情報地質 第27巻 第2号 056-057頁 2016年
Geoinformatics, vol.27, no.2, pp.056-057, 2016

Investigation of BS-Horizon Parameter Settings for Topographic Surface Generation

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Key words : BS-Horizon, DEM interpolation, Bi-cubic spline, elevation constraints

1. Introduction

BS-Horizon is a DEM generation program which was developed by Nonogaki *et al.*, 2012. In this study, we take up a detailed investigation of parameter settings for BS-Horizon program and examine the effects in resultant topographic surface. Results reveal the reliance of generated surface on different parameters in BS-Horizon program including M_x and M_y, α, m_1 and m_2.

2. BS-Horizon DEM generation

BS-Horizon program (Nonogaki *et al.,* 2012) was developed based on bi-cubic spline interpolation algorithm and exterior penalty function. Method used in BS-Horizon program was already described in Nonogaki *et al.,* 2012. Several parameters were set for BS-Horizon DEM calculation included M_x, M_y, α min, α max, N_{ITR}, m_1 and m_2. In summary they can be explained as below;

- M_x and M_y: the numbers of tiles that constitute the surface domain (Ω) for the bi-cubic spline function
- α min, α max: minimum and maximum penalties in penalty function. α controls the balance between smoothness of surface ($J(f)$) and the degree of violation of constraints ($R(f)$).
- Number of iterations (N_{ITR}): number of times running program in a given α range.
- m_1, m_2: weight coefficients for the functions derived from first and second order partial derivatives of interpolated surface.

3. Data Used

Test site is an lowland area located in the south of Danang City, Vietnam. The topography is flat with elevation range from 0 to 7.2m. In this area, equality constraints which are 9,730 elevation points have been collected during field survey in 2009. In addition, the inequality constraints is characterized by elevation between 0m and 10m contours in topographic map in 2010. An inequality data included *XY* location, *Z* coordinate and relation to neighboring elevation was generated. Subsequently, the elevation points was combined with inequality constraints to create an equality-inequality constrained data (in csv format) and used as input for BS-Horizon program.

4. Results and Discussion

Batch processing was carried out to perform surface approximation in different parameter settings. M_x and M_y were examined from 50 to 400. α was ranging from 1 to 10^{12}. m_1, m_2 were values ranging between 0 and 1. Effects of these parameter settings on the resultant surface estimation were examined.

4.1 Effects of *M* and α settings

Firstly $m_1 = 0.0$, $m_2 = 1.0$ was set as default in order to analyze the effects of remaining parameters. BS-Horizon DEM generation was applied using both equality and equality-inequality constraints. As the results, DEMs generated at first α value are same in *J*, *R* and all other statistical parameters with respect to all *M* settings. The iterative calculation by exterior penalty function method enforces surfaces gradually satisfy constrained condition.

In case of DEM derived from only equality data, when $M = 50$ to $M = 100$, *R* does not change much, but *J* steeply increases. Surface smoothness reduces significantly by the increase of α. Surfaces tend to expand areas of undershoot and overshoot elevation when α increases. When $M = 150$ and above, *R* is rapidly reduced by the change of α. *R* is obtained as around 0.49 at first stage of α and gradually minimized to value around 0.0025 in the later stage of α. *J* and *R* tend to become constant in the upper α range. From $M = 150$, *R* is obtained as minimum (0.0025) in upper α range and is not improved even larger *M* settings.

In case of DEM generation using equality-inequality data, when $M = 50$ to $M = 200$, there are three different zones of *J* and *R* according to α. Zone A shows the steady increase of *J* and steady decrease of *R*. In zone B, *J* continuously increases and *R* tends to minimum values. In zone C, both *J* and *R* show spikes especially the DEM error (*R*) becomes maximum. When $M = 250$ to $M = 400$, there are no unstable zones (C zone). *J* and *R* become constant in the upper range of alpha. The degree of constraints violation (*R*) is also minimized with value around 0.0025 in the B zone. *R* is obtained as minimum value and the B zone does not change from $M = 300$.

Distribution of field survey elevation points on study area in different M settings show that, M from 150 and above have more than 50% of tiles having no elevation points that may cause different representations to the earth surface. On the contrary, M from $M = 50$ to $M = 90$ provide large number of tiles having more than four control points which also increase RMS error of spline interpolation results. In this case study, M from 100 to 120 are suitable for BS-Horizon DEM generation, since number of tiles without elevation points is about 30 - 40% and most elevation points in a tile distribute within four. This study is using $M = 100$ as parameter setting for BS-Horizon surface estimation (Figure 1)

Comparing α at first stage ($\alpha = 1.0\times10^1$ to $\alpha = 1.0\times10^3$) and later stage ($\alpha = 1.0\times10^6$ to $\alpha = 1.0\times10^{12}$), it is observed that contours extracted from DEM at later stage of α are rounded up in some areas especially along roads and in the boundary between two topographic areas. In most cases of M, DEM at first stage of α are more clearly in representing topography of some main features such as roads or rivers, and the contours are also enough detail. This study is applying $\alpha = 1.0\times10^1$ (Figure 1a) in case of DEM generation using equality constraints and $\alpha = 1.0\times10^3$ (Figure 1b) in case of using equality-inequality constraints.

4.2. Evaluating effect of m_1 and m_2 setting

m_1, m_2 were set as different values starting from $m_1 = 0.0$, $m_2 = 1.0$ to $m_1 = 1.0$, $m_2 = 0.0$ with increment step of 0.1. DEM representations gradually change according to the increase of m_1 at any value of M or alpha. However, the degrees of change are not same at every condition. In case of small alpha ($\alpha = 1.0\times10^1$ to $\alpha = 1.0\times10^3$) the topographic change from $m_1 = 0.0$ to $m_1 = 1.0$ are obvious. DEM surfaces tend to be steeper according to the increase of m_1. The generated contours usually round up where elevation points are available. This is because of the slope gradient is increased around these elevation points. On the contrary, when m_1 is small and m_2 is emphasized, surface curvature around elevation points is increased and generated contour becomes undulated which considering relation to neighboring elevation points. In the upper α range, surfaces are not much difference from $m_1 = 0.0$ to $m_1 = 0.9$ since the RMS error are same. The only difference is DEM in case of $m_1 = 1.0$.

m_1, m_2 have different effect on surface representation. The weights for these parameters depend on the application and characteristics of study area. This study aims to generate DEM for a lowland area which has small slope gradient, therefore, $m_1 = 0.0$, $m_2 = 1.0$ is used as condition for BS-Horizon DEM generation.

4.3. Discussion

Considering surface behaviors in case of using only equality and case of using equality-inequality data, it can be seen that;

In case of DEM generated from only equality data, J and R become stable in upper α range when $M = 150$. In case of DEM from equality-inequality constraints, J and R become stable in latter stage of alpha from $M = 250$. This study is using alpha in early stage therefore $M = 100$ can be applied for both DEMs from equality and equality-inequality constraints. In case of applying upper alpha range for DEM generation, it should consider different M settings for each case.

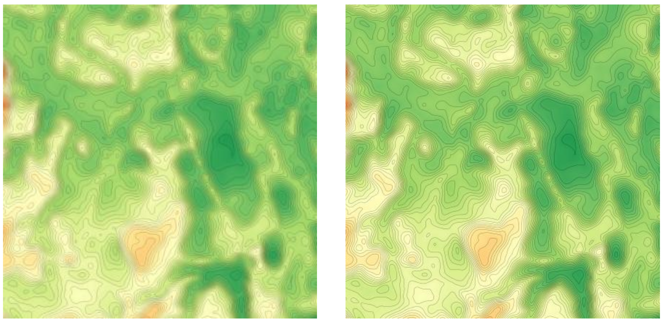
The suitable surface in case of DEM using equality data is obtained at $\alpha = 1.0\times10^1$. In case of DEM derived from equality-inequality constraints, the suitable one is obtained at $\alpha = 1.0\times10^3$ which is slightly shifted from case using equality data.

DEM generated from only equality data usually provide significant undershoot elevation. These undershoots mainly locate along rivers where there are no field data or in the transition between two different land-use. The integration of inequality constraint into BS-Horizon reduces the number of undershoot elevation on the approximation results. However DEMs generated from equality-inequality constraints still remain some places having undershoots, especially when alpha setting is significant increased.

The parameters in BS-Horizon may be different in other study areas depending on the size and topographic characteristics of study area. It is therefore suggested that suitable parameters need to carefully examined, considering the characteristics of particular study area.

5. Conclusion

Bi-cubic spline algorithm and exterior penalty function method implemented in the BS-Horizon program offers advantage of defining equality-inequality elevation constraints to interpolate topographic surface. Evaluation of parameter settings for BS-Horizon topographic surface estimation has provided a better understanding of effects of parameters such as M, α, and m_1, m_2 that are involved in the estimation. The results of this experiment are very important in effectively using available data to generate more reliable estimate of the topographic surface.



a. DEM generated from equality data. ($\alpha = 1.0\times10^1$)

b. DEM generated from equality-inequality data. ($\alpha = 1.0\times10^3$)

Figure 1. Results of DEM generation using BS-Horizon program. ($M = 100$, $m_1 = 0.0$, $m_2 = 1.0$)

References

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