5-18-2020

An effective method to obtain contour of fisheye images based on explicit level set method

Xuegang Wu

Zhijun Qiao
The University of Texas Rio Grande Valley

Recommended Citation

Xuegang Wu, Zhijun Qiao, "An effective method to obtain contour of fisheye images based on explicit level set method," Proc. SPIE 11395, Big Data II: Learning, Analytics, and Applications, 113950J (18 May 2020); doi:10.1117/12.2560764

PROCEEDINGS OF SPIE

SPIEDigitalLibrary.org/conference-proceedings-of-spie

An effective method to obtain contour of fisheye images based on explicit level set method

Wu, Xuegang, Qiao, Zhijun

Xuegang Wu, Zhijun Qiao, "An effective method to obtain contour of fisheye images based on explicit level set method," Proc. SPIE 11395, Big Data II: Learning, Analytics, and Applications, 113950J (18 May 2020); doi: 10.1117/12.2560764

Event: SPIE Defense + Commercial Sensing, 2020, Online Only

An effective method to obtain contour of fisheye images based on explicit level set method

Xuegang Wu[a] and Zhijun Qiao[b]

[a]School of Big Data and Intelligent Engineering,Yantze Normal University, Fuling , Chongqing, China
[b]School of Mathematical and Statistical Sciences, University of Texas Rio Grande Valley, Edinburg, TX, USA

ABSTRACT

Obtaining the effective contour from an image taken by fisheye lens is important for the following transactions. Many studies try to develop suitable methods to get accurate contours of fisheye images. Using the traditional level set method (CV model) is hard to meet the desire task that the final segmentation region is a circle. Therefore, the preprocessing of fisheye images and the improvement of traditional level set method are redesigned to get a final circular segmentation which may be suitable to other applications. In this paper, we use the local entropy method to make the value of pixels be even inside the effective circular region, further threshold method to remove the hole(s), and at last the explicit circular level set method to get final segmentation. The final experimental results show that the segmentation is effective.

Keywords: Fisheye image; Level set; Local entropy; Threshold

1. INTRODUCTION

Image stitching[1,2] is widely used in the fields of science and engineering, such as medical images processing, geological surveys, the distortion correction[3–6] and panoramic roaming. In the real application problems, a full-view image is usually required. At present, the common cameras have limited viewing angles and cannot use them to directly generate a panoramic photo. A group of photos with overlapping areas are obtained within a time period, then the stitching algorithm is used to get a panoramic photo. Otherwise, the fisheye lens have irreplaceable advantages.

Although the fisheye bulging lens can make the image being severe distortion, compared with the flat lens of ordinary cameras, the physical structure of the lens determines that the range of angles of the view that can be captured in the same area is much larger than that of the flat lens. Especially, it also produces large distortions at the edge of the image. The information of the center position of the image taken by the fisheye lens is much more, and the deformation is the smaller. With the increase of the radius, the image information is gradually reduced and the deformation is continuously increased. In the case of the panoramic view required, it is difficult to use the flat lens, but easy to the fisheye lens. In general, only 2-3 fisheye images by the fisheye lens are needed to obtain a panoramic view.

The image taken by the fisheye lens is with the characteristics of a dark scene enclosing the central focus area. That is, an image with a circular area embedded in the middle (an effective area and an invalid background). In this paper, we want to find the middle circular portion. Therefore, we need to figure out the center and radius of the middle circular portion. Then, according to its center and radius, the contour of the effective fisheye image can be extracted.

In general, there are currently four main methods for extracting the effective area of the fisheye image. The first method is to find the center and radius of the effective part of the fisheye image through computing the

Further author information: (Send correspondence to Zhijun Qiao)
Zhijun Qiao: E-mail: zhijun.qiao@utrgv.edu, Phone: 1 956 665 3406

Big Data II: Learning, Analytics, and Applications, edited by Fauzia Ahmad,
Proc. of SPIE Vol. 11395, 113950J · © 2020 SPIE · CCC
code: 0277-786X/20/$21 · doi: 10.1117/12.2560764

centroid and area of the binarized image.[7] This method is simple and efficient, however, sometimes inaccurate when pure black areas exist inside the image. Also, it could be bad segmentation result when a small number of bright blocks appear near the edge of the effective area. These bright blocks directly affect the accuracy of final segmentation. The second one[8] is the scan line method. Using four or eight scanning lines to move from the outermost edge of the image to its inside. When the current scanning line scans pixels whose brightness is higher than a certain threshold, the process stops, and then looks the scan line as the tangent of the circle to obtain the parameters of the circle. Although almost not affected by the internal black area, the method will still be disturbed when there are pure black blocks existing inside the round edge or outside bright blocks. The third one[9] is the contour extraction algorithm based on the region growth. This method begins to perform region growth after binarizing the image, and then extracts its edge information with the least squares fitting method. The regional growth mainly depends on the edge curvature of the brightness block. During the process, all internal black holes and external recessed parts will be filled. This method is also incapable of a small number of brightness blocks outside the effective area or even makes the segmentation case more worse, further, the filling of the recessed part is incomplete, which ultimately leads to the inaccurate results. The fourth one[10] is the effective area based on the Hough transformation method. However, it is time-consuming and can not give good results in the cluttered environments.

In the fisheye image, the center and radius of the fisheye image need to be calculated. The current algorithm mostly uses gradient detection to find the area with the largest gradient change to obtain the approximate outer contour of the circle, and then the least squares fitting method is applied to the outer circular contour. However, in practice, the edges of the fisheye are relatively blurry, and it is almost impossible to filter out the outline of the circle through the threshold of the gradient. Therefore, we consider that the region-based level set method generally may achieve better performance. Through our observation, unfortunately, the traditional level set method (CV model)[11] can't be directly applied to extract the effective region from fisheye images because of the non homogeneous in their effective areas. And it also can't get the circular contour of effective area under the assumption that the effective region of a fisheye image is a circle. In this paper, the local entropy method is firstly used to adapted to meet the homogeneous requirement by the level set method, then that the segmentation contour is a circle will be looked as the known condition which plays its role in the energy function of level set method. Through adjusting and optimizing the parameters, and the final experimental result can keep consistent with the actual fisheye circle area. The obvious advantage of the proposed method in this paper is that the algorithm has better performance. When the edge is blurred and there is a light spot outside the effective area, the problem will be solved through the local entropy method and threshold.

2. THE PROPOSED METHOD

In this section, the local entropy[12] and the threshold method are both used in the images taken by fisheye lens to get the effective area with uniform pixel values. The local entropy method is firstly used and then thresholds the image, then, there are probably some holes emerged in the effective area. The hole(s) will bring us some difficulties to the improved level set model in segmentation. So, the threshold method is proposed to solve the problem. In Fig.2, we can see the case.

2.1 Local Entropy and threshold method

2.1.1 Local Entropy

For an image, local entropy is related to the different pixels changes happened inside a given local neighborhood, usually determined by their actual cases. It can detect subtle variations in the local gray level distribution. Through observation, when using local entropy in an image, it will cause the diffusion of the target ranges of small detection area. In Fig.1, the texture of the local entropy image becomes blur.

Next, we introduce the local entropy, and suppose that $f(x, y)$ is the grey scale value of position (x, y). It is obviously that $f(x, y) > 0$. For an image with height M and width N, the local entropy image is defined as follows,

$$L_f = -\sum_{i=1}^{m}\sum_{j=1}^{n} p_{ij} \log p_{ij}$$

$$p_{ij} = f(i,j)/\sum_{a=1}^{m}\sum_{b=1}^{n} f(a,b), \quad (1 \le i \le m,\ 1 \le j \le n),$$

where, L_f is the local entropy of the local region $m \times n$, p_{ij} is the distribution of grey scale in the region.

When used in the object detection study, the blur result is regarded as the defect of the local entropy method. However, it can make the grey scale value of each pixel to be even within the effective area. According to the observation, our method just needs to make the fisheye image pixels to be approach. Finally, in Fig.1, each pixel in the effective area are actually related with the part of the pixels in this area.

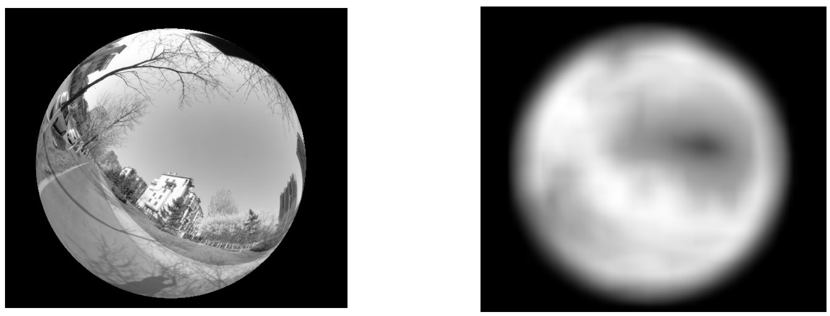

Figure 1. Left: the original image Right: the image obtained using local entropy method

2.1.2 Threshold method

After using local entropy method to a image, the distribution of pixels of local area can be attained. Through our observation, the effective region edge in the local entropy image become blur. Therefore, we consider using the threshold to further find the holds in the effective area. The threshold method is as follows,

$$\begin{cases} 1, & L_f(i,j) \ge threshold, \\ 0, & L_f(i,j) < threshold. \end{cases}$$

in which, L_f is the value of local entropy with position of $p(i,j)$; $threshold$ is the parameter set to find the hole(s).

Next, the hole(s) in the effective area will be removed. We only address the inner them in the effective area. If the holes be happen in the edge of the effective area, we don't process.

let M is the height of an image and N its width. (i,j) is the position of a pixel with height i and width j in a image. So, the processing method is as follows,

$$\begin{cases} p(i,*) = 1, & j \le i < k \ and \ \ p(j,*) = p(k,*) = 1, \\ \quad\quad or & \\ p(*,q) = 1, & m \le q < n \ and \ \ p(*,m) = p(*,n) = 1. \end{cases}$$

where i is the x coordinate in the interval $j \le i < k$ and q $m \le q < n$.

2.2 Restricted level set method

We proposed an objective function which combined traditional level set method and the explicit level set function. The objective function is as follows,

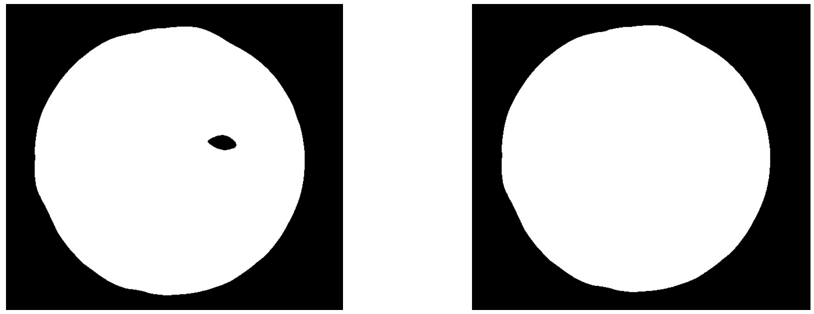

Figure 2. Left:a hole emerged in the local entropy image using threshold Right: get the image with even foreground and background.

$$\min \int_{x,y \in I} J(x,y)dxdy$$

$$J = \lambda_1 \cdot (H(\phi(C_x, C_y, R)) \cdot (L_f - C_1))^2 + \lambda_2 \cdot ((1 - H(\phi(C_x, C_y, R))) \cdot (L_f - C_2))^2,$$

in which, C_1 and C_2 are the mean values of inner and outer regions separated by level set function, ϕ related with position (x, y) is a two dimension function. It is positive in inner region and negative in outer region. And, these three parameters C_x,C_y,R are involved with the following circle equation,

$$\phi(x,y) = R^2 - (x - C_x)^2 - (y - C_y)^2,$$

where C_x, C_y, R are the function of time, that is $C_x(t)$, $C_y(t)$, $R(t)$.

To normalize and adjust the function ϕ, in the paper, we use the following equation to process,

$$H(\phi) = 1/2 \cdot [1 + 2/\pi \cdot arctan(\phi))].$$

Then, we minimize the energy function

$$E = \int_{x,y \in I} J(x,y)dxdy.$$

Next, we compute the partial derivative with respect of C_x, C_y, R, and we get

$$\frac{\partial E}{\partial C_x} = \int_{x,y} \frac{\partial J}{\partial C_x} dxdy = \int_{x,y} \frac{\partial J}{\partial \phi} \frac{\partial \phi}{\partial C_x} dxdy$$

$$= \int_{x,y} \frac{2 \cdot (\lambda_1 \cdot (L_f(x,y) - c_1)^2 - \lambda_2 \cdot (L_f(x,y) - c_2)^2)}{\pi \cdot (1 + \phi^2)} \cdot (x - C_x)dxdy.$$

With the same computing,

$$\frac{\partial E}{\partial C_y} = \int_{x,y} \frac{\partial J}{\partial C_y} dxdy = \int_{x,y} \frac{\partial J}{\partial \phi} \frac{\partial \phi}{\partial C_y} dxdy$$

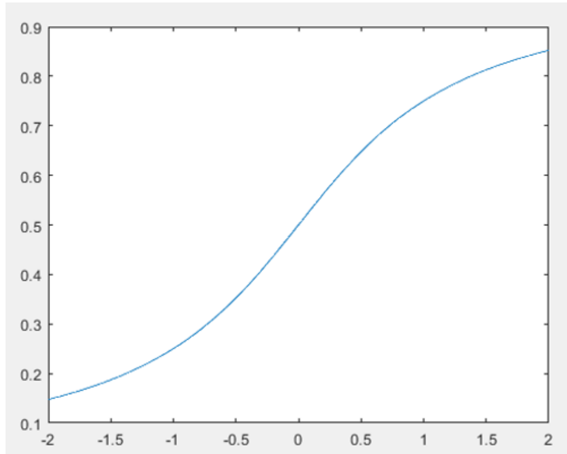

Figure 3. Curve of $H(\phi)$ function .

$$= \int_{x,y} \frac{2 \cdot (\lambda_1 \cdot (L_f(x,y) - c_1)^2 - \lambda_2 \cdot (L_f(x,y) - c_2)^2)}{\pi \cdot (1 + \phi^2)} \cdot (y - C_y) dxdy$$

$$\frac{\partial E}{\partial R} = \int_{x,y} \frac{\partial J}{\partial R} dxdy = \int_{x,y} \frac{\partial J}{\partial \phi} \frac{\partial \phi}{\partial R} dxdy$$

$$= \int_{x,y} \frac{2R \cdot (\lambda_1 \cdot (L_f(x,y) - c_1)^2 - \lambda_2 \cdot (L_f(x,y) - c_2)^2)}{\pi \cdot (1 + \phi^2)} dxdy.$$

At last, newton iteration is used to update,

$$C_x^2 = C_x^1 - s_1 \cdot 1/\frac{\partial E}{\partial C_x} \cdot E,$$

$$C_y^2 = C_y^1 - s_2 \cdot 1/\frac{\partial E}{\partial C_y} \cdot E,$$

$$R^2 = R^1 - s_3 \cdot 1/\frac{\partial E}{\partial R} \cdot .E,$$

where s_1, s_2, s_3 denote the step sizes separately, superscript 1 current iteration, 2 next iteration.

3. EXPERIMENTAL RESULTS

The algorithm is implemented in Matlab R2019b. The radius of template of local entropy method is set as 30 in the paper. Parameters λ_1 and λ_2 in the explicit level set are both set as 1. In the Left figure in Fig.4, although the traditional level set method can get accurate segmentation, this can not get the circular region. Comparing with the traditional method, the presented method can get the accurate circular region which is suitable to further processing. In the experiment, we found that when the local entropy method is used, the outer edge will enlarge. So, we control the iteration to try to attain the ideal result by reducing the number of iteration. Especially, in Fig.5, the final segmentation proves that the proposed method is better than traditional one.

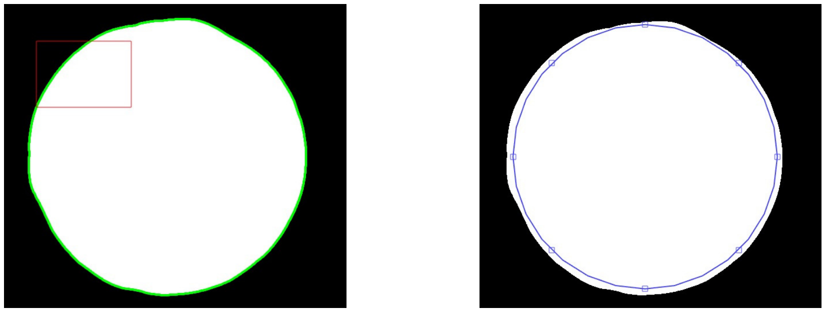

Figure 4. Left:the segmentation result with traditional level set method Right: the result with the presented method.

Figure 5. Left: the image with the initialization Right: get the final segmentation image with the proposed method

4. CONCLUSION AND FUTURE

We will further study the better improved method combined with the results attained by traditional level set, and also study the deformation of fisheye image. In the proposed method, we found that in some cases, the final convergence of objective function is time consuming. And, the proposed method has its defect. When making the image to be suitable to the traditional level set method, the restricted circular level set can segment the image. However the effective area is not a real circle. When the iteration processes, especially almost reaches the best solution, the sensitive disturbance will be happened. So, we use a limited number of iteration to get the final results. we still require to further work to address the problem. Next, we will work on these problem to be resolved.

ACKNOWLEDGMENTS

The author Xuegang Wu thanks for the financial support from China Scholarship Council (No.201908500066) and also thanks the team led by Dr. Zhijun Qiao and the good studying environment of the University of Texas Rio Grande Valley.

REFERENCES

[1] Lo, I.-C., Shih, K.-T., Yu, P. C., Hung, C.-T., Shih, M., Odamaki, M., and Chen, H. H., "Seamless stitching dual fisheye images for 360 free view," in [*2019 IEEE International Conference on Image Processing (ICIP)*], 2459–2459, IEEE (2019).

[2] Dong, Y., Pei, M., Zhang, L., Xu, B., Wu, Y., and Jia, Y., "Stitching videos from a fisheye lens camera and a wide-angle lens camera for telepresence robots," *arXiv preprint arXiv:1903.06319* (2019).

[3] ZHOU, H., LUO, F., LI, H.-j., and FENG, B.-s., "Study on fisheye image correction based on cylinder model [j]," *Journal of Computer Applications* **10**, 061 (2008).

[4] Kun, B., Feifei, H., and Cheng, W., "An image correction method of fisheye lens based on bilinear interpolation," in [*2011 Fourth International Conference on Intelligent Computation Technology and Automation*], **2**, 428–431, IEEE (2011).

[5] Ying, X.-H. and Hu, Z.-Y., "Fisheye lense distortion correction using spherical perspective projection constraint," *CHINESE JOURNAL OF COMPUTERS-CHINESE EDITION-* **26**(12), 1702–1708 (2003).

[6] YANG, J.-j., CHEN, G.-s., and YIN, W.-b., "Algorithm for fisheye image correction based on geometric properties [j]," *Computer Engineering* **3** (2012).

[7] WANG, J.-y., YANG, X.-q., and ZHANG, C.-m., "Environments of full view navigation based on picture taken by eye fish lens [j]," *Acta Simulata Systematica Sinica S* **2** (2001).

[8] Chen, C., Yang, H., Fan, J., Ding, Y., and Han, C., "Robust contour extraction of fisheye images for image-based virtual reality," in [*2010 3rd International Congress on Image and Signal Processing*], **3**, 1014–1017, IEEE (2010).

[9] YANG, D., YOU, L., ZHANG, X.-h., and LI, B., "Fisheye image contour extraction algorithm based on region growing [j]," *Computer Engineering* **8** (2010).

[10] ming Dong, X. and Yuan, K., "Landmark design and real-time recognition based on fisheye image for robot navigation," in [*2010 2nd International Conference on Computer Engineering and Technology*], **1**, V1–437, IEEE (2010).

[11] Chan, T. F. and Vese, L. A., "Active contours without edges," *IEEE Transactions on image processing* **10**(2), 266–277 (2001).

[12] Yan, C., Sang, N., and Zhang, T., "Local entropy-based transition region extraction and thresholding," *Pattern Recognition Letters* **24**(16), 2935–2941 (2003).