Photogrammetry for First Response in Wenchuan Earthquake

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Figure1. The aerial flight path in Wenchuan earthquake area.

Introduction

To inspect the damages caused by the Wenchuang earthquake on May 12, 2008, aerial photography was practiced in an unconventional manner. The f ight was largely irregular, along the roads, in cities and towns in order to obtain the f rst-time damage information about main roads, bridges and other transportation infrastructure . Hovering f ight is necessary to get more ground information about residential areas when the plane is over the city. All this challenges for advanced techniques to process such collected images in a timely manner. Some key algorithms and data-processing mechanisms in conventional practices should be upgraded to meet this need. This paper mainly focuses on the rapid data processing and applications of mass unconventional aerial images in Wenchuan earthquake relief and emergency response.

Diff culties of First Response Photogrammetry

After the earthquake, China Aero Geophysical Survey & Remote Sensing Center for Land and Resources (AGRS) carried out a large number of aerial f ights using different sensors over the disaster area. The urgent task of Wuhan University was to rapidly process more than 4000 images taken by a DMC digital camera with POS (GPS/IMU) over an area of 4486 km^2 in the earthquake zone and generate the 3D models to support earthquake relief operations. The DMC aerial photography f ight paths in the Wenchuan earthquake area are shown in Figure 1 and the 3D f ight paths from Yingxiu to Maoxian on May 15, 2008 are shown in Figure 2.

Figure 2. The 3D flight line and image orientations of aerial photography on May 15, 2008.

Compared with the traditional aerial photography, the following characteristics can be identif ed in the f rst response f ight :

1) Due to the high mountainous terrain, the maximum altitude difference is 2897 m, which is about one half of the f ight height. This leads to considerable changes in the overlap between adjacent images and creates diff culties in determining the searching range in image matching.
2) The hovering f ight results in a large relative rotation angle of up to 30° between adjacent images. Therefore, the conventional image matching method based on grayscale area correlation may not yield reliable and precise correspondence.
3) The images of the “broken” f ight course due to clouds, restart of the camera, and other reasons raise a certain level of diff culty for conventional aerial photogrammetry.
4) Neither a GPS base station nor a ground control point (GCP) was available. Since the POS system was used for photography without pre-calibration, the average vertical parallax is 6.8 pixels with a maximum of 16.8 pixels. The quality of such POS data can not be directly used for epipolar line matching or ortho image production.

5) Mass data up to 1400 GB aerial images were obtained due to the large area covered by the strong earthquake. Therefore, the need for rapid processing became a key to the rescue operation.

Solutions with Digital Photogrammetry

Parallel Processing

Wuhan University has developed a fast processing system called Digital Photogrammetric Grid (DPGrid) for parallel processing of aerospace images. High-performance computers are used as computing nodes. According to the number of computing nodes available in a local network, tasks, including image preprocessing, image matching, DEM and orthoimage generation, are distributed and carried out automatically. The general procedure of parallel processing is f rstly building a sampling task list, and then the tasks can be assigned to each available computing node to perform the corresponding processing. As a result, parallel processing is more time eff cient when compared with the traditional image by image processing strategy.

Automated Relative Orientation

In order to achieve the fast, high-precision matching of a stereo pair with a large relative rotation angle, the original image is f rst down sampled to carry out SIFT (scale-invariant feature transform) feature matching. The matching results are used to compute the rotation angle θ and overlap between adjacent images. After a rotation of -θ degree is applied to the right image, a multi-level correlation is conducted along with a least squares matching on the original stereo pair. Figure 3 shows the matching results of a stereo pair with 30° relative rotation, which has 7958 matched points, with a mismatch rate of less than 1/1000 and remaining vertical parallax of 0.58 pixels.

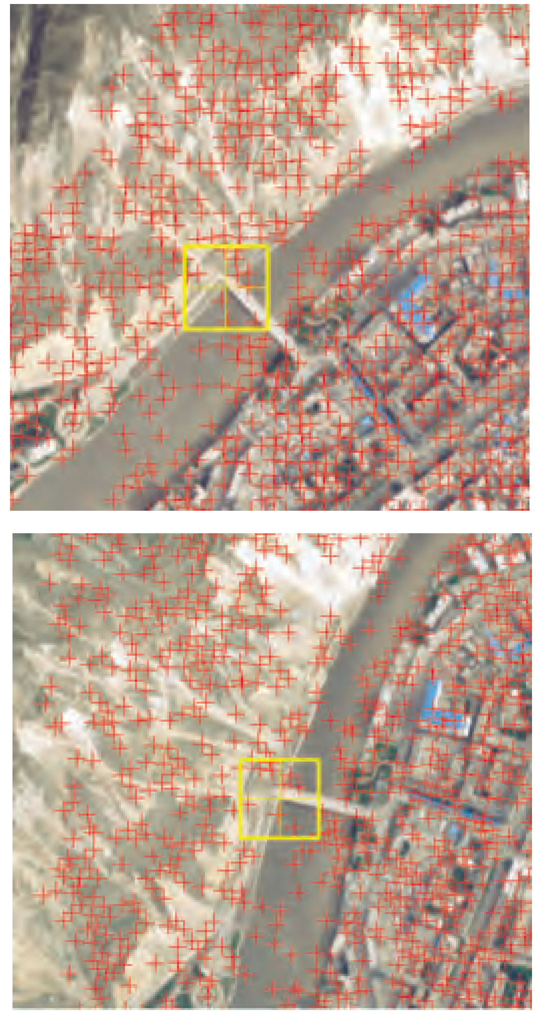
Figure 3. Stereo matching results of images with a 30° rotation angle.

POS Supported Bundle Adjustment

Since there is no ground control point available, the only non-photogrammetric data that can be used are POS observations, which can be used as initial position and orientation parameters of each image. After bundle adjustment, the maximum disparity was reduced from 0.202 mm (16.8 pixels) to 0.0066 mm (0.55 pixels). As shown in the left part of Figure 4, the epipolar line does not overlap with the corresponding features before bundle adjustment. However, it is superimposed on the corresponding features after bundle adjustment (Figure 4 right pair). It is clear that bundle adjustment can effectively reduce the effect of the relative errors in the POS data.

Figure 4. Y-parallax before (left pair) and after (right pair) POS supported bundle adjustment.

continued on page 512

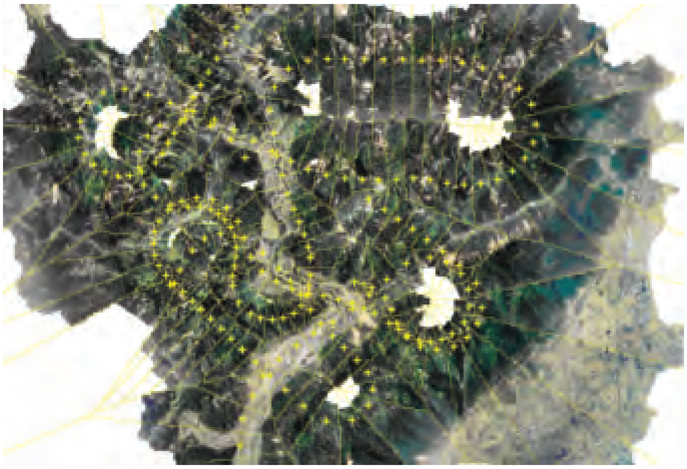

Figure 5. The ortho image based on automatic selection of mosaic line and parallel ortho rectification.

Figure 6 Distance measuring of broken roads and bridges.

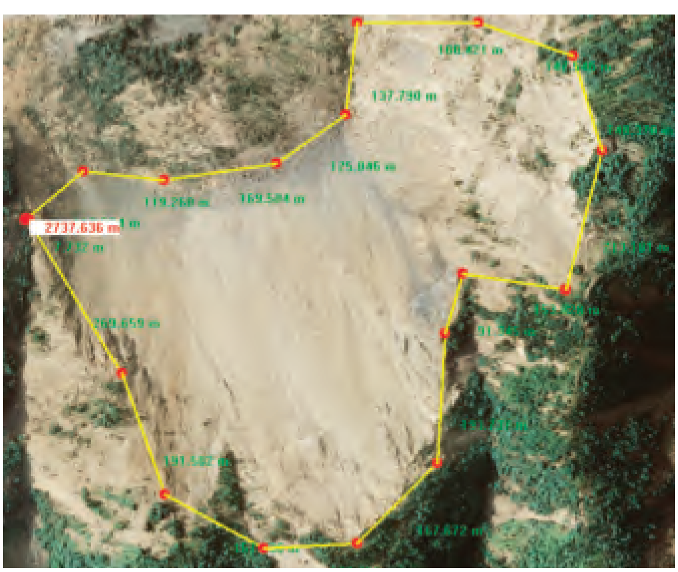

Figure 7. Area and earth volume measuring of a landslide.

Multi-image Matching

Hovering f ight provides multiple coverage, whereas its POS data often have linear drifts. To address this problem, multi-image matching is adopted, which uses exterior orientation parameters and collinearity condition as constraints. Features points extracted from the interested image are used for matching on all overlapped multi-images. The high redundancy of multi-images assures a better quality of image matching. With points obtained by multi-image matching, one more bundle adjustment with POS data can further reduce its effect on DEM and orthoimage generation.

Automatic Mosaic and Ortho Image Generation

After bundle adjustment, the dense matched points and the exterior orientation elements are used to generate a digital surface model. Digital rectif cation of the original images is carried out to produce ortho images. To automatically generate mosaic lines among the ortho images, the Voronoi map of the exposure centers is used. As shown in Figure 5, the bold crosses are the exposure centers, and the polygon boundaries represent the mosaic lines. The background of Figure 6 shows part of the rectif ed ortho image of the Wenchuan earthquake area.

Support for Decision Making

Image maps at a resolution of 0.3 m were produced on May 19, four days after the images were collected for the Yingxiu - Wenchuan - Maoxian f ight strip. The processing of a total of 4507 DMC images and rapid production of an orthophoto map were completed within 111 CPU hours. As shown in Table 1, the DPGrid system can automatically process about 40 images per hour, which is much higher than the rate of a few images per hour in the conventional digital photogrammetry workstation.

Further, more products and applications of aerial photogrammetry are shown. Figure 6 shows the measured length of broken roads and bridges on the ortho image, while Figure 7 shows the measured area and collapsed earth volume by using the DEM and ortho image. Figure 8 shows the contour lines overlaid atop the ortho image, which are helpful for disaster estimation and rebuilding. Figure 9 shows the 3D landscape of the barrier lake of Tangjia Mountain.

Table 1. CPU time of parallel processing with 3 PCs as computing nodes.

Flight date	Number of images	Resolution of ortho image	Size of ortho image	Time
May 15, 2008	316	0.3 m	219.00 GB	20.0 h
May 16	530	1.0 m	22.40 GB	11.0 h
May 18	507	1.0 m	20.10 GB	5.5 h
May 19	174	1.0 m	2.99 GB	2.0 h
May 27 to May 31	2980	1.0 m	18.00 GB	72.0 h
Total	**4507**	---	**282.49 GB**	**110.5 h**

Summary

It was probably the f rst time in China that advanced photogrammetric technique was used to process mass unconventional aerial images for fast response under a time critical situation. It played an irreplaceable positive role in providing timely information for earthquake rescue activities.

The experience with parallel processing was extremely successful and demonstrates the need and its potential for such technology to be part of the national emergency response system in the future.

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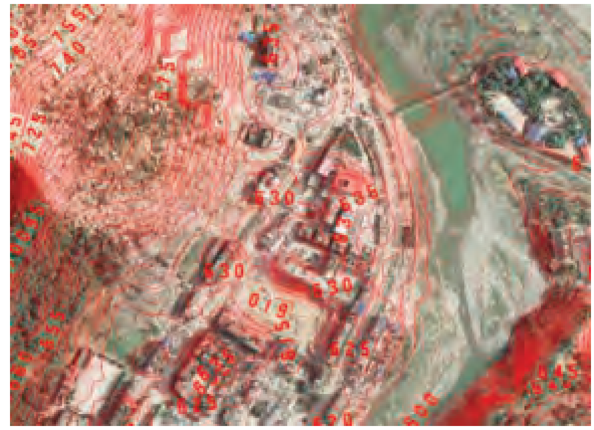

Figure 8. Ortho image superimposed with contour lines.

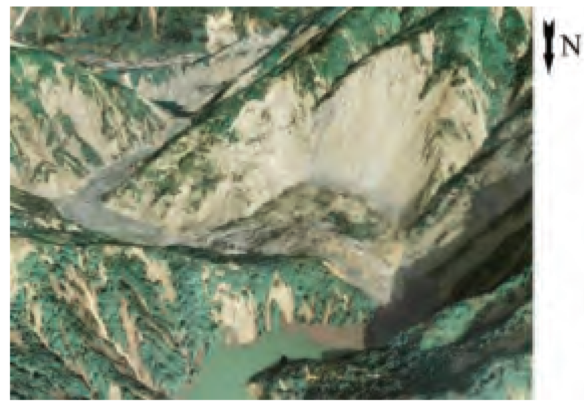

Figure 9. 3D landscape of barrier lake of Tangjia Mountain.