Object-based Dense Matching with Feature Constraints for DSM Generation

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ABSTRACT:
Semi-global matching (SGM) matches every pixel regardless if it is a feature point. The procedure integrates local and global image information for each pixel to achieve the quality DSMs. However, the geometric continuity in the feature position might not be directly taken into account. Conventionally, SGM locates the conjugates for a pair of two images at a time. Instead of starting from object space, the method is performed only in the image space. The object-based matching method is more favorable to connect three or more images. Thus, this paper proposes the object-based dense matching with feature constraints for DSMs generation.
The major works contain feature extraction, object-based dense matching, and DSMs reconstruction. For each pixel, we calculate the correlation coefficients in different corresponding elevations. In the feature positioning, we use the multi-window strategy to enhance the matching reliability. Then the SGM algorithm is employed to determine the conjugates associated with the object positioning. Experimental results show that the proposed method can reconstruct quality DSMs.

1. INTRODUCTION

Image matching is a practical method for the generation of digital surface models (DSMs). According to the matching targets, the image matching can be divided into two categories, namely feature-based matching and dense matching. The feature-based matching is to match point (Suveg and Vosselman, 2004), line (Ok et al., 2010), or shape (Belongie et al., 2002) features. Then the corresponding 3D coordinates can be determined by those conjugates and the images' orientation parameters. So, it is favorable to collect the 3D information in the feature positions. On the other hand, the dense matching algorithm, such as semi-global matching (SGM) (Hirschmüller 2005), matches every pixel regardless if it is a feature point. Generally, the dense matching could achieve the quality DSM (Xiao et al., 2013). However, the geometric continuity in the feature position might not be taken into account.
Conventionally, SGM locates the conjugates for a pair of two images at a time. Instead of starting from object space, the matching procedure is processed only in the image space. The object-based matching method (Otto and Chau, 1989, Zhang and Gruen, 2006) connects the correspondences in different images through a same object location. So it is more favorable to connect three or more images. Thus, this paper proposes the object-based dense matching (OBDM) with feature constraints for DSM generation using aerial images.

2. METHODOLOGY

This proposed method combines the advantages of dense matching and feature-based matching. Based on the dense matching, we use the multi-window matching method, a strategy of feature-based matching, in the feature positions to reach reliable results. Thus, the major works contain feature extraction, OBDM, and DSM reconstruction. The components of the proposed method are in the following.

2.1 Feature Extraction

Since the most of man-made structures are composed of straight line features, the extraction of straight lines is employed in this study. We thus, use Canny detection (Canny, 1986) with Hough transform (Hough, 1959) to extract the straight line features.

2.1 Object-Based Dense Matching (OBDM)

For each pixel, we calculate the correlation coefficients in different correspond elevation. In the feature positions, we use the multi-window strategy (Hsu, 1990) to enhance the matching reliability. Then the SGM algorithm is employed to determine the conjugates associated with the object positioning. SGM method is a pixelwise matching and approximating a global matching. The procedure integrates local and global image information for each pixel. An additional constraint is added to support the smoothness by penalizing. Aggregation of matching costs provides to find the maximum similarity by 1D paths. This paper uses Normalized Cross Correlation (NCC) as the cost index. Besides, the multi-window strategy is included in the feature position for the matching costs evaluation. Considering the feature direction, we put the matching target, the components of straight line feature, at different position in target window. In this way, it could avoid the window including surface discontinuity around the building boundaries.

2.3 DSM Reconstruction

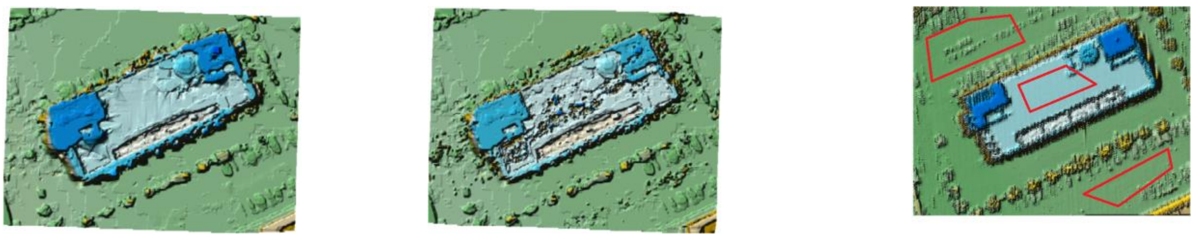
OBDM is a pixelwise image matching from the object space. It determines the conjugates and the corresponding 3D coordinates at same time for each groundel. However, there are still some pixels with low correlation coefficients, which yield unreliable matching. Thus, we exclude those pixels via a threshold first. Then the inverse to distance square method is employed in the interpolation for surface modeling.

3. EXPERIMENTS

The test site locates in Taipei City of Taiwan. The datasets include five Digital Mapping Camera II images with 10cm spatial resolution, as shown in Figure 1. The proposed method OBDM integrates local and global image information to match each pixel. Then we set a threshold to exclude the outliers for surface modeling. The original SGM is performed without a threshold. The method removes the outliers via that check the results of left-to-right matching and right-to-left matching in a pair. Since the OBDM is an optimal solution for all employed images, the left-to-right and right-to-left matching check does not apply in this method. Thus, this paper compares the results from the proposed method and the results without the threshold.

Figure 1. Overlapped Images of Test Data

The results of DSM reconstruction and the reference data are shown in Figure 2. This study evaluates the accuracy of generated DSM by the reference DSM which is built from LIDAR point clouds. The LIDAR point clouds were acquired by an Optech ALTM Pegasus with a density of 15 pts/m^2. To examine the justifiable differences between the generated DSM and the reference DSM, we selected some regions, as shown in red of Figure 2(C), to analyze the accuracy. Table 1 shows the successful rate of matching results and the accuracy of generated DSM.
According to the Figure 2(A) and Figure 2(B), there are obviously incorrect points on the roof of the results without a threshold. Although the successful rate of OBDM reduces to 77.5%, the accuracy can be improved significantly. The RMSE in this case can reach 0.28m in Z direction.



(A) OBDM (B) OBDM without threshold (C) Reference DSM and the check regions

Figure 2. The Results of DSM Reconstruction and The Reference DSM

Table 1. Successful Rate of Matching Results and Accuracy of DSM

	Successful Rate of Matching Results	Accuracy of DSM
OBDM	77.48%	0.28 m
OBDM without Threshold (Original SGM)	100%	2.26 m

4. CONCLUSIONS

This investigation proposes the OBDM with feature constraints for DSM generation using aerial images. The experimental results indicate that the proposed method could improve the better quality DSM as well as maintain the enough matching successful rate for surface modeling. The RMSE of the test case can reach 0.28m in Z direction using DMC-2 camera with 1200m flying height.

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