IMPROVEMENT OF MAPPING ACCURACY BY APPLYING TRIPLET MATCHING TO SPOT IMAGERY

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ABSTRACT

One of serious problems of stereo matching based on image correlation is that it is impossible to verify whether a recognized conjugate point is correct or not. The past experiences showed that a point with maximum correlation is not always a correct conjugate point. In order to improve this weakness, authors proposed two kinds of triplet matching methods, in which the coordinate of ground point is given as that of a intersection of three stereo rays. These methods were applied to SPOT images with three sights, that is, right, center and left. The results of test cases using SPOT images showed matching accuracy and reliablity were improved by applying the triplet matching methods in comparison with a conventional stereo matching method based on image correlation though computing time increased by 52～92 percent.

INTRODUCTION

Though many stereo matching methods have been proposed, improvement of accuracy and reliability still remains one of serious problems. With conventional stereo matching method based on image correlation, it is impossible to verify how likely recognized conjugate points are correct.

One of the solutions is multi-point matching method [1], where conjugate points are determined to let weighted sum of image correlation and smoothness of terrain shape determined from neighboring conjugate points be optimal. In multi-point matching, the apriori information on smoothness of terrain shape is reflected on the weight value and used to verify the correctness of conjugate points.

Another approach is triplet matching. Position of ground point is determined from three stereo rays. In case of SPOT image with three sight, that is, right, center and left images, a conjugate point is likely correct, only if the point which is determined from a stereo pair of left and center images coincides with the point which is determined from another stereo pair of right and center images.

Authors already proposed triplet matching methods and showed it's validity with simulated linear array sensor data [2]. In this study, the result of applying triplet matching to SPOT images are shown.

TRIPLET MATCHING ALGORITHMS

The following two triplet matching algorithms based on image correlation were proposed and compared with a conventional stereo matching method.

(1) Independent Matching Method (Fig.1)

Two pairs of stereo rays, that is, ray No.1 and No.2, ray No.1 and No.3 are independently matched. Discrepancy between two computed heights, Z12 and Z23 is checked as shown in Figure 1. If height discrepancy $\triangle Z$ is less than a threshold value, the result of the triplet matching can be considered reliable. If the discrepancy exceeds the threshold, the matching is repeated until either the criteria is satisfied or iterration count exceeds a limit.

(2) Simultaneous Matching Method (Fig.2)

Three rays are simultaneously matched under the condition that three rays should be intersected at a point, as shown in Figure 2.

In both methods, shape of correlation windows is changed so as to cancell difference of parallax within each window using neighboring conjugate points as the matching procedure proceeds from 'coarse' to 'fine'. The appropriate size of windows and threshold value for height discrepancy were determined from several trials carried out in the test cases.

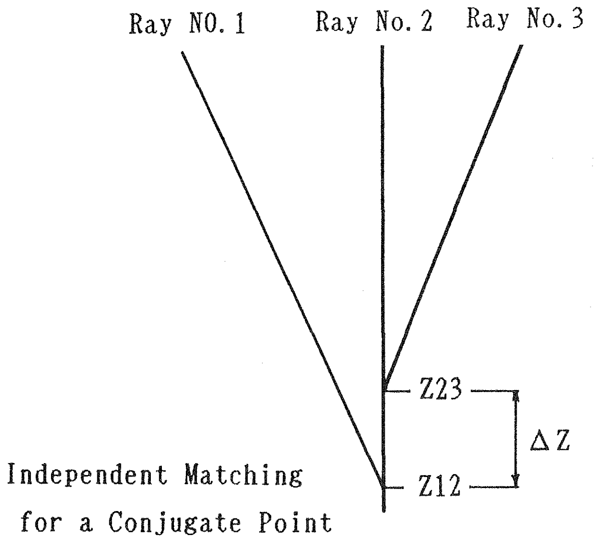


Figure 1 Concept of Triplet Matching
(Independent Matching)

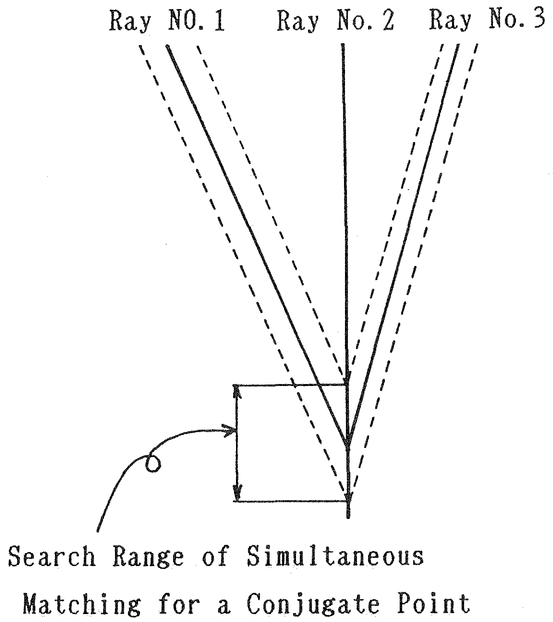


Figure 2 Concept of Triplet Matching
(Simultaneous Matching)

TEST AREA

Test cases for triplet matching were carried out using three SPOT images of a mountainous area around Mt. Fuji. Figure 3 shows location of test area. Figure 4 shows date and sensor angles of three SPOT images (left, center and right images). Photo 1, 2 and 3 are SPOT images of the test area.

TEST CASES

Height accuracy of digital terrain models obtained through stereo or triplet matching was used for evaluating matching accuracy. Cases shown in Table 1 were examined for comparison of height accuracy and computing time. The threshold value for checking height discrepancy in the independent matching method was 40 meters. Window size used in both stereo and triplet matching was 9 x 9 or 7 x 7, which was determined from several trials.

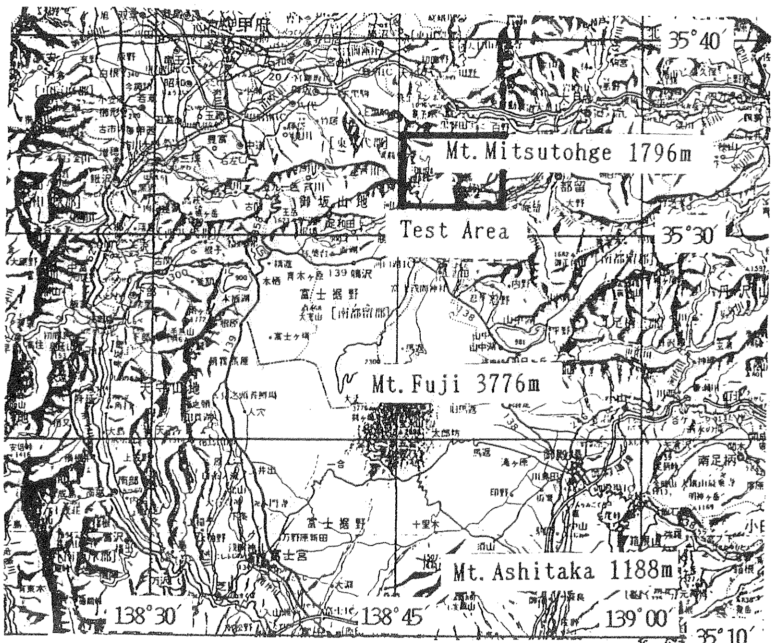


Figure 3 Location of Test Area

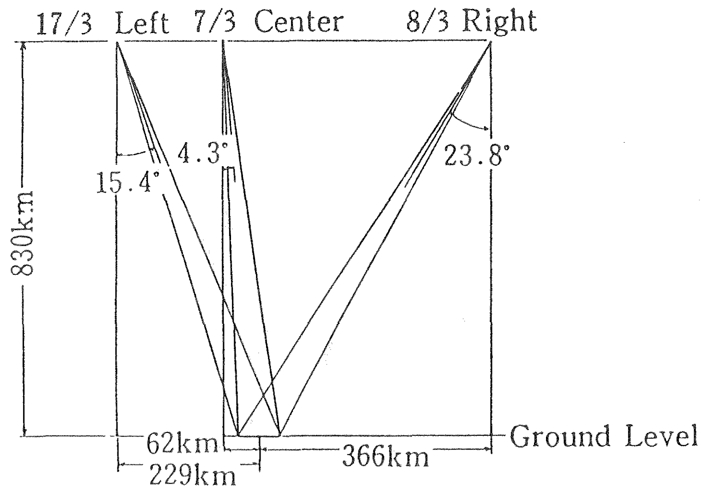


Figure 4 Dates and Sensor Angles of SPOT Images

RESULTS AND DISCUSSIONS

Height accuracy and computing time of each test case is shown in Table 2 and 3. Figure 5 show frequency of height errors between the actual digital terrain model and those obtained through stereo or triplet matching. There exist some biases of height error the sizes of which are almost the same in all cases. Because the biases were thought to be caused by orientation errors of three SPOT images used in test cases, standard deviation (STD) of errors would be more appropriate indicator for assessing matching accuracy.

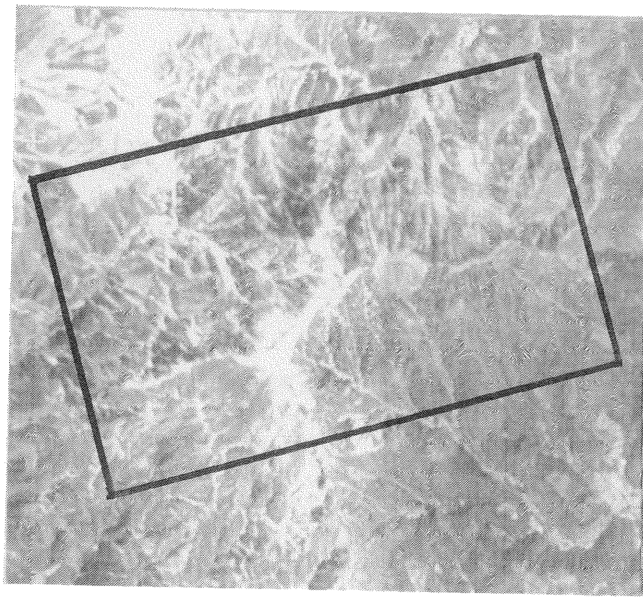


Photo 2 SPOT Left Image (17, Mar.)

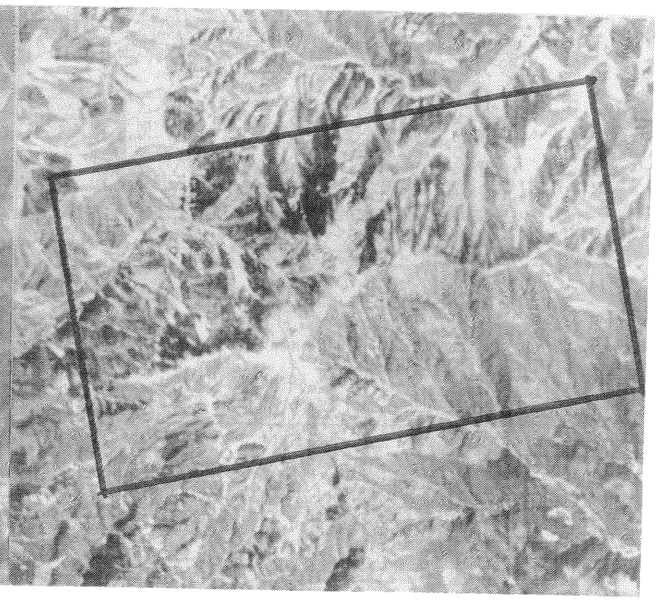


Photo 1 SPOT Center Image (7, Mar.)

B/H = 0.20

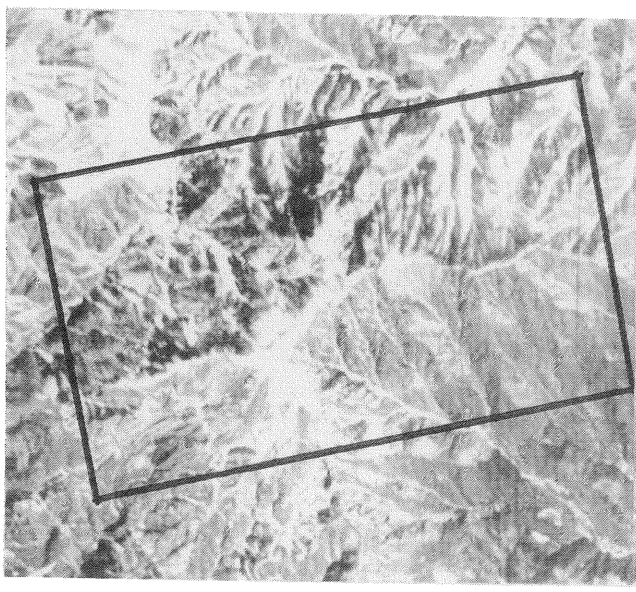


Photo 3 SPOT Right Image (8, Mar.)

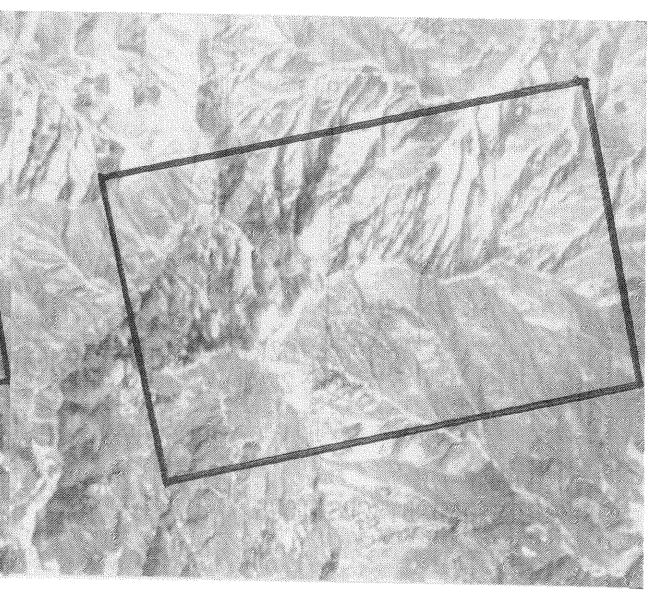


Photo 1 SPOT Center Image (7, Mar.)

B/H = 0.52

The best result of stereo matching (Case 1-2) come very close to the results of triplet matching. However, rest of the results of stereo matching are much inferior to those of triplet matching in terms of both STD error and maximum error (error range). It is clearly seen in Figure 5 that the triplet matching methods could reduce the number of gross errors. It could be concluded that the triplet matching methods showed better accuracy and reliablity than a conventional stereo matching method based on image correlation.

Computing time for triplet matching method increase by 52 percent～92 percent (respectively for the simultaneous matching method and the independent matching method). The independent matching method requires more time than the simultaneous matching method because the matching procedure is iterrated until either the threshold for height discrepancy is satisfied or iterration count exceeds a limit.

CONCLUSION

(1) The triplet matching methos showed better accuracy and reliability than a conventional stereo matching method based on image correlation, though they require more computing time by 52～92 percent. The triplet matching methods were effective especially in reducing gross errors.

(2) The simultaneous matching method was slightly more accurate and reliable than the independent matching method. As for computing time, the independent matching method requires more time.

REFERENCES

[1] Rosenholm, D., :Multi Point Matching Using the Least-Squares Technique for Evaluation of Three-Dimensional Models, Photogrammetric Engineering and Remote Sensing vol. 53, No. 6, June 1987, pp. 621-626

[2] Shibasaki, R., Murai, S. ;Stereo Matching for Stereo Mode CCD Linear Sensors, Com. III Symposium, Robaniemi, Aug., 1986.

Table 1 Test Cases

Case 1	Conventional Stereo Matching	
Case 1-1	B/H ratio = 0.20	(Center and Left)
Case 1-2	B/H ratio = 0.52	(Center and Right)
Case 1-3	B/H ratio = 0.72	(Right and Left)

Case 2	Triplet Matching
Case 2-1	Independent Matching
Case 2-2	Simultaneous Matching

Table 2 Height Accuracy

Case	Average Error	Error Range	RMSE	STDE
1 Stereo Matching				
1-1 B/H = 0.20	-23.9m	-141～ 53m	29.6m	17.6m
1-2 B/H = 0.52	-20.3m	-81～ 50m	24.3m	13.4m
1-3 B/H = 0.72	-23.0m	-182～142m	28.6m	17.1m
2 Triplet Matching				
2-1 Independent Matching	-21.5m	-75～ 32m	25.4m	13.7m
2-2 Simultaneous Matching	-21.3m	-68～ 35m	25.1m	13.4m

(STDE : Standard Deviation of Errors)

Table 3 Computing Time for determining a Conjugate Point

Case	Computing time	(Average Time)
1 Stereo Matching		
1-1 B/H = 0.20	49.6msec	89.7msec (100)
1-2 B/H = 0.52	94.9msec	
1-3 B/H = 0.72	124.6msec	
2 Triplet Matching		
2-1 Independent Matching	172.0msec	(192)
2-2 Simultaneous Matching	136.7msec	(152)

(Computer : HITAC M-680H)

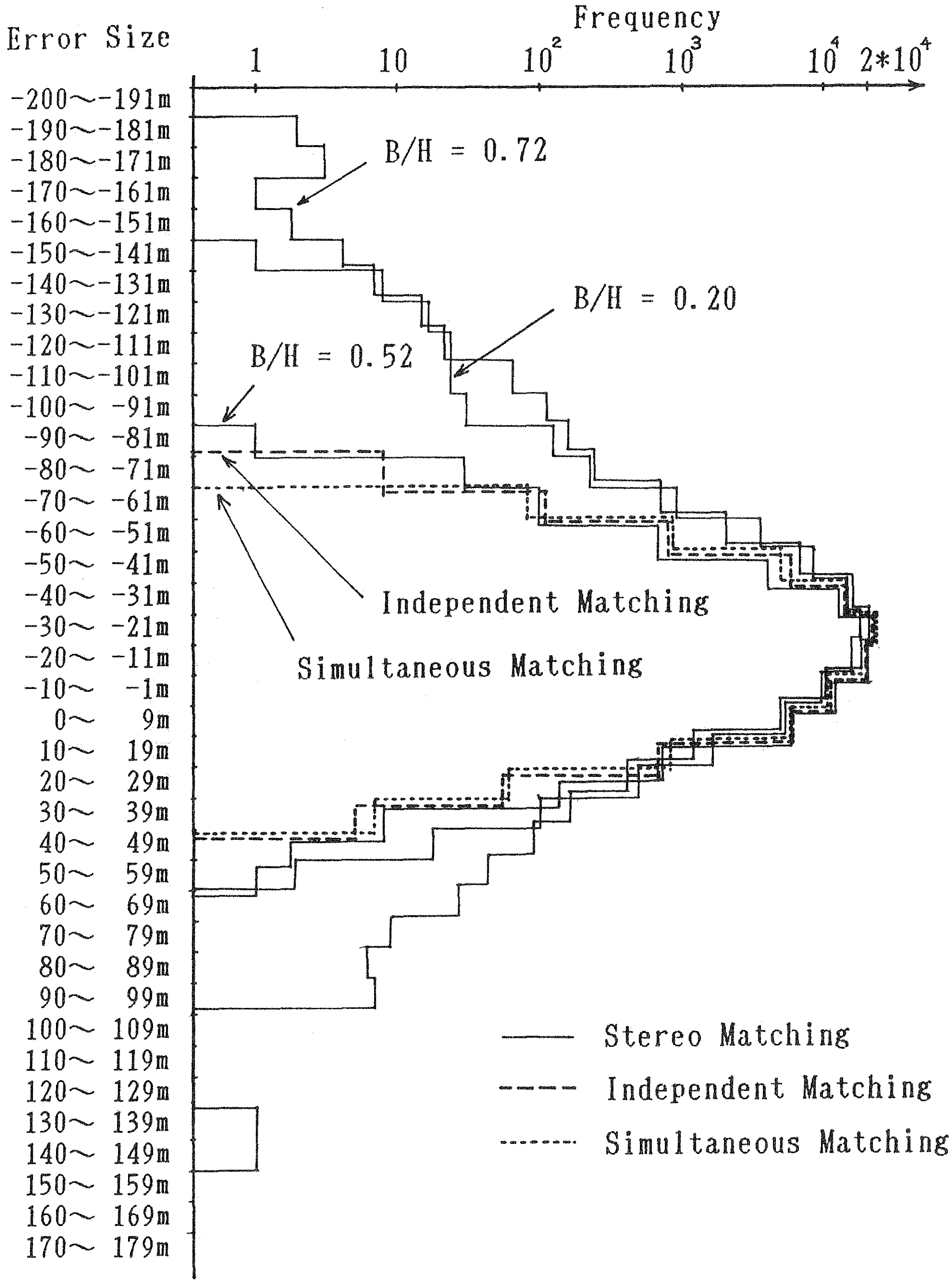
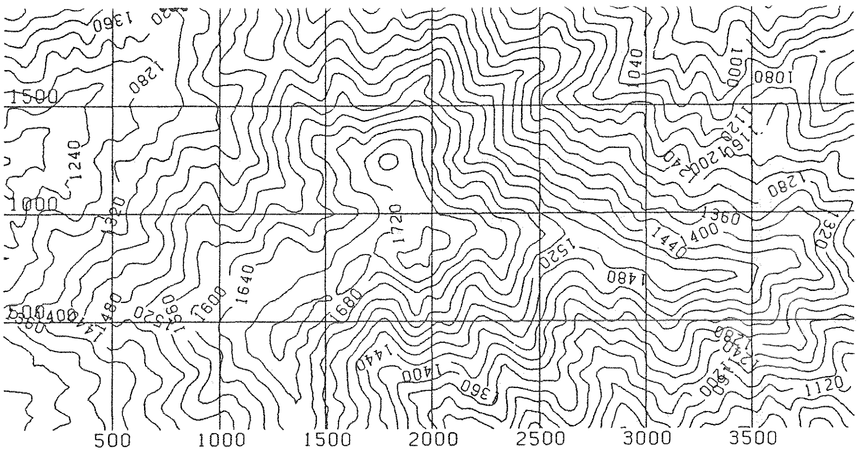
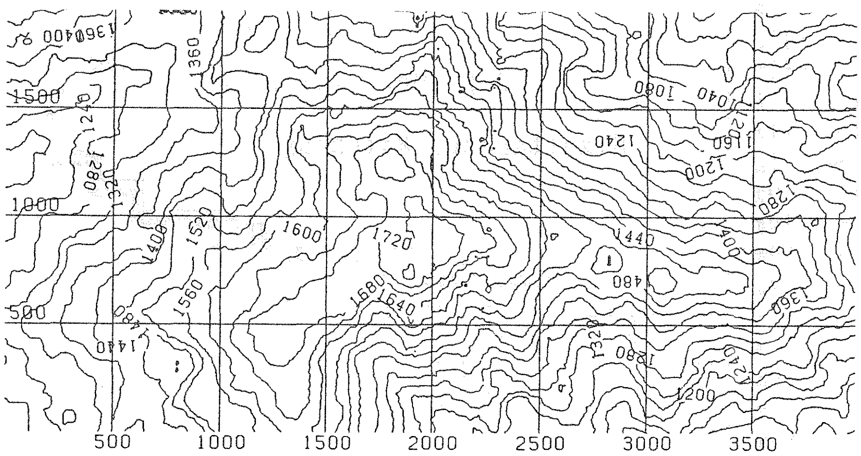


Figure 5 Frequency of Height Errors

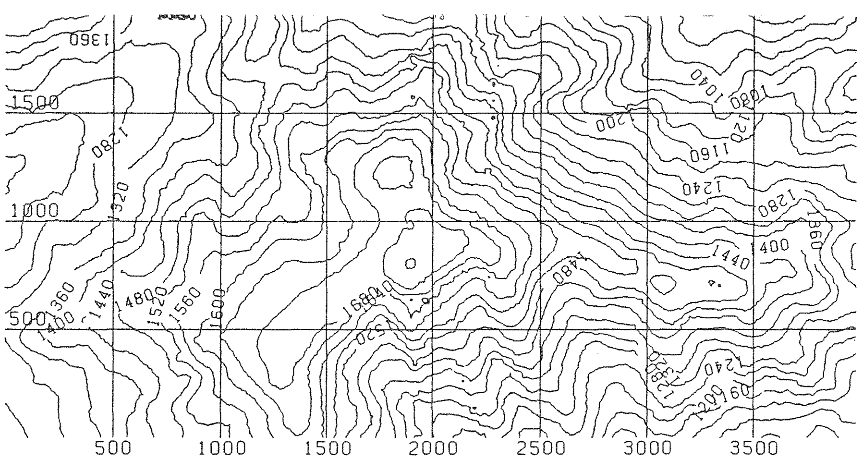


(Contour Interval; 40m)

Figure 6 Contour Image of Actual DTM



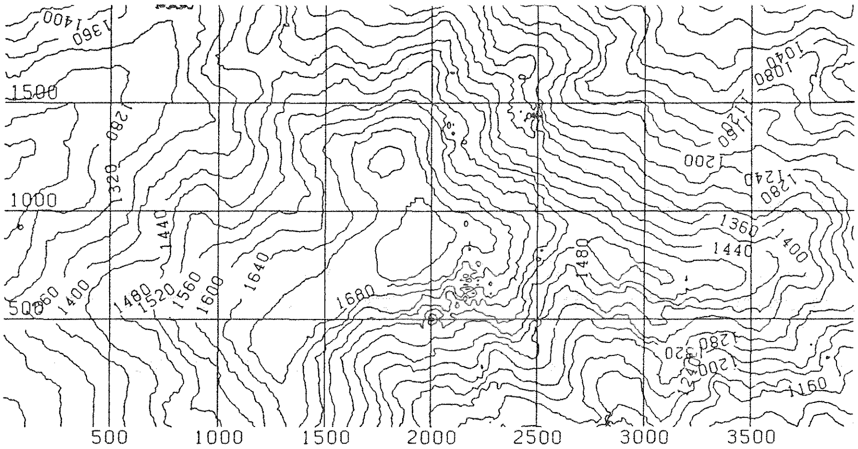
(1) Stereo Matching (B/H = 0.20)



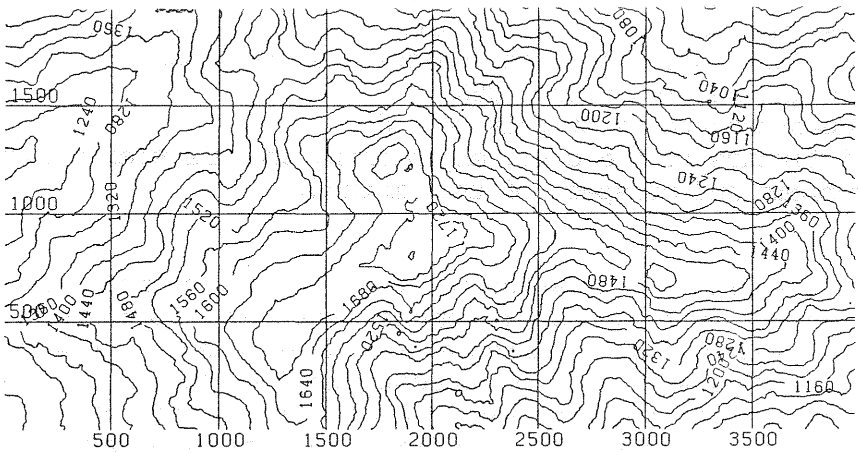
(2) Stereo Matching (B/H = 0.52)

Figure 7 Contour Image of Measured DTMs

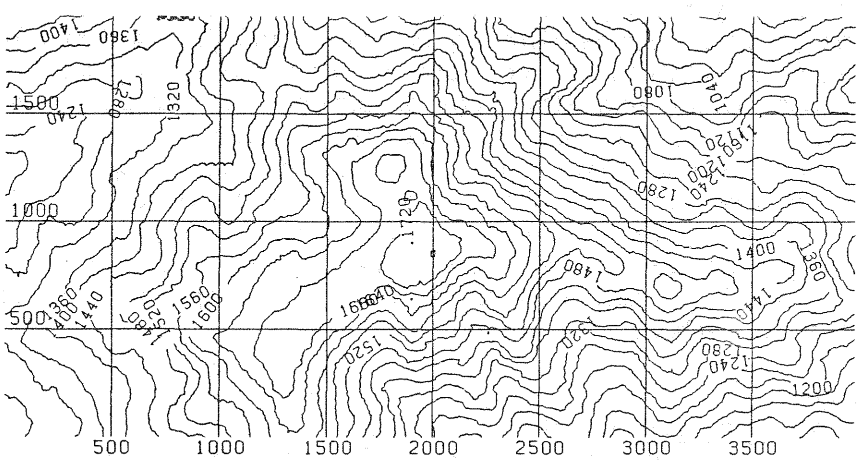
(Contour Interval; 40m)



(3) Stereo Matching (B/H = 0.72)



(4) Triplet Matching (Independent Matching)



(5) Triplet Matching (Simultaneous Matching)

Figure 7 Contour Image of Measured DTMs

(Contour Interval; 40m)