Research on Image Splicing Based on Weighted POISSON Fusion

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Abstract—*Image splicing aims to process the images with similar scenes and overlapping parts through a series of matching and fusion algorithm, eventually produce a large image with wide field of vision. For the seamlessness of splicing, this paper presents an algorithm about image matching which combined method of weighted average and Poisson fusion algorithm. Firstly, process images by weighted average smoothing. Then adjust the brightness of images uniformly in order to reduce the difference of exposure between images. Finally, embed the images processed into the scene by Poisson fusion. Experiments show that the proposed algorithm can not only realize the image splicing, but also improve the marks of splicing.*

Keywords-Image splicing; Image fusion; Weighted average; POISSON fusion

I. INTRODUCTION

In the field of digital image processing, wide Angle image has been more and more widely used. But because of the limitations on camera view, it is difficult to get wide perspective of high resolution image. In order to solve this problem, the image splicing algorithm arises at the historic moment. The processing ideas are as follows: firstly, operate the input images with preprocessing, then extract feature information of the image and match and fuse them, finally generate high resolution full image through image matching algorithm. Among them, the feature point extraction, image matching, image fusion are the key of image splicing problem, they directly determines the effect of the image splicing algorithm. Currently, algorithms about feature point extraction and image matching are relatively mature, but the consistency of image fusion remains to be improved.

II. RELATED WORK

Image fusion refers to splicing a collection of original image into a high resolution and full image with wide angle of view, its function is to eliminate image splicing trace of the original image which overlaps, and realize smooth transition without shadow, at the same time ensure that the details of the source image have no loss.

Over the nearly 20 years, scholars at home and abroad made a deep research on image fusion field. Image fusion technology is limited to simple and direct integration, the effect is poor. After wavelet theory put forward[1], the image fusion technology has a big leap. At present the image fusion technology[2] can be divided into three levels: pixel level, feature level and decision level. Pixel level fusion technology is the foundation of high-rise fusion processing, the purpose is to keep the details of original image as much as possible, preparing for subsequent analysis. This level can be subdivided into spatial domain and transform domain algorithms, spatial domain usually uses fusion algorithm such as logic filter, weighted average, compared to adjust and so on, transform domain usually uses multiresolution pyramid fusion[3] and wavelet transform fusion[4]. Feature level fusion is the middle level of information fusion, the main function is to summary the information extracted after preprocessing the source image and extracting the feature. Based on pixel level, using the model, statistical analysis[5] and other analysis, provide the required information for decision-making analysis. The main fusion method of this level are clustering analysis and bayesian estimation method. Decision level is the top level of fusion technology, which makes the optimal decision according to some fusion rules and the corresponding credibility. At this point, the fusion algorithm has good real-time performance, and has a certain tolerance.

In addition to the above mentioned method: the weighted average fusion method, multiresolution spline fusion method, the image fusion method based on principal component[6] and fusion algorithm based on wavelet transform, Poisson equation has also been used to image fusion splicing processing in recent years[7]. After that, many kinds of optimization of the fusion algorithm was proposed. In order to improve the final effect of Poisson image editing, Jiaya proposed optimal fusion boundary[8] on its basis. In order to enhance the processing speed and simplify the solution of the poisson equation, Zeev proposed using Mean value coordinates based on gradient domain[9] to calculate, this method is simple, and the efficiency has a good improvement. Image fusion technology is developing continuously, there are still many problems to be solved, image fusion effect remains to

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be further promoted, and image fusion field has not been unified by a theoretical framework and mathematical model, where a mature and stable system has not yet formed.

III. THE BASIC FLOW OF WEIGHTED POISSON FUSION

According to the weighted average fusion and Poisson fusion, this paper proposed a new image fusion algorithm, which can better match images whose brightness have a big difference. Its basic idea is to combine the method of weighted average and Poisson fusion algorithm. Firstly, process images by weighted average smoothing. Then adjust the brightness of images uniformly in order to reduce the difference of exposure between images. Finally, embed the images processed into the scene by Poisson fusion. Algorithm of overall process is shown in figure 1.

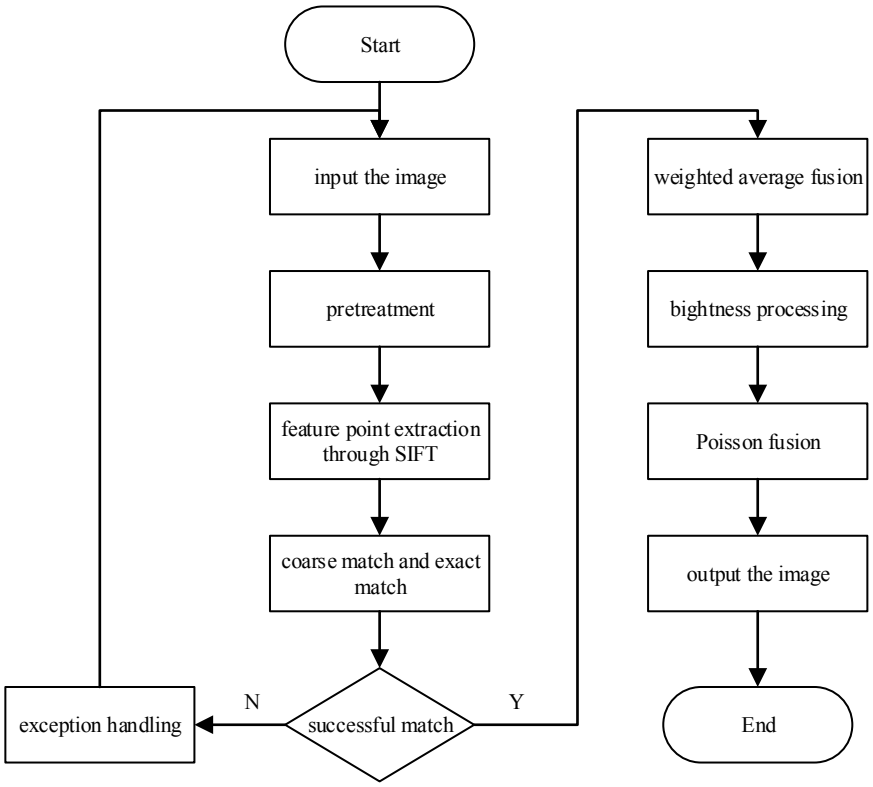


Figure 1. Flow chart of weighted poisson fusion splicing algorithm

IV. WEIGHTED POISSON FUSION ALGORITHM

A. The weighted average fusion

The thought of weighted average fusion algorithm is making weighted operation on the pixel value and then cumulate for average in the treatment of the overlapping scene area. As shown in formula (1), w_1 and w_2 are respectively weighted value of pixels which match the image overlap scene, and satisfied $w_1+w_2=1$ $0<w_1, w_2<1$. Select the optimal weight can achieve coincidence scene smooth transition, and eliminate the obvious splicing trace.

$$f(x,y)=\begin{cases} f_1(x,y) & (x,y)\in f_1 \\ w_1(x,y)f_1(x,y)+w_2(x,y)f_1(x,y) & (x,y)\in f_1\cap f_2 \\ f_2(x,y) & (x,y)\in f_2 \end{cases} \quad (1)$$

This paper adopts gradually into the method for choosing weights, in order to smooth stitching line. Assuming that f_1, f_2 are splicing source images, superimpose the two images on the space, the pixel values of the fused images are shown in formula (2) :

$$f(x,y)=\begin{cases} f_1(x,y) & (x,y)\in f_1 \\ d_1 f_1(x,y)+d_2 f_1(x,y) & (x,y)\in f_1\cap f_2 \\ f_2(x,y) & (x,y)\in f_2 \end{cases} \quad (2)$$

Among them, d_1 and d_2 are weight, they meet $d_1+d_2=1$, $0<d_1, d_2<1$, and the value of weight relate to the overlapping area about the size of the scene. In the overlapping scenes, d_1 gradient from 1 to 0, while d_2 gradient from 0 to 1, which can realize a smooth transition from f_1 to f_2 in the overlapping scene.

B. Poisson fusion

Poisson fusion is originally used in the fusion of scene, as on the premise of keep the gradient information of the image, it can well eliminate splicing trace. The basic thought of the fusion method is to use guide model for interpolation processing, and reconstruct the area of the pixel value, so as to realize seamless integration between scenario, the basic principle is shown in figure 2:

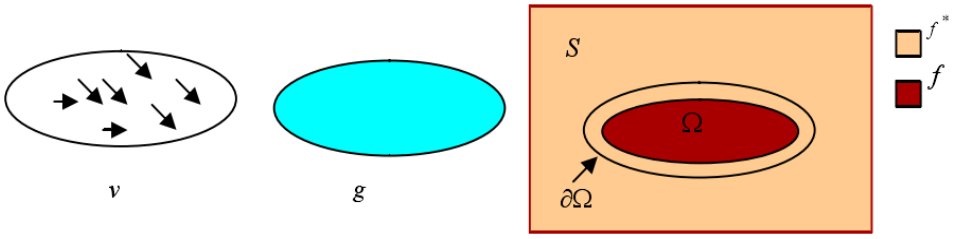


Figure 2. The principle of Poisson fusion

Among them, g is the scene of the original image, v is a gradient field of g, S is image domain after fusion , Ω is the scene covered in S, $\partial\Omega$ is its border, f^* is the scalar function which said the pixel values outside Ω, f is unknown scalar function which said the pixel values outside Ω. To realize smooth transition without aperture, Ω the gradient value should be as small as possible, so as to convert image seamless fusion processing into gradient minimization problem. Variable f can be solved by formula (3):

$$\min_f \iint_\Omega \|\nabla f\|^2, f \mid \partial\Omega == f^* \mid \partial\Omega \quad (3)$$

Among them, $\nabla=\left[\frac{\partial}{\partial x},\frac{\partial}{\partial y}\right]$ is the gradient operator, function $F=\|\nabla f\|^2=f_x^2+f_y^2$, the minimum value of F meets eulerian - Lagrangian equation, so its solution can be expressed by Laplace equation:

$$\Delta f=0,(x,y)\in\Omega, f\mid\partial\Omega=f^*\mid\partial\Omega \quad (4)$$

$\Delta=\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}$ is the Laplace operator.

The solution procedure in practice can appear too smooth, which will lead to the gradient falloff, thus the fusion effect is not ideal. Poisson equation using the gradient field v of g as the guide field to solve above problems. The purpose of the guide field is to get as close as possible to the gradient of f and the gradient of g, not only keep the maximum detail information of image, but also ensure there are not obvious transition boundary traces. The optimized using formula (5) :

$$\min_f \iint_\Omega \|\nabla f-v\|^2=\min_f \iint_\Omega \|\nabla f-\nabla g\|^2, f\mid\partial\Omega=f^*\mid\partial\Omega \quad (5)$$

Generate again into the euler - Lagrange equation, the results are as follows:

$$\Delta f=div(v)=div(\nabla g), f\mid\partial\Omega=f^*\mid\partial\Omega \quad (6)$$

Among them, div(v) is the divergence of gradient field v. The mathematical is the foundation for the construction of poisson fusion technology, in image splicing processing of the overlap of scene, using the image of the gradient field as the guidance, can realize image fusion.

C. Weighted Poisson fusion algorithm

Poisson fusion can maintain the detail information of image while solving the problem of splicing trace, but when the difference of exposure is very big, poisson fusion may lead to uneven image color, and the effect is not ideal. This paper applies Poisson fusion principle in the boundary transition area of overlap scene to optimizing the effect of splicing. After balancing the global brightness, apply the weighted fusion and Poisson fusion, mainly to improving the fusion effect of splicing algorithm. The specific steps are as follows:

1) The weighted average fusion processing. Use the method gradually in and out to determine the weights, which is not only simple to deal with, but also can achieve good coincidence scene matching fusion, and the method has an effect in smooth transition for splicing line, the fusion effect is better.

2) Brightness uniformity. If the difference of exposure for two images is big, the fusion effect will hava very obvious traces splicing, and it will also impact the subsequent operations of Poisson fusion. This paper proposes a brightness uniformity, which can better abate the influence of the exposure difference, specific process is as follows:

a) Calculate the average brightness of global image.

b) Segment the fusion image into small pieces and calculate the brightness matrix for each area.

c) Use the brightness matrix minus the global average brightness, get the brightness difference matrix, at this time the high brightness and low brightness area can be judged by differential value.

d) Operate the brightness difference matrix by cubic convolution interpolation algorithm, extend to the whole image operation, which will get global brightness difference matrix.

e) Use the source image brightness value minus the corresponding values in global brightness difference matrix, which can achieve strengthening the low brightness and weakening the high brightness.

f) According to the original fusion image brightness's extremum, process smoothing operation on each area, which makes the intensity distribution of area is reasonable, to realize smooth transition.

The above steps process luminance equalization operation for each subdomain through regional segmentation, finally reaching the purpose of weakening exposure difference.

3) Poisson fusion solves the splicing trace. After the first two steps of processing, it can not completely eliminate the splicing marks, as there still appear obvious splicing trace in the border of image. So in this paper, on the basis of poisson fusion, propose a overlap transition poisson fusion thought: the original image as a reference datum, use the space transformation model to merge the overlapping scenario to image, so as to achieve the aim of seamless splicing. The main process is as follows:

a) Determine the fusion zone. After dealing with the weighted fusion, there will be a scene splicing trace where is the overlap of the border, so expand outward from the boundaries of overlapping scene $\triangle x_M$, $\triangle x_N$ respectively, get the area Ω_M and Ω_N waiting for fusion. The size for expanding decide on the size of overlap scene, generally take 1/50 of the overlapping scene area. Effect is shown in figure 3:

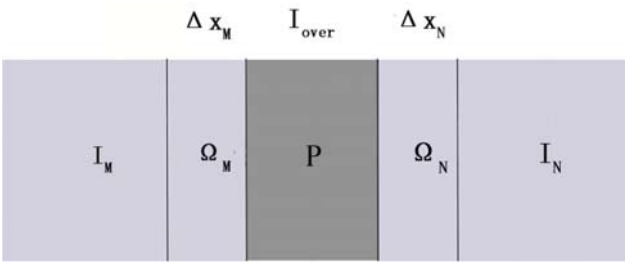


Figure 3. Determine the fusion zone

b) Initialize the parameters: take corresponding regions of the gradient field in the original images as the guidance of the fusion area Ω_M and Ω_N. Get pixels corresponding to the original image on both sides of the

border, when the size of two images is same and transform is scale-free, the upper and lower boundary can set no value, take for 0.

c) Poisson fusion processing. Take the results of weighted fusion as the target image, fusion formula is used to fuse the area corresponding to the original image to image seamlessly

V. ALGORITHM SIMULATION AND RESULTS ANALYSIS

A. The simulation environment and the input image

Carry on the experimental simulation and the analysis of experimental results according to the fusion algorithm of weighted Poisson, use C++ as the development language, and use the open-source library OpenCV 2.4, device for image acquisition are cameras and mobile phones, acquisition way is handheld and rotary translation.

This paper selects two groups of images for experimenting, there is no exposure difference, scale change and rotation factors between the two pictures in figure 4, their size is 816×612. In figure 5, the left image adjust the brightness and strengthen the exposure difference when shooting, as both image size are 1024×768.

(a)The left image for splicing (b) The right image for splicing

Figure 4. The first group of images

(a)The left image for splicing (b) The right image for splicing

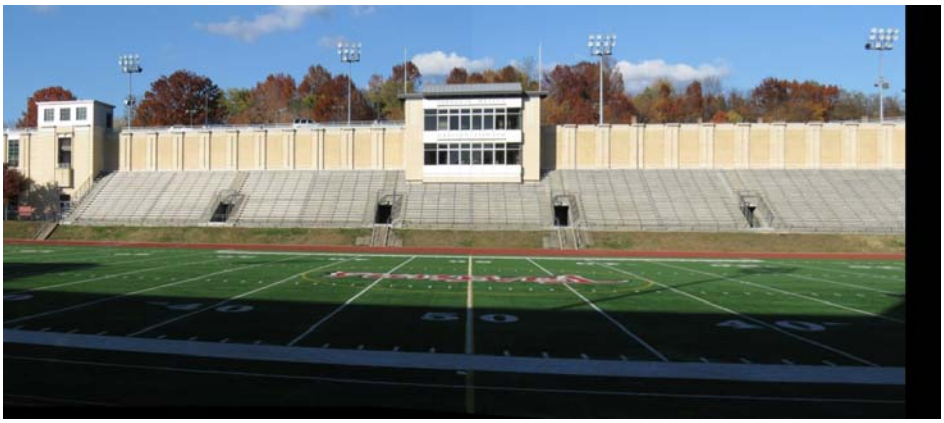
Figure 5. The second group of images

B. Image fusion experiment

Finally the fusion of two experiments results as shown in the figure below. The figure 6 is direct weighted fusion, it can be seen that the fusion effect is poor. Traditional SIFT splicing algorithm also apply the integration strategy, but the effect difference can not be identified through naked eye. Here does not repeat. Figure 7 is the

result of processing the brightness uniformity, as the previous group of experimental exposure difference is not obvious, so the results do not have too big difference, only list the brightness of the second set of experiments uniform processing's result. Figure 8 is the result applying Poisson fusion based on the treatment effect of the two, it can be seen that splicing trace has been smooth processing.

The effect of weighted average fusion :



(a) The first experimental group of fusion

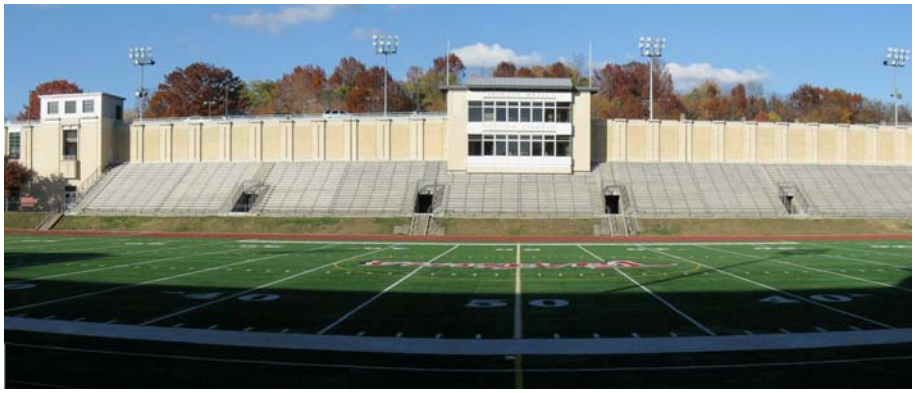
(b) The second experimental group of fusion

Figure 6. Two experiments using the weighted average fusion processing

Because the first group of experiments through brightness uniformity processing can not be seen significant difference by naked eye, here no longer list. Only list the results of the second experiments through brightness uniformity processing. It is worth noting that the brightness uniformity processing is to adjust the global brightness, will not eliminate the splicing.

Figure 7. The second group of experiment with brightness uniformity processing

The effect of Poisson fusion :



(a) The first experimental group of fusion

(b) The second experimental group of fusion

Figure 8. Two groups of experiment using the Poisson fusion

Take the second group of experiments as an example, use different fusion algorithm to run the program for ten times and record the time needed for fusion (based on the algorithm contains the brightness uniformity processing time), clarity, and the relevance with the original image. The relevance is to evaluate the similarity with the original image, the ideal state is 1. Parameter standard is similar with the mean square error, which

mainly used to judge the effect of fusion with ideal effect. This paper takes the fusion image and the source image as the object for comparing, calculation formula is shown in formula (7) :

$$R = \frac{\sum_{m=1}^{M}\sum_{n=1}^{N} A(m,n)B(m,n)}{\sqrt{\sum_{m=1}^{M}\sum_{n=1}^{N} A(m,n)^2}\sqrt{\sum_{m=1}^{M}\sum_{n=1}^{N} B(m,n)^2}} \tag{7}$$

Definition: the average gradient, can be used to evaluate the image of differences in minute details, the greater the value, the better the fusion effect. Calculation formula is shown in formula (8) :

$$\Delta\overline{G} = \frac{1}{MN}\sum_{m=1}^{M}\sum_{n=1}^{N}\sqrt{\frac{\Delta F_x^2(m,n) + \Delta F_y^2(m,n)}{2}} \tag{8}$$

$\Delta F_i^2(m,n)$ is the difference of the image whose size is M×N on the direction i .

The final fusion results are shown in table 1 (in seconds) :

TABLE I. THE FUSION RESULTS DATA TABLE

fusion algorithm	relevance	clarity	running time
weighted average	0.911	3.286	0.199
Poisson fusion	0.952	4.452	0.332
weighted average Poisson fusion	0.983	4.455	0.623

VI. CONCLUSION

For the problem of sensitive exposure difference and image splicing traces, this paper proposed a weighted fusion poisson thought. Firstly, apply the weighted average fusion strategy for smooth operation, through the control of parameter, eventually splicing traces will only appear in the border, to prepare for subsequent Poisson fusion processing. Then carry out brightness uniformity processing on the whole image, in order to reduce the exposure difference, improve the robustness of follow-up Poisson fusion algorithm. Finally take the original image as the reference images, apply the Poisson fusion method with overlapping transition to embedding its corresponding area to the effect of weighted fusion, so as to achieve the effect of eliminating the splicing traces.

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