; in the embedded terminal, the image 30fps will be required in real time, and the real-time and effect should be taken into account, and bilinear interpolation is generally selected. Of course, there are also three linear interpolations, which are not discussed here. This paper mainly focuses on the improvement of bilinear interpolation efficiency, to be specific, parallel operation. In fact, the entire fisheye image processing, in embedded cameras, can be processed using parallel computing, in order to meet the high-resolution (such as 4-channel 12-megapixel fisheye) real-time applications.

4. Summary

According to the image of fisheye distortion in coal mine monitoring system, this paper discusses the whole process in detail, including fisheye rounding pretreatment, fisheye correction and post-correction treatment. For the pre-processing circle finding algorithm, a detailed demonstration and comparison is made on the advantages and disadvantages of the fisheye correction algorithm. In the case that the system performance is not particularly limited, the Hough transform synthesis method can be preferentially used to find the circle, and then the panoramic expansion is used. The method is corrected and then post-processed using a bilinear interpolation algorithm. The experimental results show that the method has better effects on adaptability and precision.

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