Optimum forward looking angle for stereoscopic view taking into account steep of the terrain based on auto-regressive model

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Abstract

A simulation study has been conducted to determine an optimum forward looking angle for stereoscopic view from space. It is obvious that height estimation accuracy depends on B/H ratio. Image defects such as geometric distortion, invisible areas(Occlusion), however, increases with B/H ratio so that an optimum angle must exist for maximize height estimation accuracy. In this study auto-regressive model is assumed to represent a steep of the terrain.

1.Introduction

In estimation of Digital Terrain Model(DEM) with stereo pair of satellite images obtained with two optics, forward and nadir, theoretical limit of DEM estimation accuracy depends on Base/Height Ratio(B/H). It depends on not only B/H but also satellite position knowledge, attitude knowledge, satellite clock accuracy, stereo matching error, steepness of the terrain of interest, atmospheric effect, and so on. On the other hand, well known occlusion effect that one of the stereo pair images the terrain of interest while the other does not images the terrain, should be taken into account. Image defects such as geometric distortion, invisible areas(Occlusion), in general, increases with B/H ratio so that an optimum angle must exist for maximize height estimation accuracy.

In this paper, an optimum B/H ratio will be introduced taking into account the aforementioned occlusion effect. In this stage, it is assumed that the aforementioned other error sources are the same except occlusion effect. In order to clarify the effect, 0th order Markov chain is introduced to represent the steepness of the terrain(DEM) with the parameters of mean and variance of the terrain of interest.

2. Occlusion effect

2.1 DEM estimation for the occluded areas

Theoretical DEM accuracy, dZ is expressed the following equation.

$$dZ = \frac{H}{B} \cdot \frac{H}{f} \cdot dP \qquad (1)$$

where B, H, f and dP are base line length, satellite altitude, focal length and spatial resolution on image plane, respectively. If f and dP are known, then dZ depends on B/H ratio so that dZ is improved with increasing the angle between two optics, forward and nadir. Meanwhile occluded area is increased in accordance with the angle results in existence of an optimum angle or B/H ratio to achieve the maximum DEM estimation accuracy.

As is shown in Fig.1, an illustrative explanation of occlusion, the points B, C, D and E are occluded for forward viewing thus the heights for the occluded areas are misjudged as the height for the point A then the errors i, j, k and l are made. The error due to occlusion is evaluated with Root Mean Square(RMS).

2.2 Simulation data generation

Occlusion effect depends on not only B/H ratio but also steepness of the terrain of interest. In order to represent the steepness, two dimensional 0th order Markov chain with two parameters, mean and variance is introduced. From the Digital Terrain Model of the area around Unzen Shimabara, one of the active volcano in Japan, steep and calm areas are extracted as image chips consisted 64 x 64 pixels. The original DEM data is shown in Fig.2. Mean and variance of the steep and calm areas are shown in Table 1.

Based on two dimensional Markov random field with the parameters shown in Table 1, simulated DEM are generated with Normally distributed random number. The simulated DEMs for steep and calm areas are shown in Fig.3 (a) and (b), respectively.

2.3 DEM estimation error due to occlusion

DEM estimation error due to occlusion was evaluated with the simulated DEM. The RMS errors for steep

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and calm DEMs are shown in Fig.4 together with theoretical DEM accuracy expressed by equation (1). In the figure, 47.66 degree implies that all the points included in the simulated DEM are occluded corresponding to the tangent line from the satellite position, H = 800 Km to the earth's surface(radius of the earth is assumed 6378Km). Cross points between theoretical DEM accuracy and DEM estimation error due to occlusion show optimum angle between viewing vectors shown in Table 2.

3. Concluding remarks

The proposed method for determination of optimum B/H ratio which maximize DEM estimation accuracy with consideration on occlusion effect is applicable to the stereoscopic sensors which have two optics for instance nadir and backward. Also the representation of steepness of the terrain of interest is useful for other application to ground surface analysis.

Next step is to take into account atmospheric influence, geometry among sun, terrain and satellite, for determination of more realistic optimum B/H ratio.

Table 1 Mean and Variance of the steep and calm areas consists of 64 x 64 pixels

	Steep area	Calm area
Mean	150.63	22.97
Variance	275.89	58.83

Table 2 Optimum angle and corresponding B/H ratio by taking into account occlusion effect.

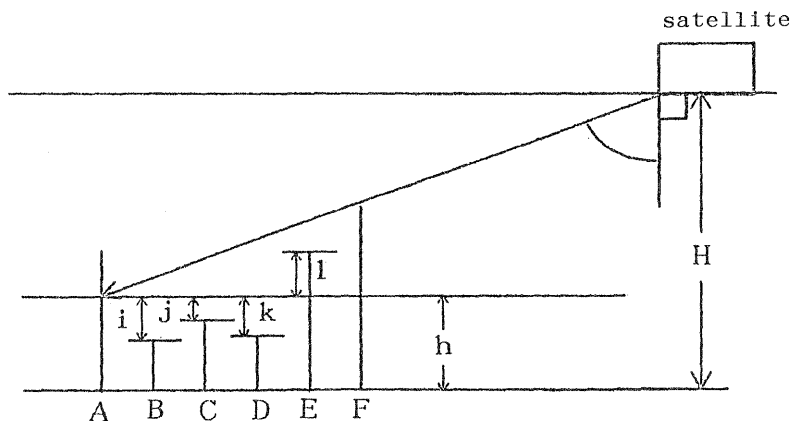|	Optimum angle	Optimum B/H ratio
Steep DEM	40.78	6.85
Calm DEM	45.54	6.19

Fig.1 An illustrative explanation of occlusion, the points B, C, D and E are occluded for forward viewing thus the heights for the occluded areas are misjudged as the height for the point A then the errors i, j, k and l are made.
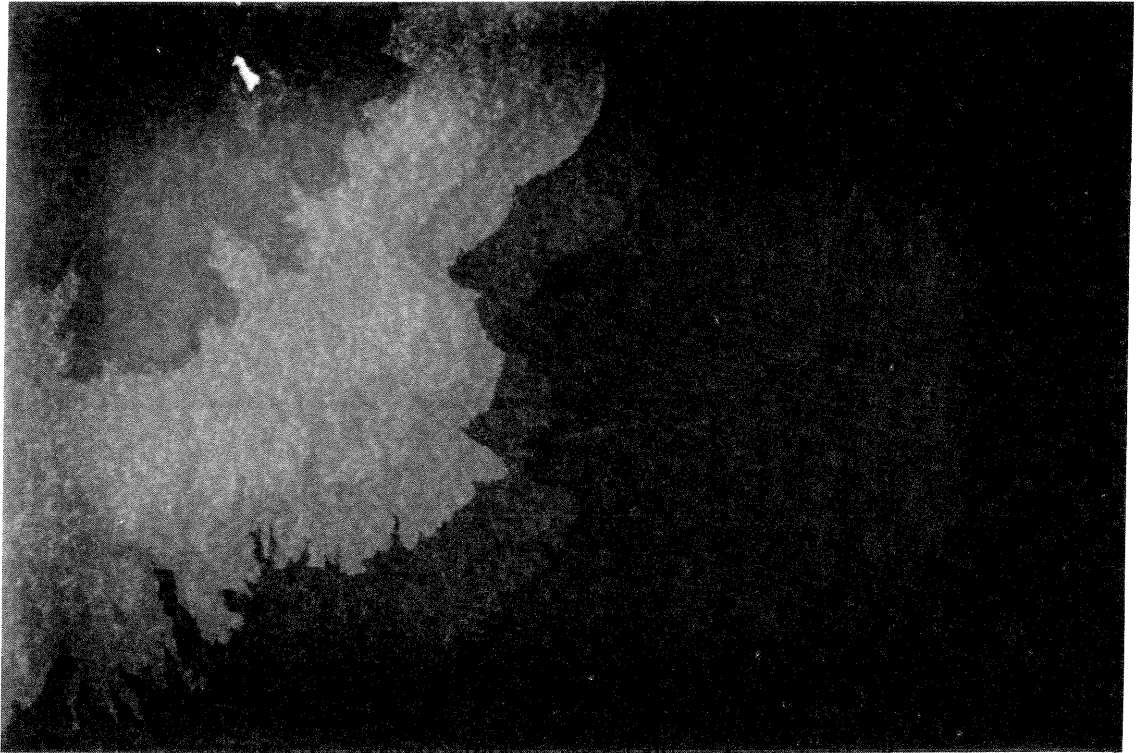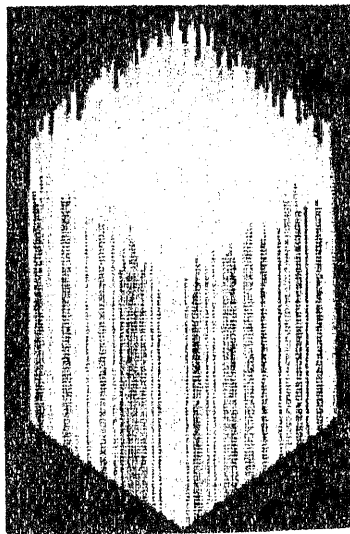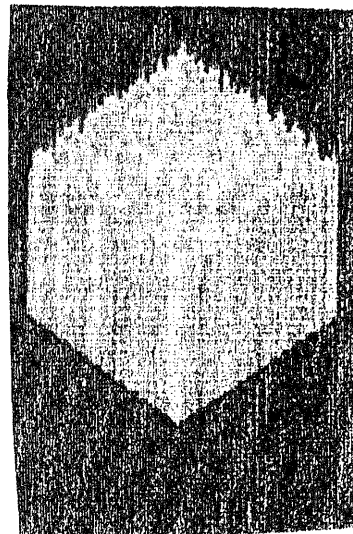
Fig.2 The Digital Terrain Model of the
area around Unzen Shimabara, one of the
active volcano in Japan, steep and calm
areas are extracted as image chips
consisted 64 x 64 pixels.

(a)The simulated DEM for steep area

(b)The simulated DEM for calm area

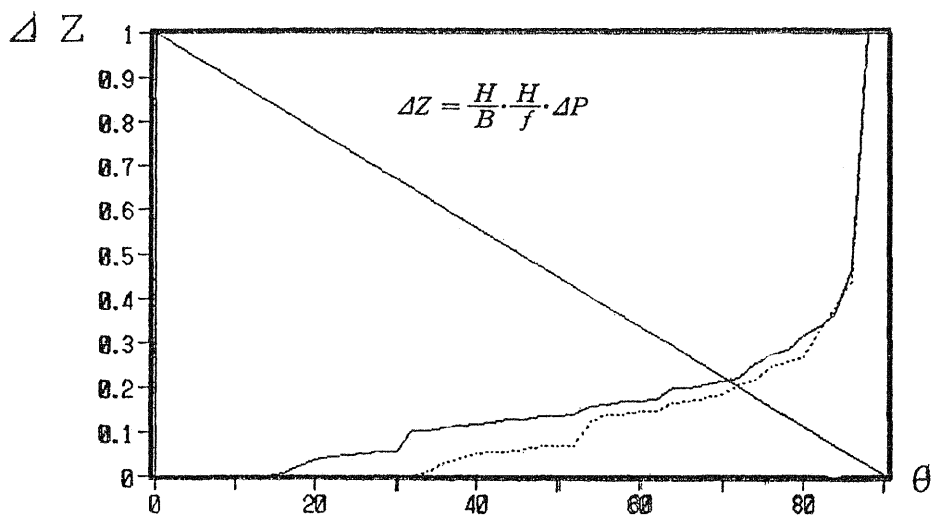Fig.3 The simulated DEMs for steep and
calm areas

Fig.4 DEM estimation error due to occlusion, evaluated with the simulated steep and calm DEM together with theoretical DEM accuracy.

    In the figure, 47.66 degree implies that all the points included in the simulated DEM are occluded corresponding to the tangent line from the satellite position, H = 800 Km to the earth's surface(radius of the earth is assumed 6378Km). Cross points between theoretical DEM accuracy and DEM estimation error due to occlusion show optimum angle between viewing vectors shown in Table 2.