Parameter Optimization of Feature-Aided Dense Matching for Multi-angle Images

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ABSTRACT:
Semi-Global Matching (SGM) combines local and global image information with smoothness constraints to reach reliable results for digital surface model reconstruction. However, smoothness constraint might be unable to cope with the matching ambiguity in the area with surface discontinuity. Multi-window matching considers local feature constraint to increase matching quality around feature regions. Thus, the integration of multi-window matching and SGM is proposed in this investigation.
In multiple image matching, how to selecting an optimal solution is an important task. Traditionally, researches use average of all image pairs' correlation coefficients to determine the optimal conjugate points. However, this average approach may account for the hidden area without any treatments. That usually leads to low correlation. In this investigation, a strategy only employing good enough image pairs is proposed. The RMSE of the test cases can reach 0.28m in Z direction using DMC-2 camera with 1200m flying height.

1. INTRODUCTION

Digital Surface Model (DSM), which may be generated from 3D point clouds, is an important data source in various geoinformatic applications. It is a practical way to generate high quality 3D point clouds by matching multiple images (Baillard and Zisserman, 2000; Noronha and Nevatia, 2001; Zhang and Gruen, 2006; Hirschmüller, 2008). In addition, both of image matching method and parameter selection may influence the 3D point clouds quality.
Semi-Global Matching (SGM) (Hirschmüller, 2008; 2012) considers connected paths with smoothness constraints. SGM also combines local and global image information so it can get stable results. However, smoothness constraint might be unable to cope with the matching ambiguity in the area with surface discontinuity. With the inclusion of feature constraints, SGM may be improved in terms of matching quality for edge areas. Multi-window matching (Hsu, 1999) considers local feature constraint using multiple matching windows to increase matching quality around feature regions. Thus, the integration of multi-window matching and SGM might improve the quality for DSM reconstruction.
In multiple image matching, how to select optimal images is an important task. Traditionally, researches use average of all image pairs' correlation coefficients to determine the optimal conjugate points (Zhang and Gruen, 2006). However, this average approach may account for the hidden area without any treatments. That usually leads to low correlation. In this investigation, we propose the Feature-Aided Dense Matching (FADM) to combine the SGM and multi-window matching algorithms. In addition, a strategy considering good image pairs with different parameter is discussed in this study.

2. METHODOLOGY

The integration of multi-window matching and SGM is proposed in this investigation. Based on the SGM, we use the multi-window matching method in the feature positions to improve the result of SGM. Thus, the major works contain feature extraction, image matching by FADM, and DSM reconstruction. The details of each process part are given below.

2.1 Feature Extraction

Considering most of the buildings' contours are composed of straight lines, we extract the straight lines for the follow-up FADM. In this step, Canny (Canny, 1986) edge detection is utilized to detect the connecting points firstly.

Then the straight line features can be detected through Hough transform (Hough, 1959).

2.2 Feature-Aided Dense Matching (FADM)

The FADM algorithm is based on the SGM method with multi-window strategy in the feature position. The idea of SGM method is a pixelwise matching and approximating a global matching. An additional constraint is added that supports smoothness by penalizing. Aggregation of matching costs provides to find the minimization of energy by many 1D paths. This paper uses eight directions to aggregate the matching costs. Besides, the multi-window strategy is included in the feature position for the matching costs evaluation.

In this investigation, we use the average method (AM) and conditional average method (CAM) to calculate the costs, respectively. Normalized Cross Correlation (NCC) is employed as the cost index. The larger value of NCC means the smaller matching cost. The AM uses average of all image pairs' correlation coefficients to determine the matching costs. On the other hand, the CAM excludes the pairs' results with the NCC values lower than the threshold. It means that we only select the reliable image pairs to determine the final costs. According to the number of selected pairs, we can set the different thresholds. We assume that the results might be more reliable with more pairs' composition. Thus, the threshold is tight if only one pair is matched, while the threshold for two or more pairs' cases will be set lower.

2.3 DSM Reconstruction

After the matching procedure, we can get 3D point clouds to generate DSM by surface modeling. In this paper, the triangulated irregular networks (TIN) method is employed for DSM reconstruction.

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.

Figure 1. Overlapped Images of Test Data.

Table 1 and Table 2 show the matching results of AM and CAM, respectively. The number of check point is 285. We set several thresholds to test the results. Two thresholds in CAM mean the two or more pairs' and only one pair's cases. According to Table 2, it is observed that the results of CAM are stable. Four threshold sets were with the same results. Compared to the AM, the results of CAM are also with better performance is successful rate.

Table 1. Matching Results of AM

Threshold	Successful Rate	Correct Rate
0.6	97.544%	95.684%
0.65	97.544%	95.684%
0.7	97.193%	95.668%
0.75	97.193%	95.668%
0.8	96.842%	95.652%
0.85	96.491%	95.636%
0.9	96.14%	95.62%
0.95	87.368%	95.984%

Table 2. Matching Results of CAM

Threshold	Successful Rate	Correct Rate
0.7/0.7	100 %	95.789%
0.8/0.8	100%	95.789%
0.8/0.9	100%	95.789%
0.9/0.9	100%	95.789%

The results of DSM reconstruction 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. The red frame in Figure 3 illustrates the checked area. And the accuracy is 0.276m.

Figure 2. The Results of DSM.

Figure 3. The Checked Area.

4. CONCLUSIONS

This investigation combines the SGM and multi-window matching algorithms. In addition, a type considering good image pairs with different parameter is discussed in this study. The experimental results indicate that the proposed method could improve the successful rate to 95.7% correct rate in matching procedure. The accuracy of the DSM can reach 0.28m in Z direction in this case.

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REFERENCES

Baillard, C., and Zisserman, A., 2000. A plane sweep strategy for the 3D reconstruction of buildings from multiple images, International Archives of Photogrammetry and Remote Sensing, Vol. 33, Part B3, pp. 56-62.

Canny, J., 1986. A Computational Approach to Edge Detection. IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. PAMI-8, pp. 679-698.

Hough, P.V.C., 1959. Machine Analysis of Bubble Chamber Pictures. Proc. Int. Conf. High Energy Accelerators and Instrumentation.

Hsu, W.C., 1999. Building Extraction from Color Aerial Stereo Photo Pairs. Master degree dissertation, National Central University, Taiwan. (In Chinese)

Hirschmüller, H., Stereo Processing by Semi-Global Matching and Mutual Information, in IEEE Transactions of Pattern Analysis and Machine Intelligence, 2008, vol. 30, 328-341.

Hirschmüller, H., Buder, M., and Ernst, I., Memory Efficient Semi-Global Matching. ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences, 2012, vol. I-3, 371-376.

Noronha, S., and Nevatia, R., 2001. Detection and modeling of buildings from multiple aerial images, IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 23, No. 5, pp. 501-518.

Zhang, L., and Gruen, A., 2006. Multi-image matching for DSM generation from IKONOS imagery, ISPRS Journal o Photogrammetry & Remote Sensing, 60(3):195-211.