Using Horizon2000 algorithm to interpolation for data holes of SRTM-3

Yousuke Noumi

Department of Geosphere-Biosphere System Science, Faculty of Informatics,
Okayama University of Science. 1-1 Ridai-cho, Okayama 700-0005, Japan
Email: y_noumi@big.ous.ac.jp

ABSTRACT

As a method to fill the elevation data hole of SRTM-3, an application of the Horizon2000 algorithm was examined. As a result, it was confirmed that the reproduced topographic image had natural one. Furthermore, two kinds of differential calculus filters were applied to this result, and it was made clear that the topography did not lose smoothly. Therefore, the Horizon2000 algorithm is one of useful method to fill the data hole of SRTM-3. By this method, SRTM-3 would become a more practical tool for natural environments analysis or development.

1. INTRODUCTION

SRTM (Shuttle Radar Topography Mission) was carried out in a mission to get elevation data of the land surface area between latitude 56° S from 60° N by the space shuttle STS-99 in February, 2000. The elevation data by interference SAR were edited as DEM (Digital Elevation Model) with a post space of one arc second about U.S.A. and some areas, and it called SRTM-1. In the other areas, SRTM-3 was produced for three arc seconds mesh (often quote about 90 meters) by NASA (Eric Ramirez, 2006).

SRTM-3 is the only DEM which covered all land area. Thus the SRTM-3 is useful for natural environments analysis and development project for the area that cannot prepare for DEM easily. However, there is a serious problem in the practical use that there is elevation data hole of SRTM-3 by the dispersion of the radar wave. Reuter et al. (2007) applied eight kinds of interpolation methods such as Kriging, Sprine or IDW (Inverse Distance Weighting) method as a method for interpolation to fill the data hole to cope with this problem and discussed those results. Iikura (2007) suggested a method to fill with the elevation data around the data hole, and there is some software that adopted this method (example of 3DEM - Visualization Software - and others). However, the Horizon2000 (Shiono et al., 2001) algorithm that used an optimization principle has not ever been applied. In this paper, the Horizon2000 algorithm is applied for interpolation method of the data hole of SRTM-3, and is discussed about its result.

2. METHODOLOGY

An area with the 51x51 grid including a data holes part is extracted from an original data file of SRTM-3. The Horizon2000 algorithm and the two kinds of moving window average method with 3x3 pixel window are applied for the extracted elevation data, and each interpolation results are compared. And the first and the secondary differential calculus filter analysis with 3x3 pixel window are examined to check applicability of the topography analysis of the elevation data which filling to data holes completed, and those results are compared.

2.1 Study Area

This study area is a mountains area in north part of Shikoku Island, southwest Japan. This area is an area of the size of a 51x51 grid extracted from downloaded file "N33E133.hgt" of SRTM-3. The center of the extracted area is latitude 33° 47' 40” N and longitude 133° 26' 46” E of WGS 84, and there is the summit of Mt. Mitakiyama (1110m) near the center point. Fig. 1 shows the site of the study area and a contour map by SRTM-3 raw data. This area includes seven elevation data holes where form and size are different.

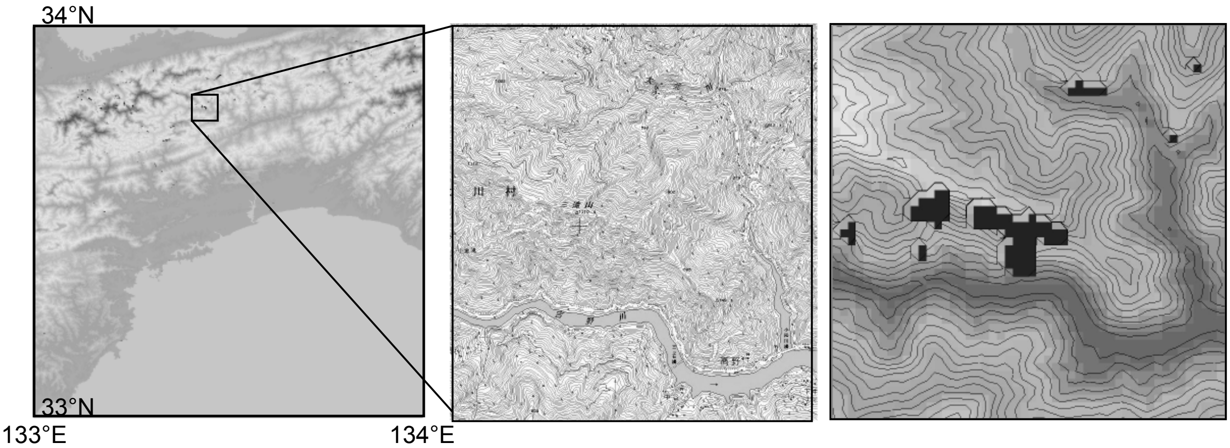

Figure 1. Location map of the Study area, its topography map, and distribution map of the data holes of SRTM-3 at study area

2.1 Horizon2000

Horizon2000 is a one of gridding algorithm which designed to determine the optimal geologic surface, and that is proposed by Shiono et al. (2001). This algorithm is used of equality, inequality height information and slope information as constraints of surface, and the smoothest surface is chosen in surfaces satisfying these constraints conditions on an exterior penalty function method. Furthermore, FORTRAN 77 programs to realize this algorithm were developed by Shiono et al. (2001). This program is translated into Visual Basic version by Sakamoto et al. (2001) and can use it in Terramod2001, which is topographic visualization software, to work on Windows.

In this study, the elevation data of SRTM-3 are used as equality height information, and it becomes constraints conditions for estimation of the topographic surface on the data holes. As for topographic surface $\boldsymbol{f}$ estimated on data holes part, the smoothest one is chosen under the parameter as an exterior penalty in surfaces satisfying constraints conditions. The objective function to evaluate smoothness of estimated surface assumes $J(\boldsymbol{f})$, and the constraint condition which is the function to evaluate goodness of fit assumes $R(\boldsymbol{f})$. When it makes augmented objective function $Q(\boldsymbol{f},\alpha)=J(\boldsymbol{f})+\alpha \cdot R(\boldsymbol{f})$ which connected linearly these functions with parameter α, $\boldsymbol{f}$ which is minimizing Q under α is the suitable solution. The elevation value of a part equivalent of $\boldsymbol{f}$ is assigned to the data hole. By this method, elevation data of the whole area which extracted from SRTM-3 are used for interpolation, and estimated surface of the whole area is calculated. On this account the interpolation is finished at one time even if there are some data holes and even if the data hole are any kind of size or form in a calculation area.

2.2 Moving Window Average

Reuter et al, (2007) examined the data hole of SRTM using eight kinds of interpolation such techniques as IDW (Inverse Distance Weighting) and MA (Moving Window Average) or Kriging method and compared those results. These methods were well known as interpolation method to void data. In this study, it is picked MA method from these interpolations, and a filling result by this method is compared with a result by Horizon2000. The MA method is taken up as an example of filling method to the data holes to the textbook of the remote sensing (Iikura, 2007), and this algorithm have ever been implemented in existing SRTM visualization software (e.g. 3dem by Eric Home and ESRI Japan, 2005).

The MA method is a method to fill a data hole by the average of elevation data of 4 or 8 around a data hole. When this method fills the data hole and improves a visual effect to show on a monitor the topography, it brings good results for SRTM-3's user.

In this study, two methods to insert for an average value of elevation of 4 and 8 data points neighboring the data hole is examined. But when there are points that data hole is united more than two, there are not 4 or 8 elevation data in the window. In this case, an average value of more than 2 elevation data in the window is inserted to the data hole. If there are not more than 2 elevation data around the data hole, the interpolation is not calculated. The same operation is performed after the scanning end of all height data points again. This operation is repeated till all data hole is filled.

2.3 Differential Calculus Window Analysis

To confirm the topographic surface of the data holes filling sites, differential calculus window analysis is examined. The differential calculus window analysis, which is slope angle and Laplacian, are calculated by height data of objective pixel and eight height data around it.

The Sobel operator is used for slope angle calculation. Figure 2 shows the distribution of the objective pixel and the neighboring height data of it. The difference of the north and south direction Δx and the difference of the west and the east Δy are given by the following expressions.

$$\Delta x = ((C+2F+I)-(A+2D+G)) / 8dx \quad (1)$$

$$\Delta y = ((A+2B+C)-(G+2H+I)) / 8dy \quad (2)$$

A	*B*	*C*
D	*E*	*F*
G	*H*	*I*

Figure 2. Data position of moving window. E is the analysis object pixel

Where dx is the distance between the pixel next to each other of the east and west direction and dy is the distance between the pixel of south and north direction. Here, dx and dy is each 90m in this study. Then the slope angle θ of the pixel of the window center is given in the next expression.

$$\theta = \sqrt{\Delta x^2 + \Delta y^2} \quad (3)$$

The Laplacian is an indicator showing the convexity degree of the topography of the neighborhood of the objective pixel. A radius of curvature is small so that this absolute value is big. It is shown that such a place has sudden topography change. Laplacian L is given in the following expressions.

$$L = (B+D+F+H) - 4 \cdot E \quad (4)$$

3. RESULTS AND DISCUSSIONS

3.1 Application Results of Horizon2000 and MA method

Figure 3 shows the results that an interpolation to the data hole of figure 1 with Horizon2000 and MW method. In Horizon2000, 100 was used for exterior penalty α, and it was calculated. From the form of these contour lines, a clear difference is not shown for the result of the interpolation to the data hole with one pixel. But the results of the data hole gathering part, especially the center area of figure 1, are different clearly. The result of Horizon2000 has good continuity of topography between data hole filling site and around there. In addition, the smooth surface is calculated there. On the other hand, for filling to all data holes by MA method, the four neighborhood average method did four times and the eight neighborhood average method did two times of repetition calculations. The result shows that there is flatness area in the part which is near the valley and the ridge. Because it was interpolated to the data hole with connect these flat areas, an unnatural steeply cliff appeared.

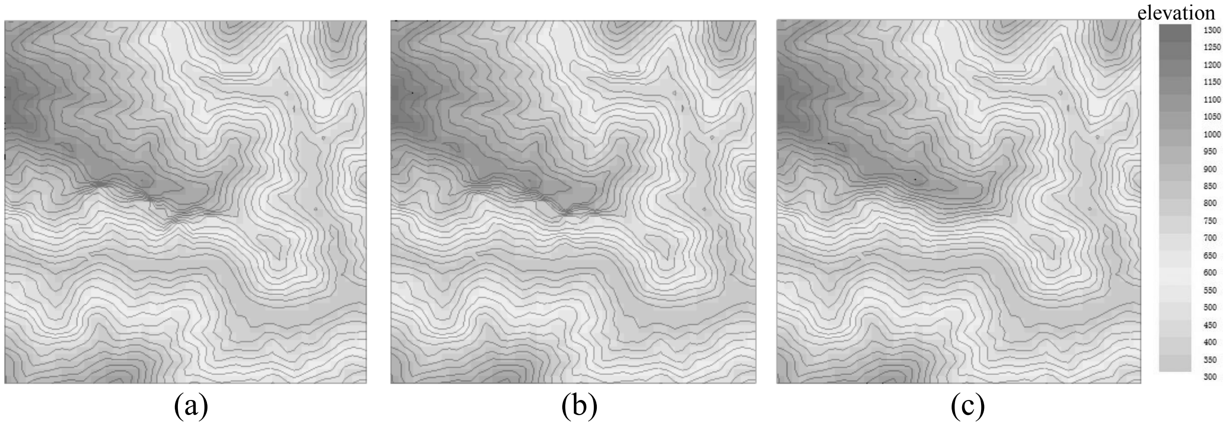

Figure 3. Results of filling data hole of SRTM-3. (a) the average of 4 neighboring height data of MA method. (b) the average of 8 neighboring height data of MA method. (c) Horizon2000

3.2 Results of the differential calculus filter analysis

The differential calculus filter behaves as a high pass filter for DEM. On this account, the results of the differential calculus filter analysis emphasize the place of the big topography change unnaturally. The grid space of SRTM-3 is 3 second, and it is equivalent to approximately 90m. This is DEM with comparatively rough grid space. Thus, it is thought that the topography provided from SRTM-3 shows the topography of smooth impression. The result of the differential calculus filter analysis for DEM of figure 3 is shown in figure 4. As for the application result of the primary differential calculus filter (slope analysis), it is clear by MA method that slope with some perpendicularly appears in the center of the biggest data hole (show figure 5 A,B and C). In contrast, the slope of Horizon2000 at the maximum is calculated form 70° to 75° , and this result is near in a value to be provided from topographical map of this area. As for the application results of the second differential calculus filter (Laplacian), the figure which emphasized the results of the primary differential calculus filter was drew (show figure5 D, E and F). By MA method, a pixel of the particularly big curvature was found on a steeply cliff part. In contrast, in Horizon2000, such a calculation value is not interpolated. Therefore, the topography filled by Horizon2000 is smooth and natural curved surface.

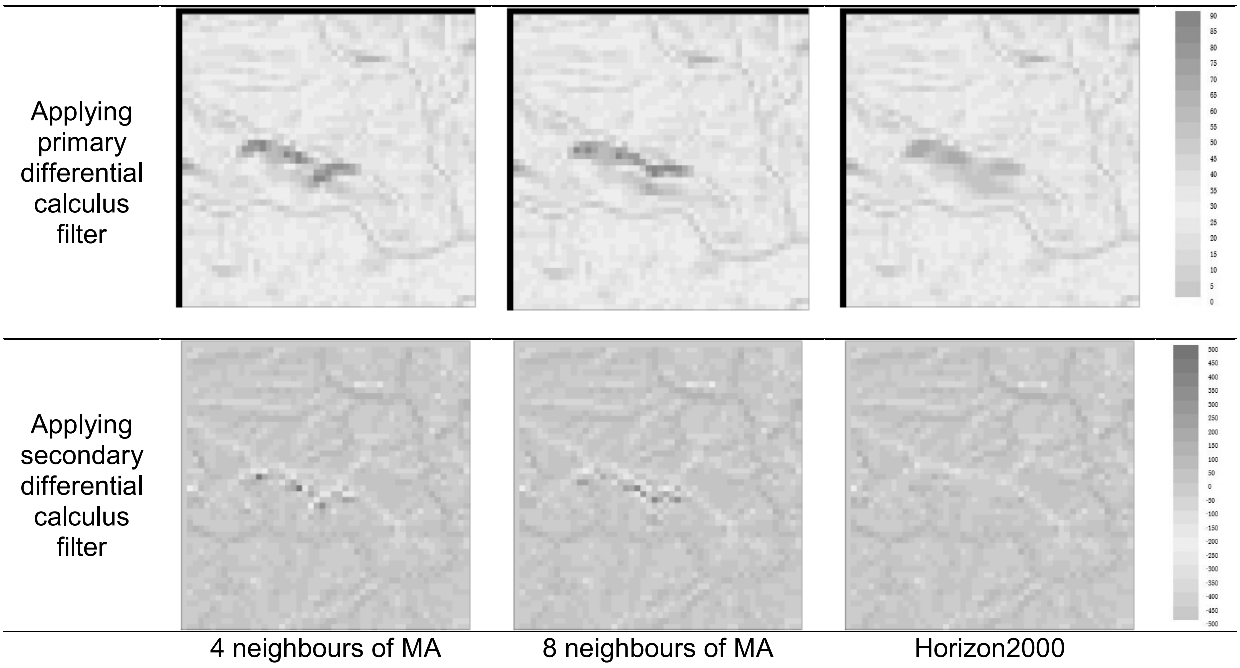

Figure 4. Results of the differential calculus filter analysis for DEMs which were filled data holes

3.3 Discussions

In the example shown in this study area, the height data of the slopes from the ridge to the valley is lacking. The MA method calculates to let the flat land continue of a ridge and the valley. In this case, the flatness topography of a ridge and the valley affects an interpolation result of MA method. Then, the unnatural topography is gotten in results of it. On the other hand, the height data of slope, as well as a ridge and valley, around the data hole influences to interpolation. Thus, Horizon2000 calculates the smooth topography. It was well shown in an analysis result with the differential calculus filter.

When big data hole is filled by MA method, repetition calculations are necessary till all data hole filling is completed. Furthermore, because this is a movement window method, the analysis window must scan all pixels. However, in Horizon2000, several data holes in the area are filled up with one calculation. On this account data filling processing time is shorter than the MA method. In this way, by the method to fill the data hole of SRTM-3, Horizon2000 has advantage more than MA method. However, Horizon2000 should be compared with other interpolation method. In addition, by the size, by the form and by the difference of the kind of the original topography of the data hole, the characteristic of interpolation result should be studied.

SRTM-3 is an only DEM which almost covers all land area of the earth. The SRTM-3 which is filled to data holes could be expected the use to the development and of the natural environment analysis

4. CONCLUSIONS

As a method to fill the data hole included in the SRTM-3, an application of Horizon2000 algorithm was examined. As a result, Horizon2000 calculated the smooth topography for comparatively big data holes area. It is necessary to study comparison with the other interpolation method in order to be more certain method.

8. REFERENCES

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