A STUDY OF REDUCING ABNORMAL EVELATIONS IN AUTOMATIC COMPUTATION OF ELEVATIONS FROM SATELLITE DATA

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ABSTRACT

Elevations of the earth surface can be estimated using a pair of stereo images obtaind from satellites. The elevations can be automatically computed by an automatic search of corresponding points between the stereo images. Mis-matches in search of the corresponding points causes abnormal elevations. In this study, causes of mis-matches were investigated in computing elevations using Landsat TM data. The variance of source window and the correlation coefficient at matched point were investigated by a discriminant analysis between the two groups of abnormal and normal elevation points. The discriminant analysis showed that the abnormal elevation points could be discriminated from normal elevation points by examining the variance of the source window area and the correlation coefficient at matched points with a pretty high probability of about 80%. A method of computing elevaitons for reducing abnormal elevaitons points using the following two ideas was proposed:
- Enlarge the size of source window if the variance of the source window is smaller than a threshold
- Assign a specified elevation if the correlation coefficient at matched points is smaller than a threshold and compute a proper elevation by an interpolation in post-processing

An elevation image generated using the above method from Landsat TM data shows the method is effective for redusing abnormal elevations.

1. INTRODUCTION

The elevations of the earth surface can be estimated using two data abserved from two different directions. The elevations of a side-lap area of Landsat scene can be computed because two Landsat scenes observed from two adjacent Paths

can be obtained in the side-lap area. SPOT has a off-nadir viewing capability which enables to compute elevations of the earth surface. Recently the elevations have been actively expressed in a three dimensional digital form (DTM:Digital Terrain Model). DTM is very useful for land development and satellite data are very beneficial for generation of DTM of a large area. Many studies have been done on automatic generation of DTM using aerial photographs and satellite data 1)-6). The most serious problem in the automatic generation of DTM is how to reduce abnormal elevations due to mis-matches in search of corresponting points between a pair of stereo images(stereocorrelation). Panton proposed to introduce reliability factor derived from correlation coefficient and patch standard deveation and soon 1). Simard and Welch changed the window sizes from large one to smaller one in a stereocorrelation 4),5). This paper investigated the characleristics of the variance of source window and the correlation coefficient at matached points of the abnormal elevation points by a discriminant analysis, and proposed a method of computing elevaitons for reducing abnormal elevation points from satellite data using the results of the discriminant analysis.

2. STUDY PROCEDURE

The anthors have generated a methd of automatic computation of elevations using system corrected satellite data 6). This study was carried out with elevations of test sites generated from Landsat TM and SPOT data using the above methed. Abnormal elevation points were apt to occur in city areas and shadow areas. It is considered that mis-matches occur due to lack of a distinguishable geographical feature in the city areas and due to low gray levels in the shadow areas. A study procedure for consideration of a method for reducing abnormal elevations as follows:
(1)Abnormal and normal elevations points were selected as test points so that No. of them may be nearly equal each other.
(2)Variances of source window and correlation coefficients at matched point of the test points were computed.
(3)No. of abnormal elevation points of the test points was investigated enlarging the size of source window.
(4)Characteristic of the variance of source window and the correlation coefficient between the abnormal and normal elevation points were investigated by a discriminat analysis.
(5)A method for reducing abnormal elevations points was considered and the availability of the method was examined using Landsat TM data.

3. SELECTION OF THE TEST POINTS

The test points were selected around the city areas where abnormal elevaitons were apt to occur. An assemblage of test points compose of 5 by 5 elevation and five assemblages of test points were elected. Totally 125 test points were selected for

Landsat TM and SPOT data respectively. 58 points were abnormal and 67 points were normal in TM case, and 50 points were abnormal and 75 points were normal in SPOT case. It was discriminated between the abnormal and the normal points according to their elevaitons. A Rough elevaitons around an assemblage of test points wes read from geographical maps and the elevations distant more than 200m from the above elevation read from the maps were considered as abnormal and the other elevations as normal. Elevations around an assemblage of the test points TM2 in TM case are shown in Fig. 1 and 13 points enclosed with a thick line were considered as abnormal because 700m was obtained from a geographical map as an elevaiton around TM2. Stereo images around TM2 and magnified stereo images of an abnormal and a normal elevation points are shown in Fig. 2, and source and search window at stereocorrelation are also shown in Fig. 2. It can be seen from Fig. 2 that only city area is included in the source window at abnormal case but a part of forest is included at normal case. It suggests that the possibility of abnormal elevaitons will be predicted by examing the variance of source widnow.

4. INVESTIGATION OF THE CHARACTERISTICS OF IMAGES AT STEREOCORRELATION

The characteristics of variance of source window and correlation coefficient at matched points were investigated by a discriminant analysis using the test points. The discriminant analysis is a classification technique of unclassified data using sample data already classified into two or more groups 7). The variance of source window and the correlation coefficient at mathched points of 125 test points were examined in search of corresponding points between the stereo images of Landsat TM and SPOT data respectively. The size of source window was 15 by 5 pixels (about 400m by 140m) in TM case and 15 by 15 pixels (about 300m by 300m) in SPOT case, and band5 of TM and band3 of SPOT multispector mode were used for stereocorrelation. The variances and the correlation coefficients of the test points were classified into two groups of abnormal and normal elevaitons and those data were supplied to a discriminant analysis in which a linear discriminant funciton is used. The results of the discriminant analysis are shown in Table 1. Table 1 (a) shows that, concerning the variance of source window in TM case, 51 points of 58 abnormal points were classified into the abnormal group (87.9%) and 39 points of 67 normal points were classified into the normal group (58.2%). Following matters can be inferred from Table 1.
(1) Concerning the varinace of source window, the classificaiton accuracy of abnormal points is pretty high, but the that of normal points is not so high, especially low in SPOT case (36%). It says following things.
(i) The possibity of abnormal elevaiton can be predicted with a pretty high probability (87.9% in TM case) by examining the variance of source window.
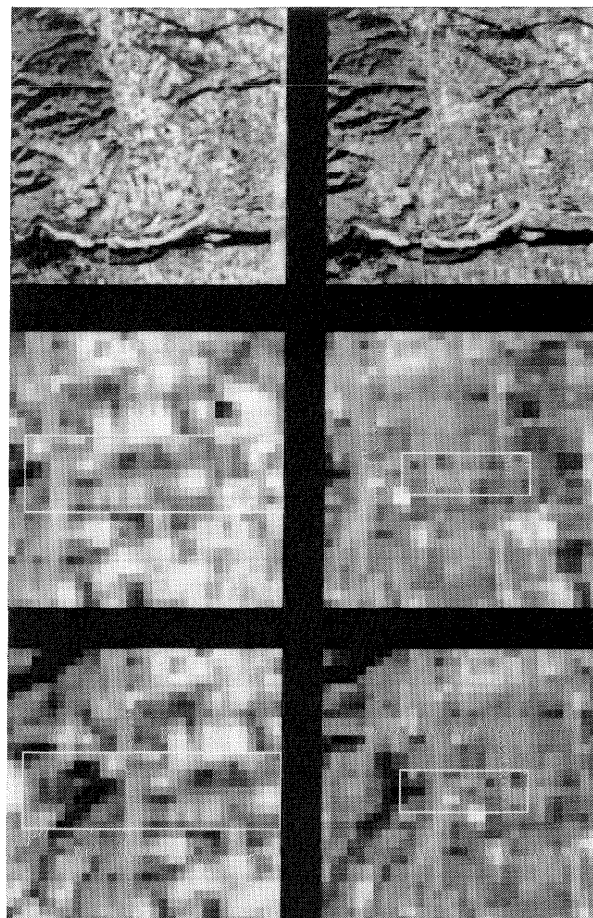(ii) Although the variance of source window predicts the possibility of normal elevaiton, abnormal elevaiton may

674	673	672	671	669
798	3376	3885	3637	918
674	673	3515	423	422
798	3640	3638	919	4251
798	717	796	3390	4128

Normal elevation 500m～900m

Fig.1 Elevations (m) around an assemblage of the test points TM2 in TM case, 13 points enclosed with a thick line are abnormal elevation points.

occur with a certain level of probability. The valaues of the variance of source window of abnormal points are lower than those of normal points.

(2) Concerning the correlation coefficients at matched points, the classification accuracies of both abnormal and normal points are pretty high. It shows that if abnormal or normal elevaitons is obtained can be predicted with a high

Upper:Stereo image around TM2
　　(128 X 128 pixels)
Middle:Magnified stereo images of
　　an abnormal elevation point
　　(32 X 32 pixels)
Lower:Magnified stereo images of
　　a normal elevation point
　　(32 X32 pixels)
Right rectangle:Source window
　　(15 X 15 pixels)
Left rectangle:A part of search
　　window (52 X 9 pixels)

Fig.2 Stereo images around an assemblage of the test points TM2 and magnified stereo images of an abnormal and a normal elevation points

Table 1. Results of the discriminant analysis of the variance of source window and the correlation coefficient at matched point for TM (a) and SPOT case (b)

(a)TM case

Item	Group	No. of Points	Class. Matrix		Class. Accuracy(%)	Mean Value
			Abnor.	Nor.		
Variance	Abnormal	5 8	5 1	7	8 7 . 9	5 7 . 4
	Normal	6 7	2 8	3 9	5 8 . 2	1 0 6 . 3
Corr.	Abnormal	5 8	5 2	6	8 9 . 7	0 . 4 7 2
Coeff.	Normal	6 7	1 8	4 9	7 3 . 1	0 . 7 2 7

No. of test points : 125

(b)SPOT case

Item	Group	No. of Points	Class. Matrix		Class. Accuracy(%)	Mean Value
			Abnor.	Nor.		
Variance	Abnormal	5 0	3 4	1 6	6 8 . 0	1 9 . 6
	Normal	7 5	4 8	2 7	3 6 . 0	2 1 . 5
Corr.	Abnormal	5 0	3 9	1 1	7 8 . 0	0 . 4 4 8
Coeff.	Normal	7 5	1 9	5 6	7 4 . 7	0 . 6 0 1

No. of test points : 125

probability by examining the correlation coefficient at matched points. The values of the correlation coefficnets of abnormal points are lower than those of normal points.

(3) The classificaiton accuracy of abnormal points are higher than those of normal points in both the variance and the correlation coefficient.

(4) The classificaiton accuracies in TM case are highter than those in SPOT case. Concerning the mean values of the variance of source window, there is a large difference between abnormal (106.3) and normal (57.4) points in TM case, but a little difference (19.6 and 21.5) in SPOT case, This is because dynamic range of TM data is larger than that of SPOT data resulting from the difference of IFOV between TM and SPOT HRV.

Table 2. No. of abnormal elevation points of the test points when the size of source window was enlarged in Landsat TM and SPOT case

Window Size Case	Landsat TM		SPOT	
	Pixels X Lines	No. of Abnor. Elev. Points	Pixels X Lines	No. of Abnor. Elev. Points
Basic Size	15×5	58	15×15	50
Size 1	23×5	44	23×15	33
Size 2	31×5	37	31×15	19

No. of test points : 125 each for TM and SPOT case

5. INVESTIGATION OF EFFECTIVENESS OF ENLARGING WINDOW SIZE

It is considered that enlarging the size of source window will increase success rate of stereocorrelation because some disting wishable geographical features may be included by enlarging the size of source widnow. No. of abnormal elevation points of the test opints were investigated, enlarging the size of source window as shown in Table 2. Size 1 and 2 are respectively the sizes 1.5 and 2 times larger than the basic size in horizontal direction. The size of search window was changed so that actural search area in stereocorrelation may be same in all cases. No. of abnormal elevation points of the test opints when the size of source window was enalarged is also shown in Table 2. Table 2 shows that no. of abnormal elevation points decreases as the size of source window is enlarged.

6. ELEVATION COMPUTATION METHOD USING VARIANTION AND CORRELATION COEFFICIENT

A method of computing elevaiotn for reducing abnormal elevaitons by examining the variance of source window and the correlation coefficient at matched points can be formed as shown in Fig. 3. The main points of the method are to enlarge the size of source window if the variance of source window is smaller than a threshold (VTH) and to assign a special elevaiton if the correlation coefficient at matched points is smaller than a threshold (RTH). A post-processing is necessary in order to elliminate abnormal elevations and the special elevations assigned, because abnormal elevations still exist even if the variance and the correlation coefficient are not smaller than the respective thresholds. The post-processing is composed of following 2 steps:
(1) If the elevations of a point is distant more than a threshold from a mean elevaiton of its adjacent 8 point,

except the special elevaitons assigned at low correlation coefficienta case, the elevations of the point is considered as abnormal and substituted with the same special elevation.

(2) The special elevaiotns are substituded with a mean elevaion of its adjacent 8 points except the special elevations.

The images of elevations computed utilizing the discrimations of the variance and the correlation coefficient from Landsat TM data is shown in Fig. 4. VTH and RTH were set to 85.0 and 0.5 respectively which were decided from the mean values of abnormal and normal group (see table 1 (a)). Size 2 of the source window of the table 2 was used as a larger window size.

Following three cases were shown in Fig. 4 in order to see the effectiveness of the method utilizing the discrimination of the variance and the correlation coefficient.
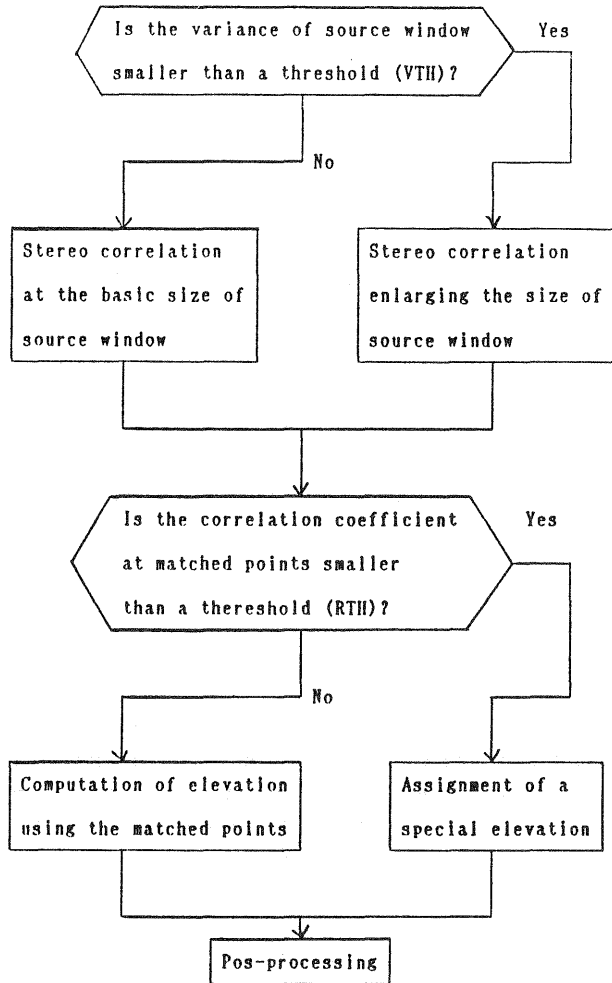

Fig. 3 A method of computing elevations for reducing abnormal elevations

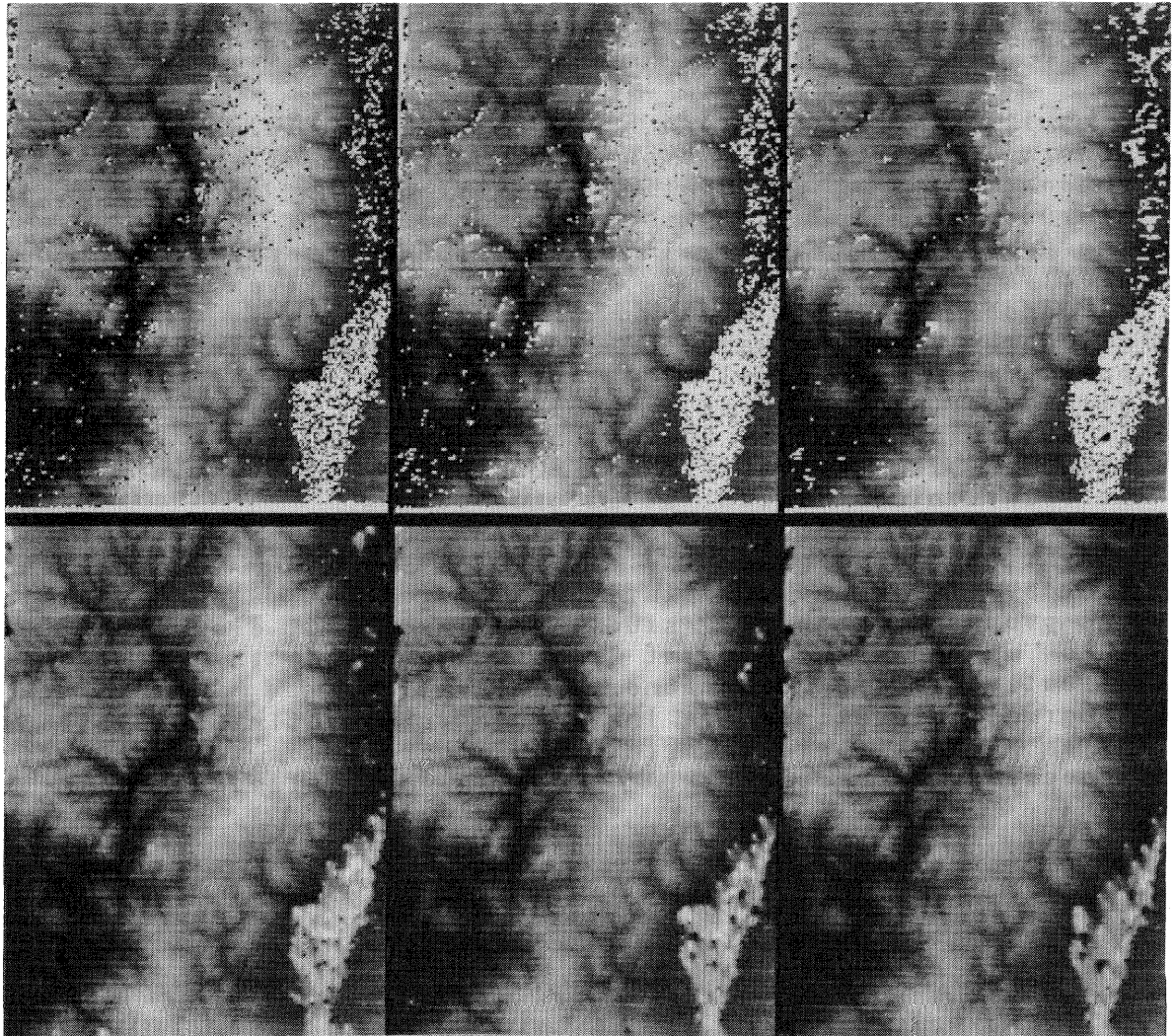Case 1: No discrimination by the variance and the corrlation caefficient
Case 2: Only discrimination by the correlation coefficient
Case 3: Discrimination by both the variance and the correlation coefficient

The upper images of Fig. 4 are original images of elevations computed and the lower images are the post-processed images. White points in Fig. 4 generally shows abnormal elevation points. Following things can be read from Fig. 4.

(1) The discrimations by the variance and the correlation coefficient are effective for reducing abnorval elevations because white points in the right side of the images can not be seen in case 3, which can be seen in case 1.

(2) The discrimination by the correlation coefficient are also effective for reducing abnormal elevations, because the white points in the right side of the images reduces in case 2 compared with case 1.

Case 1   Case 2   Case 3

Fig. 4   The images of elevations computed utilizing the discrimination
of the variance and the correlation coefficient, Upper:Original
images of elevaitons computed, Lower:Post-processed images

There are still abnormal elevations in the original elevations computed in case 3 , therefore the post-processing are necessary for reducing abnormal elevations.

7. CONCLUSION

The results of the study can be summerized as fillows:
(1) Abnormal elevations were apt to occur in city areas and shadow areas in computing elevations by an automatic stereocorrelation using satellite data.
(2) The possibity of abnormal elevations can be predicted with a pretty high probability of about 80% by examining the variance of source window.
(3) Although the varinace of source window predicts the possibility of normal elevation, abnormal elevations occur with a certain level of probability.
(4) If abnormal or normal elevation is obtained can be predicted with a high probability of about 80% by examining the correlation coefficient at matched points.
(5) A method of computing elevations for reducing abnormal elevations utilizing the discrimination the variance of source window and correlatin coefficient at matched points was proposed in this study, and the output elevaitons by this method using Landsat TM data shows that the method is effective for reducing abnormal elevations.
(6) Abnormal elevations are inevitable in computing elevations by an automatic stereocorrelation, therefore a proper post-processing is necessary for reducing abnormal elevations.

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