A NEW STRATEGY FOR DSM GENERATION FROM HIGH RESOLUTION STEREO SATELLITE IMAGES BASED ON CONTROL NETWORK INTEREST POINT MATCHING

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Commission VII

Key Words: Control Network, Interest Point Matching, High Resolution Satellite Image, Digital Surface Model

ABSTRACT:

Image matching is the key for automatic DSM generation. Currently two kinds of image matching method represent two different trends: area-based method and feature-based method. However, both of them seriously rely on the gray distribution of the image. Therefore, they share a common drawback: ambiguity in homogeneous areas, such as grass land, heavily forested area, highway, and building roofs etc. To solve this problem, a popular way is to apply different conditions to image matching to limit the search window, so that reduce the ambiguity in the homogeneous area. In the photogrammetric community, eppipolar condition is widely used in image matching to reduce the search window from two dimensions to one dimension. Unfortunately, in many cases, the eppipolar condition is not applicable. In order to solve this problem, the control network interest point matching algorithm was recently developed. This method constructs a control network based on the prominent feature points and the spatial information is provided to the image matching to limit the search window. In this paper, we proposed a new strategy based on the control network interest point matching to generate digital surface model from high resolution satellite stereo images. We commence our paper with a brief review of current research on image matching. We then introduce the proposed algorithm in detail and describe experiments with high resolution satellite images. Through experiment, the digital surface model was successfully created from the stereo images. The experiment results show that the proposed algorithm can successfully process local distortion in high resolution satellite images and can avoid ambiguity in the homogeneous areas.

1. INTRODUCTION

Image matching is the key technique for image processing. It is commonly used for DSM generation, 3D shape reconstruction, change detection, medical diagnosis, computer vision and pattern recognition. Currently numerous algorithms have been developed for different applications, and these algorithms can be grouped into two categories: area-based and feature-based. Both kinds of algorithms have their own particular advantages in specific circumstances. However they all seriously depend on the gray distribution of image and face the common problem: ambiguity in homogeneous areas, such as grass land, highway surfaces, building roofs, etc. In order to solve this problem, the eppipolar condition is usually applied to limit the search window from two dimensions to one dimension so as to reduce the ambiguity in the homogeneous area. Unfortunately, in many real-time image matching cases, the eppipolar condition is not applicable. The recent developed control network interest point matching algorithm successfully solved this problem. This algorithm constructs a control network based on the prominent feature points and then the control network provides spatial information for those interest points in the homogeneous area so as to reduce the ambiguity.

In this research, we tried to apply the control network interest point matching algorithm to generate the digital surface model from the stereo satellite images. Without the eppipolar condition, the control network is used to provide the constraint to limit the search window. Because of the large ground relief variation, an image pyramid is generated first. Then the grid point image matching is conducted based on the control network.

In the following sections of the paper, we introduce the proposed algorithm first. Then present the experiment with a stereo satellite images. Finally we give the conclusions.

2. PROPOSED ALGORITHM

The control network is generated from the prominent feature points. So the interest point is extracted first. Many interest point extraction algorithms are available. The Harris detector was used in this research. Later on a threshold is applied to those extracted interest points to extract the prominent feature points. These prominent feature points are also named super points. A super point matching is executed and a control network is formed.

This control network is used to provide spatial information to the grid points. So the grid point matching is constrained by this spatial information. The correspondence is searched in a small search window so as to reduce the ambiguity and avoid local minimum problem. However, due to the large variation of the ground relief, the control network cannot provide support to limit the search window in a small enough area to completely avoid ambiguity. So a pyramid structure is applied in this algorithm. In this way, the correspondence is found gradually so as to avoid large relief variation. The cross correlation is also used to determine the correspondence in the search window.

Finally, the conjugate points are used to determine the 3D points by using space intersection. The breakline can be added into it before the TIN is generated. The DSM is created based on TIN. Figure 1 shows the flowchart of this algorithm.

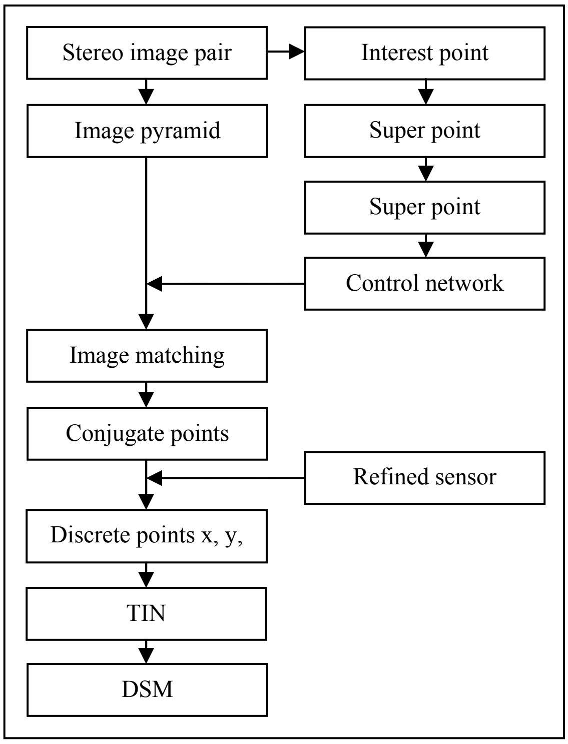

Figure 1. Flowchart of the image matching strategy for DSM extraction from stereo satellite image pair.

3. EXPERIMENT

A stereo pair of IKONOS images, acquired in February of 2003 in Hobart, Tasmania, Australia was used for this experiment (**Figure 2**). The incidence angles are forward 75° and backward 69° respectively (Fraser and Hanley, 2005). **Table 1** lists the main characteristics of images in Hobart test field.

Figure 2. Stereo pair of IKONOS images in Hobart (courtesy of the University of Melbourne)

Table 1. Characteristics of the IKONOS Imagery in Hobart Test Field (Fraser and Hanley, 2005)

	IKONOS, Hobart
Area	120 km2 (11×11 km)
Elevation Range	Sea level to 1280 m
Image Coverage (elevation angles)	Stereo triplet (69˚, 75˚, 69˚)
Number of GCPs	113
Notable Features	Full scene; mountainous terrain
Base-to-height ratio	0.8
Date of acquirement	February, 2003
GCP measurement on image	Sub-pixel accuracy for roundabout features; pixel accuracy for other features.
Scan model	Reverse model for 69˚ images; Forward model for 75˚ image

The test area includes unban area and mountain area. The elevation ranges from zero to one thousand meters. Because of its large relief variation, this is an ideal area to test the DSM generation algorithm. We have one hundred and thirteen ground control points normally distributed in the test area and collected with geodetic GPS receiver. The satellite sensor model was refined to sub-pixel accuracy (in image space) and sub-meter accuracy (in object space). Figure 3 demonstrate the original image of test area (left) and the generated DSM with the proposed algorithm.

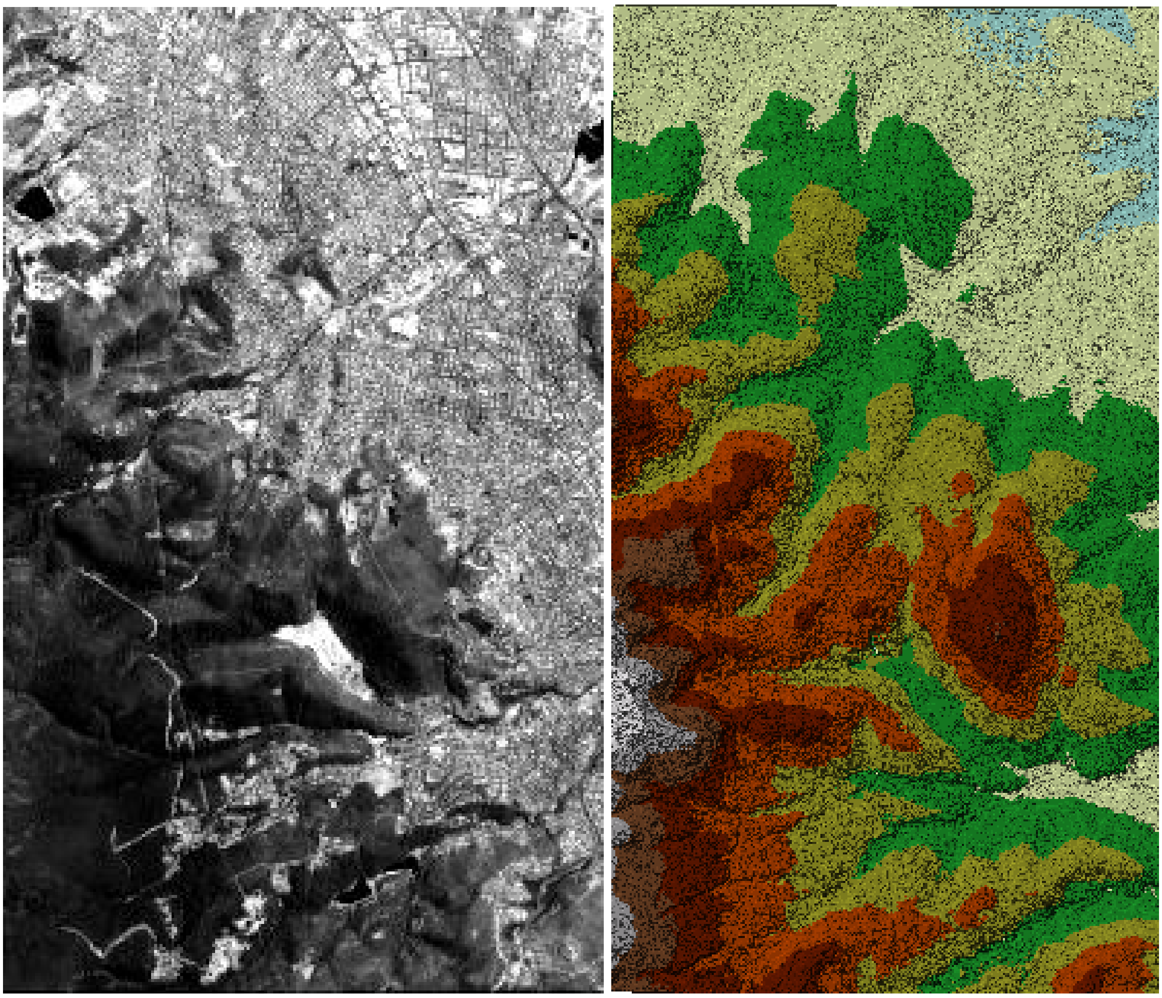

Figure 3. Original satellite image of the test area (left) and the DSM (right) generated with the proposed algorithm.

In order to observe more detail of the DSM, we cut the image and the DSM into two parts and zoom in it (**Figure 4 and 5**). Figure 4 shows the upper part of Figure 3 and Figure 5 demonstrate the lower part of Figure 3.

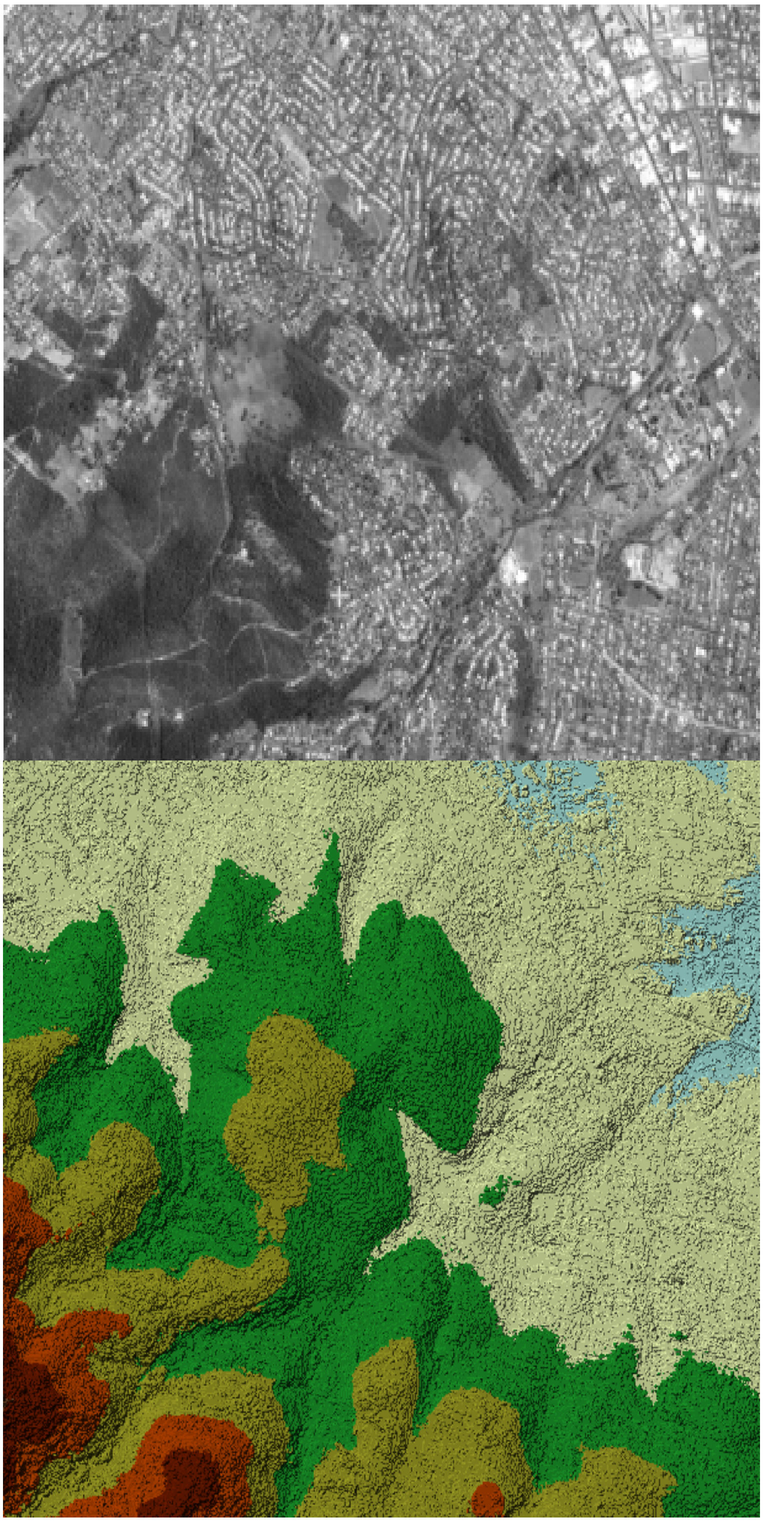

Figure 4. The original image (upper) and DSM (lower) (corresponds to the upper part of Figure 3).

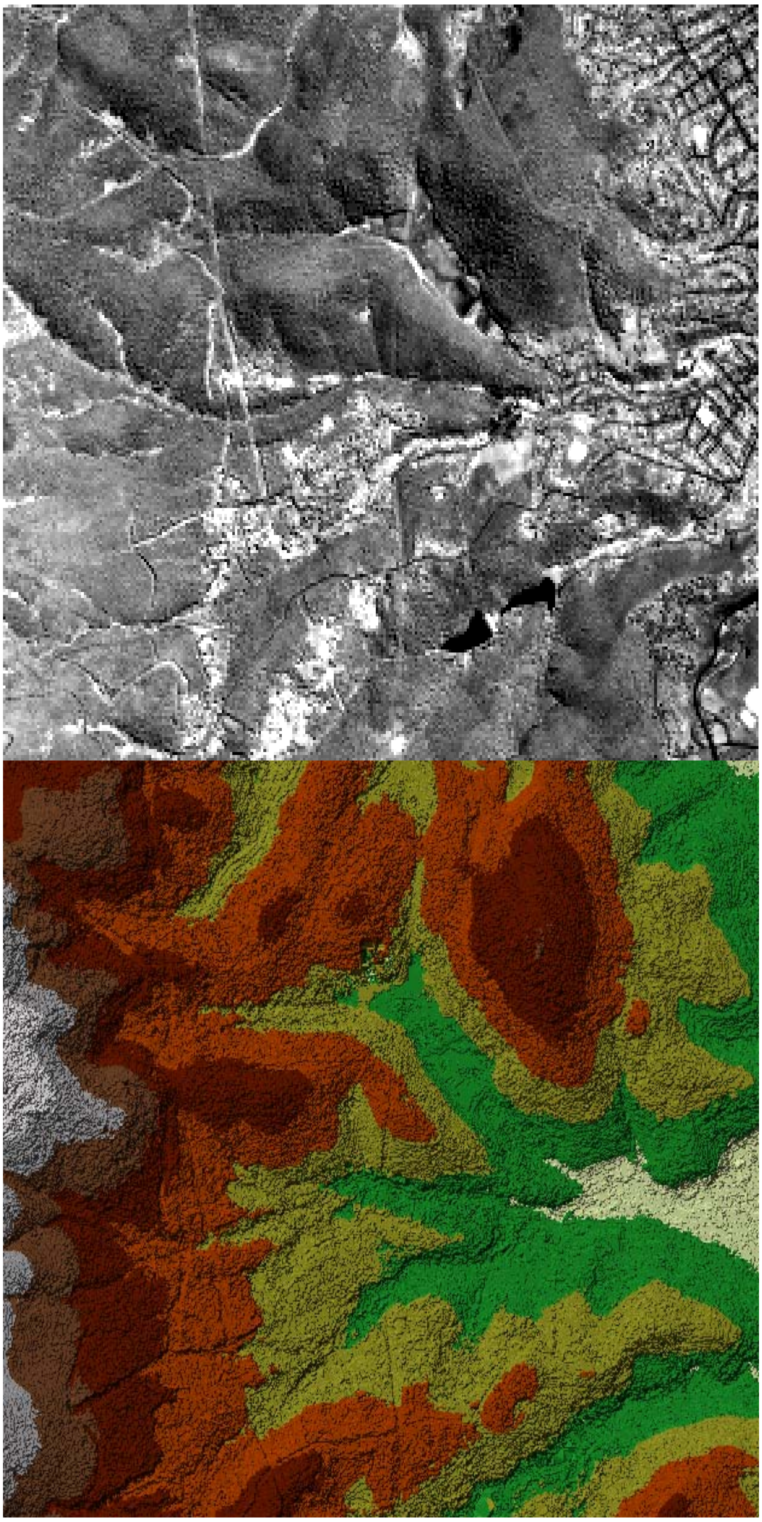

Figure 5. The original image (upper) and DSM (lower) (corresponds to the lower part of Figure 3).

In order to check the accuracy of the generated DSM, we randomly selected twenty five correspondences. We manually measured the image coordinates of the correspondences and then compared it with the image coordinates of the correspondences which are automated generated by the program. We applied space intersection to these correspondences to determine their coordinates and check their difference in the object space. Table 2 demonstrates the detail of the accuracy assessment. From this table, we can find that only one of twenty five points has deviation from the manually measured correspondences and resulted in 3.30 meters, -1.78 meters, and -3.60 meters deviation in x, y, and z dimension.

Table 2. Accuracy evaluation of DSM

No	Tie points Extracted by algorithm				Tie points extracted manually				Deviation		
	Column	Row	Column	Row	Column	Row	Column	Row	Δx(m)	Δy(m)	Δz(m)
1	2594	551	2654	546	2594	551	2654	546	0	0	0
2	4664	480	4701	571	4664	480	4701	571	0	0	0
3	7904	690	7940	791	7904	690	7940	791	0	0	0
4	1381	1938	1450	1903	1381	1938	1447	1903	0	0	0
5	4478	1565	4518	1648	4478	1565	4518	1648	0	0	0
6	6842	1549	6880	1645	6842	1549	6880	1645	0	0	0
7	1245	2376	1309	2347	1245	2376	1309	2347	0	0	0
8	3064	2927	3109	2988	3064	2927	3109	2988	0	0	0
9	6196	2412	6237	2488	6196	2412	6237	2488	0	0	0
10	177	3521	246	3479	177	3521	246	3479	0	0	0
11	3083	3310	3127	3371	3083	3310	3127	3371	0	0	0
12	5837	3903	5881	3964	5837	3903	5881	3964	0	0	0
13	929	4879	995	4839	929	4879	995	4839	0	0	0
14	2532	4965	2597	4941	2532	4965	2597	4941	0	0	0
15	5321	4839	5369	4885	5321	4839	5369	4885	0	0	0
16	7850	4150	7891	4232	7850	4150	7891	4232	0	0	0
17	2153	5575	2225	5515	2153	5575	2225	5515	0	0	0
18	4826	5352	4877	5380	4826	5352	4877	5380	0	0	0
19	7815	5005	7859	5062	7815	5005	7859	5062	0	0	0
20	5114	298	5151	393	5114	298	5150	395	0	0	0
21	2982	1621	3036	1640	2982	1621	3036	1640	3.30	-1.78	-3.6
22	6944	1740	6990	1838	6944	1740	6982	1833	0	0	0
23	5070	2186	5111	2265	5070	2186	5111	2265	0	0	0
24	2246	3935	2296	3974	2246	3935	2296	3974	0	0	0
25	4368	4772	4426	4776	4368	4772	4426	4776	0	0	0

4. CONCLUSIONS

Based on the experiment and accuracy evaluation, we draw following conclusions.

Without the help of eppipolar condition, the proposed algorithm can process homogeneous area with the assistant of control netwok and.

With the help of control network and the pyramid structure, the proposed algorithm can process the large relief variation of the satellite images.

The proposed algorithm can successfully generate DSM from the complicated area which includes both urban area and high mountain area. And the accuracy of the DSM is encouraging.

Therefore, we believe this technology has the potential to be used for 3D reconstruction in case of no camera geometry can be used to constrain the image matching to deal with the ambiguity in the homogeneous area.

This is an initial attempt of this technology. We plan to conduct extensive test to this algorithm in the near future.

ACKNOWLEDGMENTS

This research is sponsored by the Natural Sciences and Engineering Research Council of Canada through the Discovery Grant (NSERC Discovery Grant) awarded to Dr. Yun Zhang, the second author of the paper. We would like to acknowledge that Professor Clive Fraser, Department of Geomatics Engineering, University of Melbourne, Australia, provided us with satellite images and ground control points for the tests.

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Omitted.