VARIOGRAM-BASED URBAN CHARACTERIZATION USING HIGH RESOLUTION SATELLITE IMAGERY

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ABSTRACT: As even small features can be classified as high resolution imagery, urban remote sensing is regarded as one of the important application fields in time of wide use of the commercialized high resolution satellite imageries. In this study, we have analyzed the variogram properties of high resolution imagery, which was obtained in urban area through the simple modeling and applied to the real image. Based on the grasped variogram characteristics, we have tried to decomposed two high-resolution imagery such as IKONOS and QuickBird reducing window size until the unique variogram that urban feature has come out and then been indexed. Modeling results will be used as the fundamental data for variographic analysis in urban area using high resolution imagery later on. Index map also can be used for determining urban complexity or land-use classification, because the index is influenced by the feature size.

KEY WORDS: high resolution satellite imagery, KOMPSAT, urban characterization, variogram

1. INTRODUCTION

As more data can be acquired, geostatistics has been necessary to process information effectively and draw proper results. Among several geostatistics techniques, variogram is a traditional method to process fundamentally for kriging, simulation and so on. The variogram has been used in geostatistics widely to presume the value of the needed location by making use of the correlation of separated data in a specific distance.

Various trials were started to analyze not only field data but also digital image characteristics using variogram since 80s. However, unlike the field data, the variogram in remote sensing should be different from typical variogram in case of the form and analysis method. Curran (1988) and Woodcock et al. (1988a,b) provided readable introductions to the variogram. Thereafter variographic analysis has been used for the Segmentaion and land-use classification (Benoît A. St-Onge and François Cavayas, 1997; Shuo-sheng Wu et al, 2006) Some researches used for the assessment of rescale and evaluation of classification (Sergio et al, 2004; Peijun Li and Zhengxiao Li, 2001). These studies used low or middle resolution imagery or aerial photo. The research using high resolution imagery or reflecting the variographic property in urban area is rare. KOMPSAT-2, which can take 1-m spatial resolution imagery, launched successfully and KOMPSAT-3 launching is scheduled in succession. So, the necessity of various researches is getting higher to utilize high resolution imagery.

In this study, we have tried to model some features, which appear in urban area commonly and investigate the unique characteristics of variogram in high resolution imagery. Based on the grasped variogram characteristics, we have decomposed imagery deescalating window size until the unique variogram that urban feature has come out. And then index map varying with feature size has been made out by the feature.

2. METHODOLOGY

2.1 The basic of variogram

The variogram is a two-point statistical function that describes the increasing differences or decreasing correlation, or continuity between the sample values as the separation between them increases. Traditionally, the variogram has been used for the modeling of spatial variability rather than the covariance although kriging systems are more easily solved with covariance matrices. In this study, we have analyzed the spatial distribution property of each image through the variogram. The typical variogram exhibits a rise that gradually slows to form a straight horizontal line (sill) due to the fact that increasing the distance between their values. In many cases, the increase of the lag does not result in any more difference because the spatial autocorrelation between the image values normally drops beyond a certain distance. The height of the sill is normally proportional to the global image variance while the lag at which the sill is attained, as called the "range" is generally a very good indicator of texture coarseness. The variogram can be calculated along transects (Atkinson and Danson, 1988; Curran, 1988) but gives a better representation when calculated in more than one direction (Woodcock et al., 1988a) because texture is in many cases anisotropic.

$$2\gamma(h)=\frac{1}{m}\sum_{i=1}^{m}[z(x_i)-z(x_i+h)]^2 \qquad (1)$$

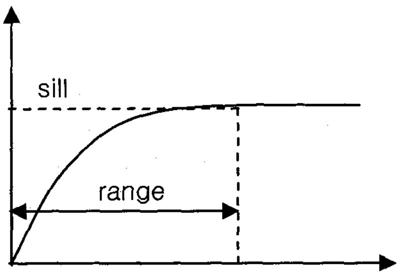


Figure 1. The typical variogram.

2.2 Variogram characteristics in images

The variogram of imagery has four wide differences from the variogram of earth science data. First of all, usually the number of data in remote sensing is more than field data because the number of pixel is same as the number of data. Secondly, the interval between data is fixed. As other earth science data don't have irregular distance ordinarily, some lag can't have the calculated value. However, there is a variogram value in every lag. The Third property is that pixel value is not always similar to the around pixel values. Kriging is fundamentally assuming that each value is similar to the value of near position. For this assumption, non-existed value can be estimated. However, it may have a totally different pixel value in the boundaries in case of image. Last property of variogram in image is that the theoretical variogram does not fit to the experimental variogram. Spherical or Gaussian model used commonly can be available in some cases. However, we may sometimes come across a case of unique variogram shape such as the periodic or aspatial variogram.

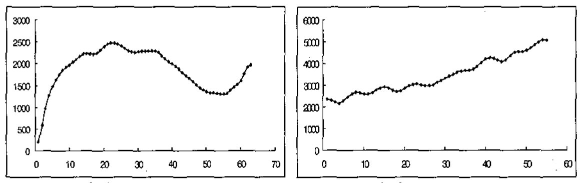

(a) Periodic (b) Aspatial

Figure 2. variograms in digital image.

3. RESULTS AND DISCUSSION

We made 6 models, which can be seen in the urban area to confirm how variogram reveals. Figure 3 show the feature simple models being seen usually in urban area. Models encapsulated road, building, multi-building and so on. Each model has 64X64 in size.


(a) (b) (c) (d) (e) (f)

Figure 3. Simple models for variogram analysis.

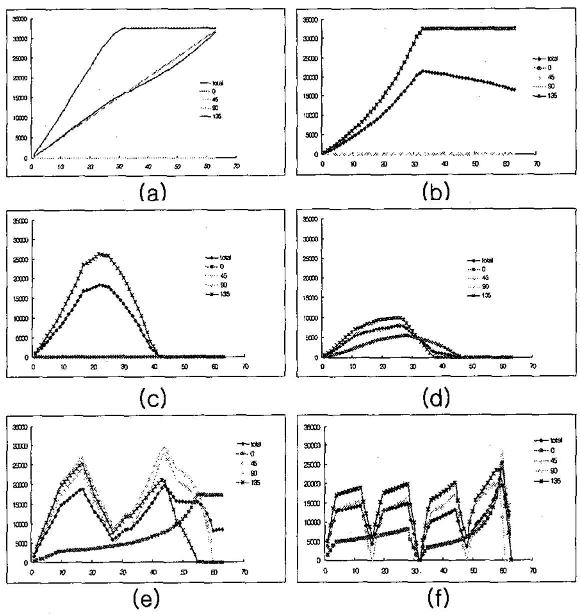
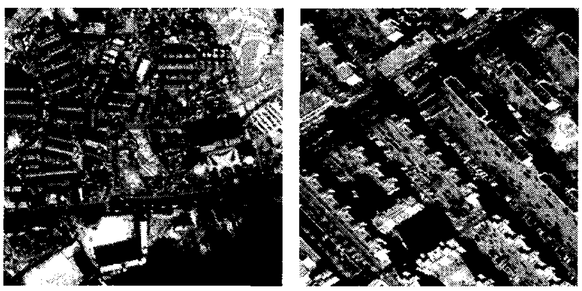


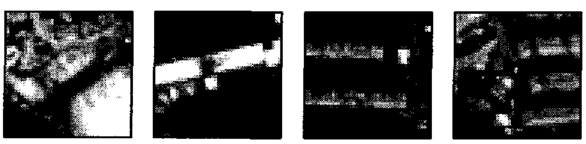
Figure 4. The variograms of simple models (Fig.3).

Figure 4 shows the results of variogram according to the models of Figure 3. In case of the diagonal feature model, that variogram is a spatial variogram increasing continuously. The variogram of vertical feature model has a sill that gradually slows to form a straight horizontal line. When buildings are in the window, variogram shows repeated pattern and it is convergent to 0. The number of repeated pattern is same as that of buildings. However, real data should be tested because these models simplify urban feature.



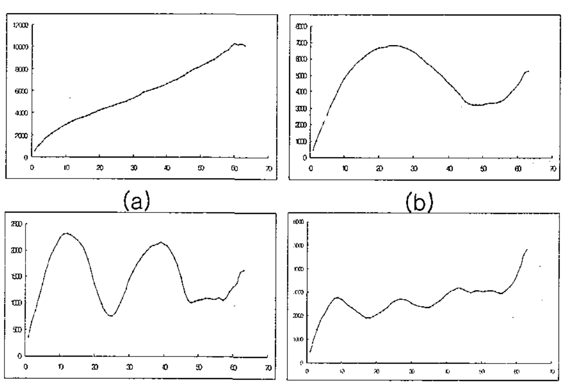
(a) IKONOS (1m) (b) QuickBird (0.61m)

Figure 5. The test datasets.



(a) (b) (c) (d)

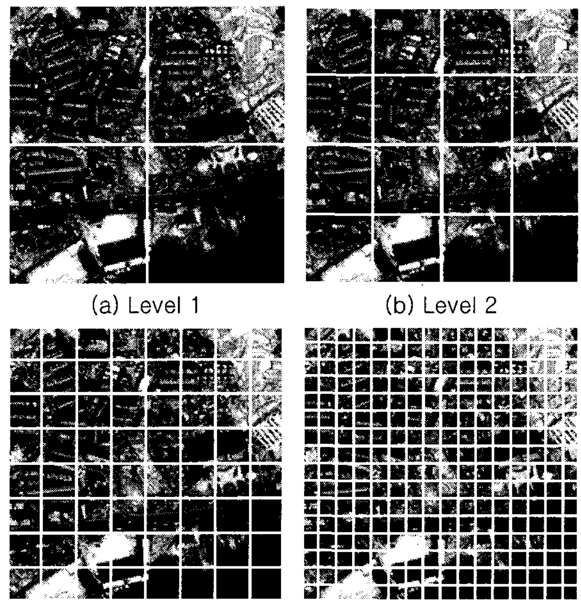
Figure 6. Some actual urban features in real image.



(a) (b) (c) (d)

Figure 7. The variograms of real sub image.

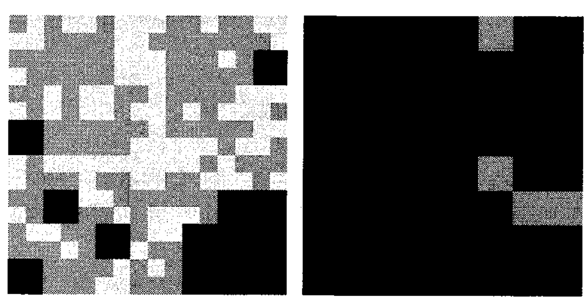
Two types of different spatial resolution images have been taken into account in this study such as IKONOS 1 m and QuickBird 0.61 m imagery(Figure 5). IKONOS image is covered with regions around Namyangju-city and QuickBird image is covered with Yeouido, Seoul. Figure 6 is the real image of 64 by 64. Four images are similar to the models selected for the test images. Figure 7 is the variogram for figure 6. In case of real image, though it is a rather complicated, it is confirmed to be the similar trend as the model.



(a) Level 1 (b) Level 2 (c) Level 3 (d) Level 4

Figure 8. Level of decomposition.

If we use the feature that the variogram has a tendency to decrease when one feature comes in the window, we are able to decompose the image according to the building size, because the window size including the whole building would be different according to the resolution or the size of the building. In this study, we have analyzed the image as steps and divided into the much smaller window, so if the convergence variogram shows up, the division would be stopped (Figure 8).



(a) IKONOS (b) QuickBird

Figure 9. Level index of test dataset.

When (a) in Figure 5 was decomposed up to 32x32 window size, most features stayed inside window.

While, the great part of the feature stayed inside of 128x128 window in case of (b) in Figure 5. This means Figure. 5 (b) has bigger feature than (a). Level decomposition result illustrated in Figure 9. The darker part means the bigger features. Not only feature size but also size of resolution has great influence on these results. Upon that imagery has same resolution, it will be used to index urbanization or building size. Upper-left part is more complex in IKONOS image. While lower-left side in QuickBird image is more complex as well. However, shadow effect and complex building shape make analysis harder in urban area. For the precise result, we should analyze the variogram with sliding window. Nevertheless, these index maps can be used for determining urban complexity or land-use classification because the index is influenced by feature size.

4. CONCLUSION

In this study, we tried to model urban structures such as building and road, which can be seen in high resolution imagery. After analyzing those variogram, we have corroborated the results using real image tested. The outcome is that there is little difference between the variogram of real image and model's. Modeling results shows that urban features have unique variogram. Using specific properties of the variogram in image that the variogram decrease, if one feature comes in the window, we decomposed the image as steps and divided to the much smaller window and classified the town image according to the building size. These results are expressed in the index map. This is helpful to detect the area that specific size feature distribute in or catch general feature size with comparing decomposition level. It will also be used as a layer for the land-use classification or analysis of urban complexity to index urbanization or building size.

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ACKNOWLEDGEMENTS

This work was a part of studies for KOMPSAT-3 Application Project, being supported by the Korea Aerospace Research Institute.