D. Fritsch, M. Englich & M. Sester, eds, 'IAPRS', Vol. 32/4, ISPRS Commission IV Symposium on GIS - Between Visions and Applications, Stuttgart, Germany.

ACCURACY OF DIGITAL ELEVATION MODEL ACCORDING TO SPATIAL RESOLUTION

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Abstract

Digital Elevation Model (DEM) is indispensable for many analyses such as topographic feature extraction, runoff analysis, slope stability analysis and so on. Beforehand such analyses, accuracy of DEM must be discussed. The accuracy of DEM is usually represented by spatial resolution and height. In this paper, the accuracy of DEM was evaluated according to spatial resolution.

Various spatial resolution (50m, 100m, 150m, 200m and 250m grid size) of DEM were prepared for evaluation. Using those DEMs, slope inclination extraction, slope aspect extraction, drainage pattern generation and slope stability analysis were carried out. Results of each analysis were compared according to spatial resolution.

The results showed spatial resolution seriously influenced to slope inclination. The inclination accuracy indicate under 40% even in 100m grid size. Slope stability analysis was also influenced because inclination is used in this analysis. However, drainage pattern generation was slightly influenced. A spatial distribution of slope aspect is used in drainage pattern generation. Information of spatial distribution of slope aspect might be kept regardless with spatial resolution.

1. Introduction

There are many kinds of DEM (Digital Elevation Model) generation methods such as a stereo-matching from aerial photograph or satellite image, an interferometry from SAR data and an interpolation of topographic maps. On the other hand, we can use some accomplished DEMs. For example, NGDC NOAA offers global land one-km base elevation (GLOBE). And USGS offers Digital Chart of the World that has elevation information also. Each DEM has various grid size and various elevation accuracy.

DEM is indispensable for many analyses such as topographic feature extraction, runoff analysis, slope stability analysis, landscape analysis and so on. We must consider which accuracy is appropriate for any analyses. Therefore, study of DEM accuracy is very important.

In this study, an accuracy of DEM according to spatial resolution will be evaluated. We prepared a various grid size of DEMs. The DEMs will be used for topographical analysis, slope stability analysis and runoff analysis. After that, results from resampled rough DEM will be compared with result from original DEM. A relationship between spatial resolution and DEM accuracy will be concluded.

2. Materials

An original DEM was generated by interpolation from 1: 25,000 contour line maps. Its grid size is 50 m. Figure 1 shows a shaded image of the original DEM where is mountainous area. So, slope stability analysis or runoff analysis can be carried out.

For evaluation of spatial resolution, a various grid size DEM was prepared from the original DEM. In this study, 100m, 150m, 200m and 250m grid size DEMs were generated by resampling. In image processing, there are some kinds of resampling methods such as nearest neighbor, bi-linear, cubic

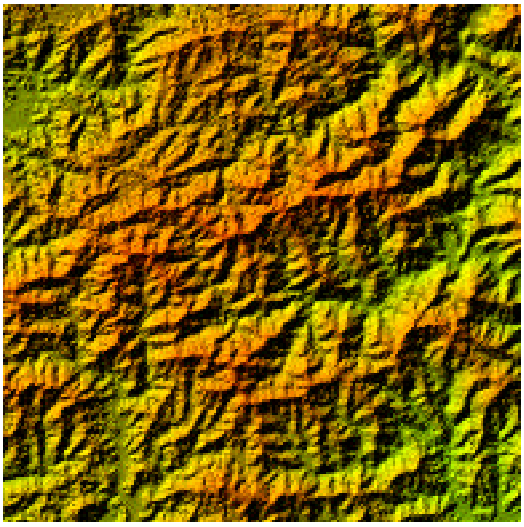

Figure 1. Shaded Image of Original DEM

convolution and so on. In case of DEM generation, nearest neighbor, mean value, maximum value and minimum value are usually used as resampling. For example, GLOBE supports maximum value, mean value and minimum value. We must consider which resampling method is suitable for any analysis. So, DEMs were generated by all resampling methods.

3. Evaluations of DEM accuracy

3.1 Slope Aspect Accuracy

A slope aspect can be expressed from DEM, which is one of the most important items for topographical analysis. In this study, slope aspect defined a direction along the maximum slope inclination. There are eight pixels around a target pixel on DEM. The slope inclination can be calculated along the eight directions.

Figure 2 shows histogram of difference between original aspect data and resampled aspect data of each grid size. The histograms show symmetrical form.

Figure 3 shows a relationship between grid size and percentages of correct pixels. The correct pixel means difference with original data indicates inside of 45 degree. In this figure, the correct percentage in every resampling method has tendency to drop with grid size increase. And maximum value sampling shows the highest accuracy, minimum value sampling showed the worst accuracy.

3.2 Slope Inclination Accuracy

A slope inclination can be expressed from DEM, which is also one of the most important items for topographical analysis. In this study, the inclination defined maximum slope inclination at a target pixel. Figure 4 shows histogram of difference between original inclination data and resampled inclination data of each grid size. The histograms show asymmetrical form that is shifted to right. It means the resampled inclination data became gentle slope. Because, detailed terrain is ignored by grid size increase.

Figure 5 shows a relationship between grid size and percentages of correct pixels. In case of slope inclination, correct pixel means difference with original data indicates inside of 20 degree. The correct pixel indicates under 40 % in even 100m grid size. It will be serious problem. On the resampling method, the nearest neighbor sampling almost showed the highest accuracy, mean value sampling showed the worst accuracy.

3.3 Slope Stability Accuracy

A slope stability analysis is popular application of DEM. Sometime we generate land slide risk map or slope failure risk map from DEM. The slope stability defined by safety factor which can be calculated by

Figure 6-b Illustration of Each Slice

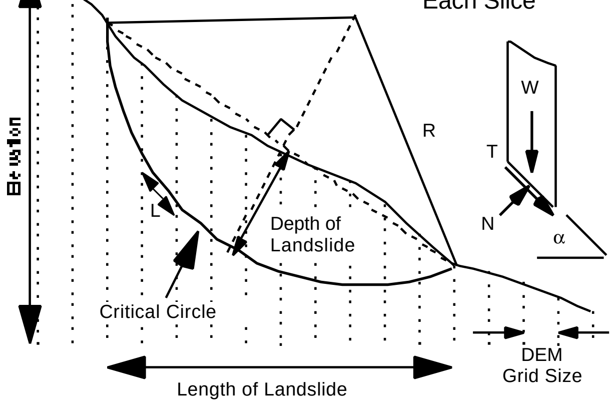

Figure 6-a Illustration of Fellenius Method

a ratio of driving moment to resistance moment along a profile of terrain. When the safety factor is calculated on every pixel, slope stability map can be generated. Fellenius method as slope stability analysis was selected in this study. In Fellenius method, landslide type is assumed rotational slip (Figure 6-a). A landslide soil is divided into some slices in order to calculate moment along the critical circle (Figure 6-b). The driving moment(T) and resistance moment(N) on each slice are calculated by the following equation.

$$T = R \cdot W \cdot \sin\alpha$$
$$N = R(C \cdot L + \tan\phi \cdot W \cdot \cos\alpha)$$

- R Radius of Critical Surface (m)
- C Cohesion (t/m^2)
- ϕ Angle of Shearing Resistance (degree)
- W Weight of Each Slice (t/m) ($W = \gamma_t A$)
- γ_t Wet Unit Weight of Soil (t/m^3)
- A Area of Slice (m^2)
- α Angle between Horizontal Axis and the Base of Slice (degree)
- L Length of the Base of Slice (m)

Therefore safety factor(Fs) is calculated by the following equation.

$$Fs = \frac{\Sigma N}{\Sigma T}$$

Originally, parameters of soil mechanics (C, ϕ, γ_t) and radius of critical surface (R) should be determined by experimental data or field survey data on every pixel. In this study, those parameters were given constant value as follows:

$R = 200m$, $C = 2.0t/m^2$, $\phi = 10^\circ$, $\gamma_t = 1.9t/m^3$

When profile at target pixel was drawn along the steepest direction, Other parameters (W, L) can be calculated by DEM. If the safety factor calculation applied every pixel, slope stability map can be mapped. In this analysis, combination of slope aspect and slope inclination will be concluded.

Figure 7 shows histogram of difference between original slope stability data and resampled slope stability data of each grid size. The histograms show asymmetrical form that is shifted to left. It means rough grid size made safety factor became bigger. The resampled inclination became gentle, which influence to safety factor. This situation will make serious problem.

Figure 8 shows a relationship between grid size and percentages of correct pixels. In case of slope stability, correct pixel means difference with original data indicates inside of 0.2 (Fs). The nearest neighbor sampling almost showed the highest accuracy, minimum value sampling showed the worst accuracy. However, each trend has very similar.

3.4 Drainage Pattern Accuracy

A runoff analysis or a drainage pattern generation is very popular application of DEM. Usually, such analysis can be carried out by using a series grid tank model. A precipitation is supplied to each grid of DEM which means one of the tanks. An inlet content which is effective rainfall for discharge is calculated by following equation.

$$Q_{in} = Ki\, R\, L^2$$

- Qin: Inlet Content (m^3)
- Ki: Infiltration
- R: Precipitation (m)
- L: Grid Size (m)

The inlet content must discharge to next grid according to slope aspect and velocity. That is to say flow tracking. The slope aspect can be calculated from DEM, the velocity can be estimated from slope inclination which is also calculated from DEM. And the flow in the grid can be expressed by a continuous equation as follows;

$$Q_{t+\Delta t} = (\Sigma q_{in} - q_{out})\Delta t$$

- Q: Remaining Content (m^3)
- q_{in}: Inlet (m^3/s)
- q_{out}: Outlet (m^3/s)
- Δt: Time (s)

By using previous equations, drainage pattern can be drawn. In this study, a parameter of infiltration was given 1.0, because purpose of this analysis is just evaluation of DEM. In this analysis, spatial distribution of slope aspect and slope inclination will be concluded.

Figure 9 shows histogram of difference between original runoff data and resampled runoff data of each grid size. The histograms show symmetrical form.

Figure 10 shows a relationship between grid size and percentages of correct pixels. In case of runoff analysis, correct pixel means difference with original data indicates inside of 20 m^3/s. The correct percentage indicates over 70% in even 250m gird. It was unexpected. On the resampling method, the nearest neighbor sampling showed the highest accuracy, minimum value sampling showed the worst accuracy.

4. Conclusions

In this study, an accuracy of DEM according to spatial resolution was considered. Spatial resolution influenced to slope inclination sensitively. The correct pixel indicates under 40 % in even 100m grid size. A terrain surface generally undulate in even one pixel, so that such detailed terrain is neglected by resampling. This situation also influence to slope stability analysis. The result showed low resolution data made safety factor become bigger. The inclination is one of the most important factor in a slope stability analysis. And almost terrain analyses use combination of slope aspect and inclination. So, we must take care to use low resolution DEM. On the other hand, spatial resolution is slightly influenced to drainage pattern generation. The drainage pattern can be generated by flow tracking which uses spatial distribution of slope aspect. So, spatial distribution of slope aspect might be kept regardless with spatial resolution.

We tried to compare with each resampling method. In those resampling method, nearest neighbor resampling showed the best method except slope aspect. Minimum value resampling showed the worst. Test area was selected from mountainous area. Minimum value makes gentle slope. so that it was much different from original data.

In this study, the highest spatial resolution is 50m grid DEM. However, we will use less than 10m grid by commercial very high resolution satellite. In future, such very high resolution DEM must be evaluated. A spatial resolution was very important for any analysis.

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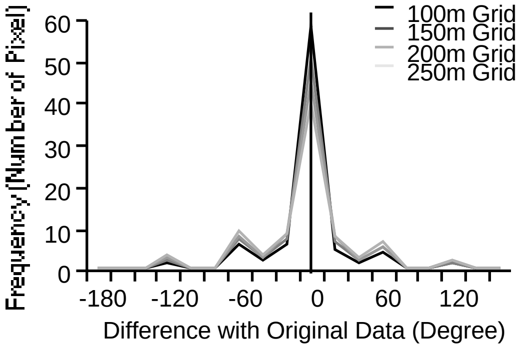

Figure 2. Accuracy of Slope Aspect according to Spatial Resolution

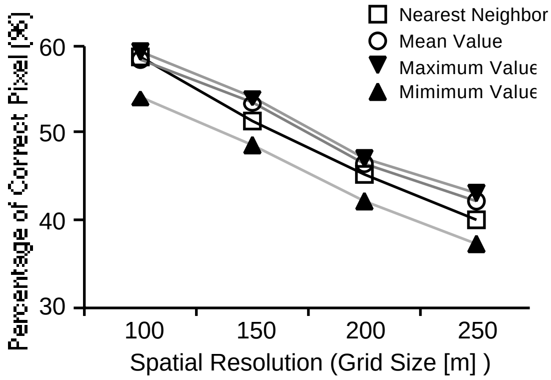

Figure 3. Accuracy of Slope Aspect according to Spatial Resolution

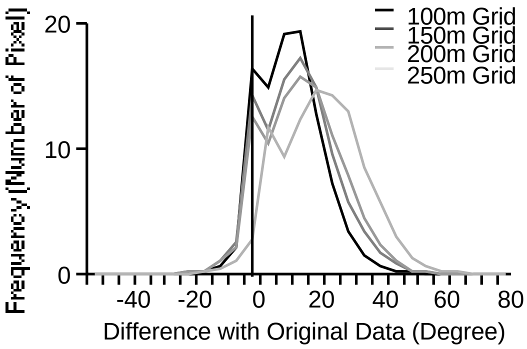

Figure 4. Accuracy of Slope Inclination according to Spatial Resolution

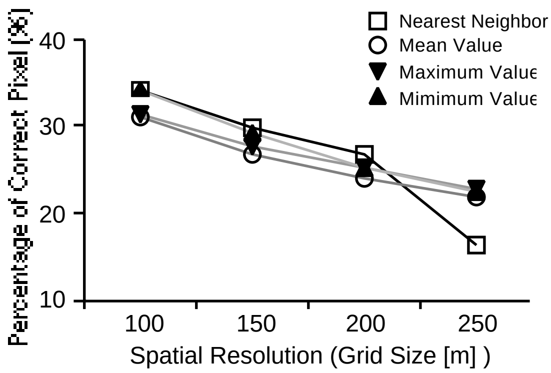

Figure 5. Accuracy of Slope Inclination according to Spatial Resolution

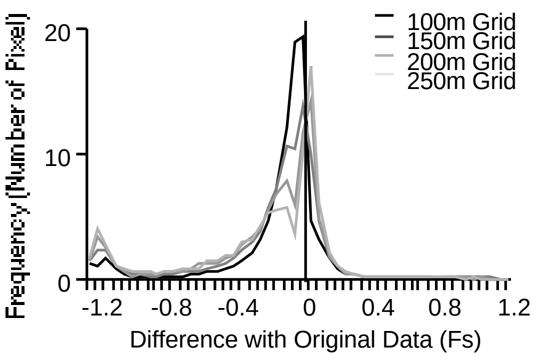

Figure 7. Accuracy of Safety Factor according to Spatial Resolution

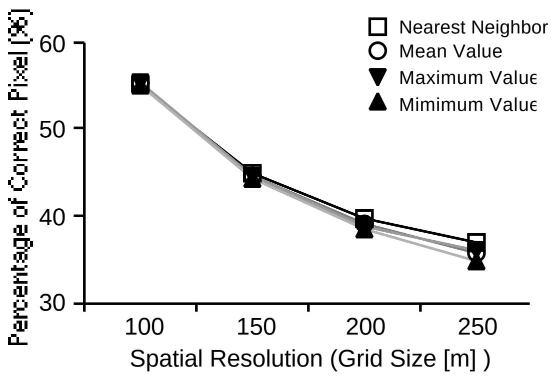

Figure 8. Accuracy of Safety Factor according to Spatial Resolution

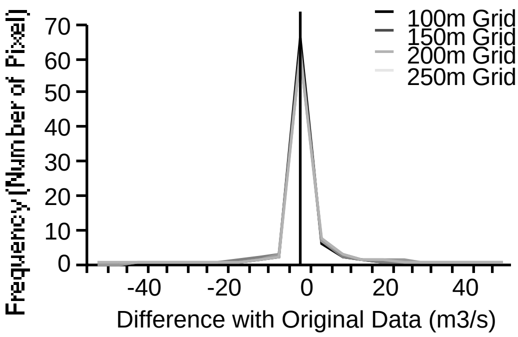

Figure 9. Accuracy of Drainage Pattern according to Spatial Resolution

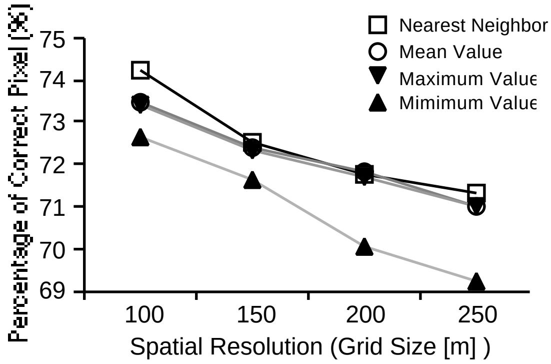

Figure 10. Accuracy of Drainage Pattern according to Spatial Resolution