Research on Mosaic Strategy and Application of GF-1 WFV Data

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Abstract. With its advantages of high resolution and large field of view, GF-1 WFV data is able to provide high precision, wide range of spatial observation data and image mapping products. Image Mosaic is an indispensable part of remote sensing image mapping. This paper summarizes the main strategy flow of GF-1 WFV data Mosaic. Some key processing techniques were discussed including true color enhancement, seam line extraction, color normalization. Analyzed of some typical study area, the image was mosaic tested by the method of gray-scale transformation enhancement, minimum gray difference determination algorithm and overlapping image dodging. Relevant strategies and methods are applied to the production of "satellite remote sensing image of Guangdong-Hong Kong-Macao Greater Bay Area nature reserve" and "satellite remote sensing image of Wanjiang economic belt". The texture color of the result image can present the characteristics of natural transition, without obvious color difference, with rich feature information, clear layers and good visibility. It is helpful to systematically and intuitively understand the current situation of regional urban construction and natural resources, and is able to provide high-quality image data for comprehensive geological survey and scientific research. Actual works has proved that the GF-1 WFV data mosaic strategy and method summarized in this paper have achieved good results in practical applications. It can provide reference for other similar satellite image mosaic work and has strong practical guiding significance.
1. Introduction

With high resolution and wide view of the GF-1 WFV data, its applications in natural resources research become more prominent. High-precision, wide-range spatial observation data and image mapping products was provided in many fields such as land use surveys, basic geological surveys, environmental and ecological surveys, and emergency investigation. Compared with traditional maps, remote sensing image maps are not only rich in information, but also intuitive in appearance, strong in current situation and good in readability [1, 2]. The rapid development of earth observation technology has further increased the demand for data mapping products. Mosaic strategies and methods are one of the important factors that determine the application effect of remote sensing image mapping.

Image mosaic strategy mainly includes image enhancement, seam line extraction, dodging and uniform color. In response to these links, relevant scholars at home and abroad have made in-depth research and achieved staged results. At present, satellite image uniformity and color processing methods mainly include reference image histogram matching [3, 4], methods based on image overlapping areas [5, 6], and methods for establishing a color reference database [7]. For satellite image enhancement processing, the current main algorithms can be divided into two categories: spatial domain [8] and frequency domain [9]. Seam line extraction methods mainly include the least square difference, the smallest relative difference, and the smallest gray difference. The main idea of these methods is to make the image of the overlapping area a difference image, and then build a mathematical model based on different principles to automatically determine the seam line.

Synthesizing the advantages and disadvantages of the algorithm proposed in a large number of literatures and practical experience in actual work, this paper summarizes the GF-1 WFV data mosaic strategy and process, and focuses on key issues such as true color enhancement, seam line extraction, and color normalization during the mosaic process. In the paper, the algorithms of gray-scale transformation enhancement, minimum gray difference determination and overlapping image dodging are used to achieve the mosaic processing and mapping of a wide range of high-resolution satellite images, which can provide reference for other similar satellite sensor image mosaic work.

2. Mosaic processing strategies

First select the orthoimages in the study area. The images with better data quality should be selected. The cloud coverage of the single scene is not greater than 10%, and the geometric error meets the mosaic requirements. Then, the true color image enhancement is performed by weighted calculation of RGB bands, statistical gray values and calculation adjustment coefficients. Then, the overlap area is calculated and the seam line is extracted by least square analysis and minimum gray value interpolation algorithm, and further uniform light and color to get the mosaic result image (Fig.1).
3. Method Description

3.1 True color enhancement

The overall brightness of the original GF-1 image is a bit darker, and the hue is a bit bluish. The edges of important information such as building land, cultivated land, river water surface, and vegetation are not easy to distinguish (Fig. 2a).

According to the characteristics of the image, the existing band weighting operation is generally used to regenerate the red, green, and blue bands, and then the three bands of the image are adjusted based on the gray-scale transformation enhancement algorithm. The adjusted R, G, and B bands are represented as:

\[ P(R_{\text{new}}) = P(R) \times k_r, \quad P(G_{\text{new}}) = P(G) \times k_g, \quad P(B_{\text{new}}) = P(B) \times k_b \]  \hspace{1cm} (1)

\[ k_r = \frac{u}{r}, \quad k_g = \frac{u}{g}, \quad k_b = \frac{u}{b} \]  \hspace{1cm} (2)

\( k_r, k_g, k_b \) are three band adjustment coefficients; \( P(R), P(G), P(B) \) are pixel gray levels of three bands of R, G, and B; \( P(R_{\text{new}}), P(G_{\text{new}}), P(B_{\text{new}}) \) is the pixel gray scale after R, G, B adjustment.

\[ r = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} R(i,j) \]  \hspace{1cm} (3)

\[ g = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} G(i,j) \]  \hspace{1cm} (4)

\[ b = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} B(i,j) \]  \hspace{1cm} (5)

\[ u = \frac{r + g + b}{3} \]  \hspace{1cm} (6)

\( R(i,j), \ G(i,j), \ B(i,j) \) are the gray values of the pixels at the three RGB bands \((i,j)\), and \( M, N \) are the number of image rows and columns[10].

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**Fig.1** Image mosaic strategy flowchart
True color enhancement has a better effect on enhancing the color gradation of features such as vegetation and water bodies, and is helpful to improve the color information of remote sensing image mapping. As shown in Figure 2b, the enhanced color image has high color saturation and rich feature information. The color is more natural and more visible than the image before the enhancement, which is more in line with the visual habits of the human eye.

![True color image before enhancement](image1) ![True color enhanced image](image2)

**Fig.2** Comparison of enhancement effect of GF-1 WFV data

### 3.2 Seam line extraction

Factors such as the gray level of the image, the incident angle of the image, and the topographical characteristics are comprehensively considered to determine the overlay relationship of the image. Seam lines were generated based on image gray and terrain features to determine the overlay relationship of multiple images. Seam lines are required to pass through smooth textured areas, such as roads, rivers, and vegetation areas, to avoid passing through obvious objects such as buildings. In addition, the selection of the seam line follows the principle of optimal image quality, so that the mosaic image is avoided from clouds, fog, snow and other areas of relatively poor quality.

According to the automatic image extraction algorithm proposed by Duplaquet [11], the minimum gray value difference method is mainly used to extract mosaic lines. This method is suitable for most image mosaic projects. The main idea is to perform a difference operation in the overlapping area of adjacent images to generate a seam line at the place with the smallest difference in gray value.

\[
E(x, y) = E_{dif}(x, y) - \lambda E_{edge}(x, y)
\]  \hspace{1cm} (7)

\[
E_{dif}(x, y) = \frac{1}{N_o} \sum_{l, j \in V} |I_1(x+i, y+j) - I_2(x+i, y+j)|
\]  \hspace{1cm} (8)

\[
E_{edge} = \min(g_1(x, y), g_2(x, y))
\]  \hspace{1cm} (9)

\(g_1, g_2\) is a gradient image of two images. \(E_{dif}\) is the average value of the difference between the extracted pixel values in the fixed area \(V\) to represent the color difference value, and \(E_{edge}\) is the minimum value of the two gradient images to represent the geometric position difference. \(N\) is the number of pixels in the fixed area \(V\).
3.3 Color normalization.

Because optical image imaging is affected by a series of factors such as seasons, atmospheric conditions, and lighting conditions, the differences in hue, brightness, and contrast between images in the same or similar areas are large (Fig. 4a), which seriously affects the mapping effect. Therefore, the image needs to be homogenized.

Based on the overlay image uniformity algorithm, the optimal radiation value of the mosaic image is determined by using the least squares analysis method in the overlapping area of adjacent images. The pixel value information on both sides of the mosaic line is used to recalculate the pixel value of the overlap area.

The formula for calculating the gray value $I_i$ of the pixels on both sides of the mosaic line is as follows:

$$I_i = IA_i + (IB_i - IA_i) \times K$$

$$K = \frac{i}{W} \quad 0 \leq i \leq W - 1$$

$IA_i$, $IB_i$ are the pixel gray values of the original image corresponding to the point on both sides of the mosaic line. $K$ is the gradation factor and $W$ is the smooth width. The value should be less than the number of pixels in the overlap area [12]. The overlap range of the GF-1 WFV image is generally not less than 10% of the entire scene image.

According to the formula (11), the image after uniform light and color is calculated (Fig. 4b). After uniformity, the color of the image is excessively natural, close to the original tone, and the texture is clear. Different terrains and landforms in the work area can be reflected, maintaining the overall color balance of the image.
4. Applications

4.1 Satellite Remote Sensing Image Map of Guangdong-Hong Kong-Macao Greater Bay Area Nature Reserve

As one of the regions with the highest degree of openness and strong economic vitality in China, the construction of the Guangdong-Hong Kong-Macao Greater Bay Area officially rose to a national strategy in 2017. In February 2019, the "Guangdong-Hong Kong-Macao Greater Bay Area Development Planning Outline" was released in full text, marking the construction of Guangdong-Hong Kong-Macao Greater Bay Area into a phase of policy formulation and coordinated implementation.

The author selected 28 scene GF-1 WFV data for image mosaic mapping. The image shooting time is from October 2018 to May 2019. The original image has completed radiation calibration, atmospheric correction and orthorectification. For the orthorectified image, a method of uniform light and color, true color enhancement, and mosaic line extraction was used to compile the "satellite remote sensing image map of the Guangdong-Hong Kong-Macao Greater Bay Area Nature Reserve" (Fig. 5). This map helps the system to intuitively understand the urban construction of the Greater Bay Area and the status of natural resources, and provides important basic data for the planning and construction of the Guangdong, Hong Kong, and Macau Greater Bay Area.
4.2 Satellite Remote Sensing Image Map of Wanjiang Economic Belt

Promoting the development and construction of the Yangtze River Economic Belt is a major national development strategy. As an important part of the Yangtze River Economic Belt, the Wanjiang Economic Belt plays a supporting role in regional coordinated development. In order to meet the economic and social development of the Wanjiang Economic Belt to the needs of geological work such as energy resources, mineral resources, ecological civilization construction, urban development, major engineering construction, agricultural modernization, etc., in response to the development strategy of the Yangtze River Economic Belt, the Ministry of Land and Resources China Geology in 2015 The Bureau of Investigation and the People's Government of Anhui Province have decided to jointly implement a comprehensive geological survey project in the Wanjiang Economic Belt. The second phase of the project has started in 2019.

According to the needs of the project, the author selected 35 scenes of 2019 GF-1 WFV as the main data source to complete the production of satellite remote sensing image maps of the Wanjiang Economic Belt (Fig. 6). The map covers 8 prefecture-level cities in Hefei, Wuhu, Ma'anshan, Anqing, Luzhou, Chizhou, Tongling, Xuancheng, and Jin'an District and Shucheng County in Lu'an City. The map and data provided timely basic image data for the comprehensive geological survey project of the Wanjiang Economic Belt, assisted in censusing the natural resources endowment and potential of the mountains, rivers, forests, lakes and grasses in the region, scientifically evaluated the carrying capacity of resources and the environment, the preparation of land use planning, Town planning and construction, major project layout, mineral resource planning and resource guarantee, promoting the
orderly progress of related geological surveys, and promoting the transformation of national basic geological work to serve local needs and closely coordinate with economic and social development.

Fig.6 Satellite Remote Sensing Image Map of Wanjiang Economic Belt

5. Conclusion
Based on the summary of the main workflow of GF-1WFV data mosaic, this paper analyzes and researches the key strategic links such as true color enhancement, seam line extraction and uniform color during the mosaic process. Some typical research fields were selected, and the mosaic experiments and applications were performed on the images by methods of gray-scale transformation enhancement, minimum gray difference determination algorithm and overlapping image dodging. The results prove that the above algorithm can well preserve the image detail information while taking into account the full-frame color balance, and has achieved a high-quality mosaic processing of high-resolution satellite images. However, this article only conducted experiments on two typical working areas. In the next step, we can try more advanced algorithms in more types of experimental areas for research, and constantly optimize the remote sensing image mosaic strategy to provide more high-quality image mapping products.

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