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SEMANTIC INFORMATION-AIDED GEOMETRIC CORRECTION OF HIGH RESOLUTION SATELLITE IMAGES

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With the rapid development of deep learning technology, the automatic classification and semantic segmentation of remote sensing imagery become more and more accurate. Meanwhile, with the improvement of the generalization, this technology is more and more widely used in the industry[1]. This paper proposes a new framework of sematic-information-aided geometric correction of high-resolution satellite images (HRSIs) to achieve higher accuracy and automation.

Accurate geometric correction of satellite images is the key to most remote sensing applications. The HRSIs should be well-registered with the base map to ensure absolute accuracy. They should also be well-registered with each other to ensure the mosaicking accuracy of large-area remote sensing products. However, in most cases, the satellite images are not captured from the strict nadir view. The off-nadir angle of HRSIs is mostly 5-20 degrees, which leads to the movement of the top of buildings, trees, and other overground objects on the ortho-rectified HRSIs (see Figure-1). Thus, the coordinates of the object top and sides deduced from the ortho-rectified HRSIs are inaccurate. In addition, the digital elevation model (DEM) cannot supply the surface elevation of the overground objects, so the overground objects should be excluded when obtaining ground control points (GCPs) through image matching.

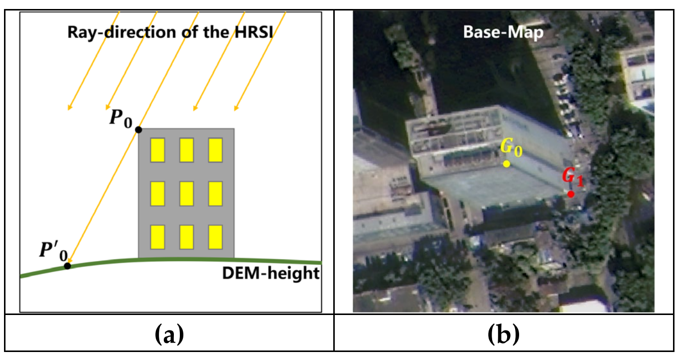

Figure 1. The problem is caused by over-ground tie-points and GCPs in the B&D-controlled geometric correction. Because of the off-nadir angle of HRSIs, points from the top of building move away from its original plane position.

Traditional satellite photogrammetric theory and technology cannot achieve the goal of filtering the overground control points(OCPs) and overground tie-points (OTPs). Many advanced methods of gross error detection and robust estimation have been proposed in recent years, and the OCPs are like gross errors during the geometric process, i.e. they have a much larger elevation difference from the DEM and much larger horizontal registration errors. However, the photogrammetric methods can only deal with the gross error under the uniform distribution hypothesis. Neither the elevation error nor the registration error of the OCPs follows the uniform-distribution hypothesis. At the same time, when the satellite images are captured from different off-nadir angles, the tops of the ground objects will be shifted to different angles, so these OTPs won't have the same location. As a result, the traditional geometric registration or block-adjustment methods can hardly achieve high accuracy without filtering the OCPs and OTPs in complicated situations like a dense residential area. Experiments show that even using very accurate base-maps and DEMs for control, the block adjustment of 0.65m-resolution GF-7 stereo images resulted in over 3m elevation RMSE (the root of mean squared error).

In this paper, a new semantic information-aided HRSI geometric correction framework is introduced to improve the block-adjustment accuracy of HRSIs under the B&D (Base-map and DEM) control mode (see Figure 2). The workflow mainly includes three steps, i.e., image matching [2,3], point filter assist by semantic segmentation, and block adjustment. Image matching and semantic segmentation can be processed simultaneously. The tie-points(TPs) and GCPs are automatically matched and then the overground points on the buildings, tall trees, and clouds are filtered by the masks generated by the

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semantic segmentation process. After that, most of the OCPs and OTPs are removed, and the remained ones will be detected as gross errors by the DEM-aided block adjustment [4]. The semantic segmentation process used three pre-trained deep learning models [5,6] which segment the area covered by buildings, trees, and clouds. The building segmentation model and tree segmentation model were trained with the National land survey data in Guangdong Province, China, and the cloud segmentation model was trained on the Landsat 7 Cloud Cover Assessment Validation dataset [7].

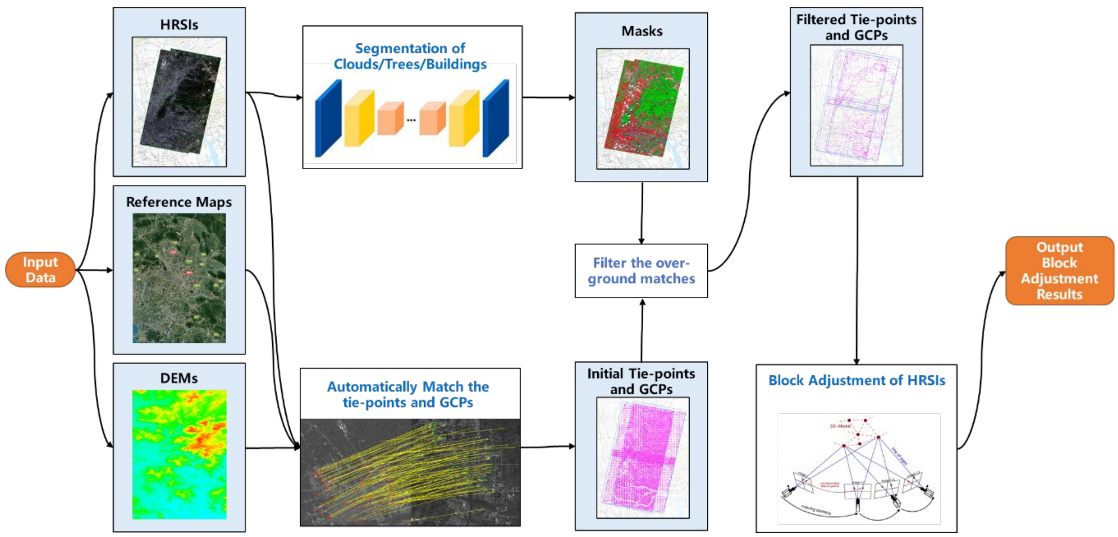

Figure 2. The workflow of the proposed HRSI geometric correction framework.

The proposed framework was demonstrated with GF-7 stereo images and SuperView-1 single-line-array images. The 0.5m-resolution base map that has better-than-1m horizontal accuracy and the 5m-resolution DEM that has better-than-1m vertical accuracy (in flat area) were used to match GCPs. The GPS-RTK control points were used as Check Points (CPs) to check the block adjustment accuracy.

Table 1. Accuracy comparison of automatic block adjustment under three different control strategies

Block Adjustment Strategies	Manual CPs Number	Planar RMSE X	Planar RMSE Y	Elevation RMSE
Forward Intersection Directly	39	4.66	7.61	21.69
No Semantic Information Assist, with Elevation Control	39	0.94	2.17	7.70
Semantic Information Assist, with Elevation Control	39	0.91	1.60	0.68
20 GCPs as Planar and Elevation Control	19	0.87	1.38	0.61

Table 1 lists the GF-7 block adjustment result. When the OCPs and OTPs are not filtered, the elevation RMSE is 7.70m. When using the semantic segmentation process, the elevation RMSE reaches 0.68m.

Table 2. SuperView-1 Images Process

Method	**RMSE**			**Min**			**Max**			**Mean**		
	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
Non-Sem	0.93	1.60	3.36	-2.02	-4.24	-0.95	0.43	1.79	5.67	-0.75	-0.89	2.82
Proposed	**0.71**	**0.62**	**1.338**	-1.46	-1.17	-1.66	0.83	1.52	3.70	-0.49	0.21	0.70

Table 2 shows the SuperView-1 image process results. 65 CPs were used to verify the effect of accuracy improvement, under the proposed framework can reach better than 1.5m horizontal RMSE and better than 1.0m vertical RMSE.

The results demonstrate that the proposed framework can achieve both a higher degree of automation and higher block-adjustment accuracy. The integrated intelligent geometric-semantic process will play a more and more important role in photogrammetry.

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