第29回日本情報地質学会講演会 講演要旨集 049-050頁 2018年

Surface Elevation Estimation Using Global DEMs and Geographically Weighted Regression

Le Van Bien*, Venkatesh Raghavan*, Tran Thi An**, Do Thi Hang*

* Graduate School for Creative Cities, Osaka City University,
3-3-138 Sugimoto, Sumiyoshi-ku, Osaka 558-8585, Japan.
** Faculty of Geography, University of Education, The University of Danang
459 Ton Duc Thang Street, Danang City, Vietnam.

Keywords：GWR, GDEM, SRTM, ALOS AW3D30, Surface Estimation

1. Introduction

Digital elevation model (DEM) has become one of the most important and essential data sources for various terrain related applications. The available global DEMs including the Advanced Land Observing Satellite World 3D-30m DEM (ALOS AW3D30 or ALOS-30), the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global DEM (GDEM) and Shuttle Radar Topographic Mission (SRTM) DEM are being used widely. Although these above global DEMs are freely access and can be effectively applied for many purposes, they still contain some height errors that affect the processing results significantly. This study presented an advanced method to improve the accuracy of global DEMs using Geographically Weighted Regression (GWR).

2. Methodology

2.1 Data set

Study area is Danang city, located in middle of Central Vietnam, with the elevation range from 0 to 1664m. Global free DEMs used in this study including ASTER GDEM version 2 (earthexplorer.usgs.gov), ALOS AW3D30 (eorc.jaxa.jp) and SRTM (srtm.csi.cgiar.org). All of the global elevation sources are in 30m resolution. The reference elevation data is spot height elevation data with more than 130,000 elevation points, was developed by Danang city government in 2009.

2.2. DEM Estimation Using Geographically Weighted Regression (GWR)

GWR is a local form of linear regression which is a method for exploring how the relationship between a dependent variable (Y) and independent variables (X). Subsequently, it will predict the dependent variable based on independent variables. In contrast to global regression, instead of using same equation coefficient for entire study area and one independent variable, GWR can use multiple independent variables and can build a separate equation for local area in the dataset within given bandwidth (neighborhood size). That means GWR can consider geographical differences in the estimation. The equation of GWR model is based on Fotheringham *et al.*, 2002.

This study has explored the advantages of GWR for estimation of a new DEM using three global DEMs (ALOS AW3D30, ASTER GDEM, SRTM) and referent elevation points. Firstly, reference points were separated randomly into two groups. One group was used for estimation DEM and the remaining group was used for validation of estimated DEM. This was done using the *r.random* function in GRASS GIS. Many cases with different number of reference points were applied for running GWR in DEM estimation. The different estimated DEMs were evaluated in relation with slope, landform, and landuse. As the results, estimated DEM used random 50.000 input points showed the best result. Therefore, we selected random 50,000 reference points for DEM estimation and the remaining reference point for validation.

In GWR model, the term of bandwidth and kernel function have effect on the estimation result. Various conditions of bandwidth and kernel were applied and bi-square function (1) with fixed bandwidth size 50 showed the best estimated DEM.

$$w_p = (1 - (d/bw)^2)^2 \quad (1)$$

Where, bw is the bandwidth, d is the distance from a pixel to the current pixel, and w_p is the weight assigned to a pixel.

GWR is available as module *r.gwr* in GRASS GIS. As a result, the estimated DEM which derived from three global DEMs and the number of 50,000 reference elevation points was generated.

2.3. Evaluation of Estimated DEM

The remaining group of reference elevation points including 80000 points was used for evaluation of the GWR derived DEM. The accuracy of the estimated DEM can be determined by statistical analysis such as Mean of Absolute Error (MAE), Root Mean Square Error (RMSE), Standard Deviation (SD) and correlation coefficient (R^2). The MAE, RMSE and SD of the estimated DEM were much improved compared to individual global DEMs. The RMSE was reduced from 7.0m in ALOS-30, 8.3m in the GDEM and 6.4m in SRTM to 4.1m in the GWR DEM. The MAE was also reduced from 5.2m in ALOS-30, 5.4m in GDEM and 4.6m in SRTM to 1.9m in the estimated DEM (Table 1).

The GWR DEM and reference data also shows the significant correlation, with R^2 = 0.9994 (Table 1). It can be, therefore, concluded that the estimated DEM shows better correlation to the reference data, comparing to global DEMs. Statistics about vertical accuracy of ALOS-30, GDEM, SRTM and the estimated DEM is shown in Table 1. The MAE, RMSE and SD of the estimated DEM show much improvement compared to ALOS, GDEM and SRTM before estimation.

Table 1: Summary statistics for the error of global DEMs and GWR DEM

DEM	MAE (m)	RMSE (m)	SD (m)	R^2
ALOS-30	5.2	7.0	5.9	0.9985
GDEM2	5.4	8.3	8.2	0.9973
SRTM	4.6	6.4	5.5	0.9987
GWR DEM	1.9	4.1	4.1	0.9994

The vertical elevation errors of estimated DEM and the global DEMs were compared again in relation to landform characteristics. The classification of landform is based on Bien Le (2017). As a result, the RMSE of estimated DEM shows really significant improvement than the individual global DEMs (Table 2). In general, the vertical error in the mountainous areas tends to be highly considerable than in the flat areas.

Table 2: RMSE of global DEMs and estimated DEM for different landforms

Landform	Root Mean Square Error (m) (RMSE)			
	ALOS	GDEM	SRTM	GWR DEM
Flat	5.5	5.0	4.4	1.6
Valley	9.1	12.4	9.7	6.9
Mountain	12.2	17.6	12.1	9.5

3. Conclusion

In this study, GWR model was applied successfully in surface elevation estimation for Danang area, using the available global DEMs and field survey elevation points. Results indicate that the estimated DEM has improved accuracy compared to individual global DEMs. It means GWR for DEM estimation can provide significant enhancement on quality of DEMs derived from various sources.

In this study, GWR only used less than a half of reference points to generate the combined DEM. However, in comparison with three global DEMs, the estimated DEM showed most accurate results. Thus, estimation an elevation model based on field survey-based and satellite-based elevation data using GWR is effective for area with limited number of survey point data.

References

[1] Fotheringham, AS., Brunsdon, C. and Charlton, M., (2002) *Geographically Weighted Regression:the analysis of spatially varying relationships,* Wiley, Chichester, pp. 13-15.

[2] Le Van Bien (2017), *Accuracy Assessment of Global DEM and Surface Elevation Estimation Using Geographically Weighted Regression: A Case Study in Danang City, Vietnam*, Master thesis, Graduate School for Creative Cities, Osaka City University, Japan.