Overview of UAV Remote Sensing Image Mosaic Technology

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Abstract: This paper mainly summarizes the UAV smoke image Mosaic technology. The UAV image Mosaic technology is widely used. UAV remote sensing data has the advantages of high resolution, high flexibility, high efficiency and low cost, and is widely used in the fields of road traffic and natural disasters. In order to expand the field of vision for better unified processing and analysis and research of UAV image information, it is often necessary to splice two or more adjacent images into a panoramic image. Image Mosaic technology is mainly divided into two parts, image registration and image fusion.

Keywords: Image mosaic, image registration, image fusion.

1. Introduction
In recent years, with the continuous progress and development of science and technology and the rise of UAV aerial photography, UAV has been widely used in military exploration, environmental detection, disaster relief, agricultural monitoring and many other fields due to its small quality, flexibility and convenience, greatly improving the accuracy and working efficiency. Although UAV aerial photography technology has been rapidly developed and widely used in all walks of life, the images it takes are small, and it is difficult for a single image to reflect the actual situation on site. At this time, several UAV images need to be spliced into a panorama of a large scene. Therefore, the research work of UAV image Mosaic technology becomes significant.

2. Overview of Image Mosaic
At present, the main factors affecting the image Mosaic effect are :(1) Image Registration. Due to the difference in sensor type, position, attitude and acquisition time of the source image, the acquired image will have certain difference in position
and geometry. (2) Image Fusion. When the source images come from a sensor, they can be images at different times or at different positions. When the source images come from different sensors, they can be the same or different position, the same or different time. Therefore, how to reduce these factors will become the focus of research.

3. Image Registration Technology

Image registration is an important prerequisite for image Mosaic. Due to the difference in sensor type, position, attitude and acquisition time of the source image, the acquired image will have certain difference in position and geometry. If we do not correct for this difference, it will greatly affect the quality of image fusion. Image registration simply means to align two or more images in space. In other words, given multiple images to be registered, one of them with a large amount of information is taken as a reference image, and the other images to be registered are aligned with the reference image in spatial position and pixel uniformity after certain geometric transformation and gray interpolation.

3.1 model of image registration technology

The mathematical model of image registration is actually a composite function, which transforms the geometric and gray values of the corresponding pixel points [33]. Take two images as an example, and respectively represent the gray value of two images at this point (where is the reference image and is the image to be registered). The mathematical model is as follows:

\[ I_2(x, y) = G(I_1(F(x, y))) \] (2.1)

Where, F represents the transformation relationship between the horizontal and vertical coordinates of two images, which is a two-dimensional transformation; G represents the transformation relation of gray value between two images, which is a one-dimensional transformation. In fact, image registration is to map the image to be registered to a new coordinate system and then resample its pixels. Its main task is to find the most suitable geometric distortion function F and gray transformation function G. In general, the grayscale transformation (G) and position transformation (F) in the image registration process are nonlinear.

3.2 common methods of image registration technology

Image registration methods mainly include image registration method based on image gray information, image transformation domain and image feature point. The commonly used methods are image feature point based registration.
(1) Registration Method Based on Gray Level Information

The method based on gray level information directly utilizes the similarity of gray level measurement between two images to be registered. When the similarity of image gray information meets a certain closed value, the registration is successful. The advantage of this method is that it is widely used easy to implement, and the disadvantage is that it is time-consuming and computationally intensive, and cannot be directly used to correct the nonlinear transformation of the image. In general, the matching of image gray level information adopts to the normalized gray level matching method. Firstly, the gray level matrix of a fixed area is selected to calculate all the gray level information in the image, and then the gray level information is searched and compared by mathematical statistics. The matrix calculation formula of gray level information is shown in (2.2):

$$R(S, T) = \frac{\sum_{x=1}^{M} \sum_{y=1}^{N} [S(x, y) - \bar{S}] [T(x, y) - \bar{T}]}{\sqrt{\left(\sum_{x=1}^{M} \sum_{y=1}^{N} [S(x, y) - \bar{S}]^2\right) \left(\sum_{x=1}^{M} \sum_{y=1}^{N} [T(x, y) - \bar{T}]^2\right)}}$$  \hspace{1cm} (2.2)

Where, R is the similarity measure value, the larger the value is, the greater the similarity is. T(x, y) the template image, S of x and y is the base image. Place the template image T(x, y) on the base image S(x, y) for translation, and then cover the template.

(2) Registration Method Based on Transformation Domain

Fourier transform method is the most typical image registration method based on transform domain. The features of shift, rotation and scaling are obviously reflected in the Fourier transform domain. Fourier transform the idea is to convert the spatial information of the original image into the frequency domain information and calculate the image to be matched through the power spectrum, translation and rotation, and then registration. Phase correlation method is a common method to register the translation imbalance between two images. Shift property, when two images $F(x, y)$ are only one shift away from each other (e, heart), transform them. The relationship is shown in (2.3):

$$f_1(x, y) = f_2(x - d_x, y - d_y)$$ \hspace{1cm} (2.3)

The Fourier transform between them only has the following relation with F2:

$$F_2(\xi, \eta) = e^{-j2\pi(\xi d_x + \eta d_y)}F_1(\xi, \eta)$$ \hspace{1cm} (2.4)

According to the above formula, the two images have the same Fourier transform amplitude and different phase relations. By the displacement According to the theory, the phase relationship between the two images is equal to the cross power spectrum of the two images, as shown in formula (2.5).

Shown below:

$$\frac{F_1(\xi, \eta)F_2(\xi, \eta)}{|F_1(\xi, \eta)F_2(\xi, \eta)|} = e^{-j2\pi(\xi d_x + \eta d_y)}F_1(\xi, \eta)$$ \hspace{1cm} (2.5)
Where, $F_2^*(\xi,\eta)$ is the total number of complex functions of $F_2(\xi,\eta)$.

(3) feature-based registration method
At present, UAV image mosaic algorithms are mostly feature-based, which is the core idea of this method. Is to extract the image features, and then extract the features of the distribution, and finally carry out the same name point Match. Feature-based registration method mainly includes two steps: feature extraction and feature matching. The purpose of feature extraction is to select a large number of obvious feature information according to the actual situation of the image, and the feature information generally includes dot features. There are three kinds of feature: feature, edge feature and region feature. Feature matching is to extract from the matched image and the image to be matched. In general, rough matching and fine matching are two steps.

4. Image Fusion
Image Fusion refers to various technologies such as computer graphics and digital Image processing. Finally, a high-quality panoramic image is synthesized by extracting the favorable information of multiple image data, so as to improve the image quality. The utilization of image information and the enhancement of spatial resolution and spectral resolution of the original image facilitate visual observation. Image fusion is widely used in medical imaging, satellite remote sensing, computer vision, weather forecasting and military outlook measurement, etc. This paper mainly introduces the realization of image fusion in UAV image Mosaic technology.

4.1 common image fusion algorithms
The image fusion process is mainly divided into two parts: image merging and seam elimination. Two parts are analyzed. At present, the commonly used image fusion methods are: direct average fusion method, weighted flat, Average fusion method, wavelet transform fusion method and multi-resolution fusion method, etc.

(1) Direct average Fusion Method
Direct average fusion method is a simple and easy algorithm to realize, which is to combine two images. The gray value of pixels in the overlapping area is simply added and then averaged, as shown in formula (4.1):

$$f(x,y) = \begin{cases} f_1(x,y) & (x,y) \in f_1 \\ \frac{f_1(x,y) + f_2(x,y)}{2} & (x,y) \in (f_1 \cap f_2) \\ f_2(x,y) & (x,y) \in f_2 \end{cases} \quad (4.1)$$

Where, $f_1(x,y)$ and $f_2(x,y)$ respectively represent the two images to be fused, and $f(x,y)$ represents the fused image.
It can be seen from formula that this algorithm only applies to the pixel grayscale of the overlapping areas of two images to be spliced. The values are then simply averaged, leaving the rest of the region unchanged. Therefore, when to fuse the two pictures when there is a significant brightness difference between the images, the fused image will show three regions with different brightness.

(2) Weighted Average Fusion Method

The weighted average fusion method is no longer to simply add the gray values of pixels in the overlapping areas to find the average, but to pair them the gray values of the images to be fused are weighted respectively and then added. As shown in formula (4.2):

\[
f(x,y) = \begin{cases} 
    f_1(x,y) & (x,y) \in f_1 \\
    w_1 f_1(x,y) + w_2 f_2(x,y) & (x,y) \in (f_1 \cap f_2) \\
    f_2(x,y) & (x,y) \in f_2
\end{cases}
\]  (4.2)

Where, \( w_1 \) and \( w_2 \) represent the grayscale weight of pixel points in the overlapping area, which meets the following conditions: \( w_1 + w_2 = 1 \).

(3) Wavelet Transform Fusion Method

The inherent characteristics of wavelet transform make it have the following advantages in image processing: perfect reconstruction ability, guarantee. There is no information loss and redundancy in the process of signal decomposition. Image conversion to the frequency domain for reconstruction, easy extract the structure information and detail information of the original image.

Wavelet transform fusion method mainly includes three steps: decomposition, fusion and inverse transformation. Because wavelet transform fusion method is to map image information to frequency domain for processing, the algorithm is complex and time-consuming is too long to meet the requirements of real-time image Mosaic of UAV. Therefore, this paper will not conduct in-depth research on it.

(4) Multi-resolution Fusion Method

The multi-resolution fusion method is similar to the wavelet transform fusion method, both of which need to decompose the image in the frequency domain. At the same time, the performance also has a long time consumption, cannot adapt to the image focal length and other shortcomings. The fusion process of the method is: first, the image is decomposed into images of different frequency bands, and then the image overlapping region is weighted average shape. Finally, the reconstruction algorithm is used to summarize each frequency into a panoramic image.

The Laplacian and Gaussian pyramid models are used in the implementation of the multiresolution fusion method. Although it has been greatly improved, it is still unable to meet the requirements of real-time image Mosaic of UAV due to the large amount
of computation and time consumption

4.2 Fusion Image Evaluation

In fact, the evaluation of fusion technology is to evaluate the quality of fused images, which mainly includes subjective evaluation and objective evaluation, both of which are aimed at pixel-level fused images.

Due to the limitation and irrationality of subjective evaluation, the objective evaluation method of image fusion should be used in most applications, so as to reduce the invalid evaluation of subjective factors on image fusion. Obviously, the objective evaluation method is to use mathematics to simulate human eyes and make judgment on the quality of fusion image through certain calculation. Data frequently used as objective evaluation include image mean, standard deviation, information entropy and sharpness.

(1) Image Mean

The image mean reflects the sensitivity of the image, so it can also be called the brightness mean. Brightness is the most basic attribute of an image, and the image mean value is expressed by the average of each pixel of the image, as shown in the following formula:

\[
\bar{T} = \frac{1}{m \times n} \sum_{i=1}^{m} \sum_{j=1}^{n} G(i, j)
\]

Where: \(G\) is the grayscale value of image pixel points; \(M\) and \(n\) are the length and width of the image; \(I\) is the graph mean. It is calculated that if the image mean is good, the visual effect of the fused image is good, that is to say, the brightness is very good in the subjective evaluation.

(2) Standard Deviation

Standard deviation is the standard deviation, which refers to the amplitude of fluctuation of the gray value of each pixel in the average gray value (image mean, namely brightness mean). The calculation formula is shown as follows:

\[
\sigma = \sqrt{\frac{1}{m \times n} \sum_{i=1}^{m} \sum_{j=1}^{n} (G(m, n) - \bar{T})^2}
\]

Where, \(\sigma\) is the standard deviation; \(G\) is the grayscale value of image pixel points; \(M\) and \(n\) are the length and width of the image; \(I\) is the graph mean. The larger the standard deviation is, the higher the contrast of the image will be, and the higher the contrast is, the better the visual quality of the image will be.

(3) Entropy (Entropy, E)

Entropy is a very important mathematical quantity in mathematics. In digital image
processing, image entropy is an important index to measure the richness of image information. The calculation formula is shown as follows:

\[ E = -\sum_{i=1}^{n} p_i \log_2 p_i \]  

(4.5)

Where: \( E \) is the grayscale distribution of the fused image; \( p_i \) is the ratio of the pixel number of \( I \) to the total pixels of the image; \( N \) is the total number of gray levels. Generally speaking, the higher the entropy value of the image, the better the fusion quality.

(4) Average Gradient

Average gradient refers to the sharpness of the image, which can be seen by the naked eye. In other words, average gradient (i.e., sharpness) can be judged by subjective evaluation method. However, in some applications requiring high definition, the human eye still cannot complete the resolution successfully, so it still needs to be evaluated by calculation. The calculation formula is shown as follows:

\[ AG = \frac{1}{m \times n} \sum_{j=1}^{m} \sum_{i=1}^{n} \frac{(G(i+1, j) - G(i, j))^2 - (G(i, j+1) - G(i, j))^2}{2} \]  

(4.6)

The larger the AG, the higher the image definition and the better the fusion quality.

By calculating the above four inputs, the fusion image can be well evaluated objectively.

5. Conclusion

By analyzing the development status of image Mosaic technology at home and abroad, this paper can see that many scholars and experts have invested a lot of research, and have achieved certain results in ideas and algorithms. However, these methods and results are basically photos taken under ordinary circumstances, and there are not many researches on panorama Mosaic of UAV aerial images with large data, irregular overlap and small images. Therefore, the key technology of UAV aerial image Mosaic is an area worth further study.

References


