MAP-BASED WEB APPLICATION FOR VISUALIZATION AND EXPLORATION OF VEGETATION CHARACTERISTICS EXTRACTED FROM ‘QUICKBIRD’ AND ‘ALOS’ SATELLITE DATA

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Commission VI, WG VI/4

KEY WORDS: Semi-variogram, vegetation, NDVI, Map-based, Quickbird, ALOS

ABSTRACT:

Vegetation index such as NDVI(Normalized Difference Vegetation Index) has been used as a good indicator of environmental change in urban areas for many years. Areas where the NDVI values are greater than certain threshold value are considered as vegetation area. Their seasonal and regional changes of NDVI can be easily observed if areas are appropriately coloured according to their NDVI values. Besides, if statistical properties of spatially distributed NDVI values are visually available, it becomes a very effective to explore those geo-spatial satellite data with high spatial resolutions. To visualize spatial structure of vegetation distribution and explore its property as an environmental monitoring index NDVI coloured map, scattergram, histogram, variogram are well organized to integrate their characteristics. Variograms’ attributes are visualized so as to play very important roles to mitigate the difficulties in extracting the features of the surface of the earth from the high-resolution satellite data which can reveal various objects on the surface. Satellite data mainly used here are products from ‘Quickbird’ with 2.8m of ground spatial resolution and also from recent ‘ALOS’with 10m of spatial resolution. Areas are restricted to urban areas of suburban district of Tokyo.
Map-based Web application is constructed and used for the exploration of the features of vegetation spatial data by useful Map data tool, ‘Google Maps’. Several visualized results are displayed in the multi-layered structures that are built on the geo-coded maps. Satellite data with high spatial resolutions was utilized effectively by the current visualization method. It is found that an interesting relation between vegetation coverage of the selected area and the variogram’s attributes of NDVI maps by the present geo-spatial analysis.

1. INTRODUCTION

It is important to keep monitoring the characteristics of vegetation in urban areas by remotely sensed data from an environmental viewpoint. Recent sensors on earth observation satellites have excellent and very high spatial resolution of a few meters on the surface of the earth. However, the higher the resolution of sensor becomes, the more difficult the analysis of land surface seems to be due to too fine aspects in the satellite imagery. Through our first attempt to apply variogram technique to NDVI maps derived from a satellite data with very high spatial resolution (Osaki, K., 2004), it was realized that there exits unresolved difficulty of determining uniquely variogram’s attributes, ‘sill’ and ‘range’. The primary objective of the research presented here is to clarify the spatial characteristics of vegetation distribution in urban areas by analyzing properties of variograms and to construct map-based Web application for an effective utilization of variogram’s analysis. To depict the spatial patterns of the observed scenes, quantity measured by second-order statistics has been used in applications such as mining exploration and other engineering fields. Related practitioners call the field of spatial statistics 'geo-statistics' (Donnay, J., 2001). An important concept of the quantity inherent to the scenes is spatial continuity and is measured as covariance and semi-variance. The semi-variance plays a very important role in the analysis of data's spatial statistics in the present research. Among many vegetation indices, NDVI(normalized difference vegetation index) has been most widely used for investigation of environmental assessment. The NDVI data used for the current analysis is derived from the multi-spectral data of ‘QuickBird’ (earth observation satellite) with the ground spatial resolution of 2.8m. The NDVI lies in its characteristics that can reduce the multidimensional data yielded from multi-spectral sensor systems to a single index which is sensitive to various characteristics related to vegetation activities such as biomass, productivity, leaf area, amount of photo-synthetically active radiation, and percent vegetative ground-cover etc.

2. SATELLITE DATA (QUICKBIRD AND ALOS)

ALOS (Advanced Land Observing Satellite DAICHI) was launched aimed at obtaining data to produce 1:25000 maps on a global basis on Jan.24,2006. One of its sensing instruments is

Figure 1. NDVI map of western part of Tokyo in Japan acquired by ‘Quickbird’ on September 3, 2003. It covers an urban area with width of 1854 pixels and with height of 1893 pixels. The more the pixel is brighter, the higher the value of NDVI shows.

AVNIR-2(Advanced Visible and Near Infrared Radiometer type 2) for obtaining data on land use and vegetation with four bands of 10-meter spatial resolution. Quickbird was launched with commercially highest ground spatial resolution on October 19,2001. Due to high cost of the product, the size of the scene that we use for vegetation analysis is usually a square of about 5km x 5km. Acquisition dates of the scenes by Quickbird and ALOS are September 3,2003 and August 29, 2006, respectively. The current targeted area in Tokyo is chosen because of the convenience of acquiring good ground truth data for checking the land coverage.It is also confirmed that geo-coded coordinates on the ‘Quickbird’ image have satisfactory correspondence to those on ‘Google Maps’.

3. SEMI-VARIOGRAMS

The semivariogram is defined as the following equation (Quattrochi, D., 1997; Wackernagel, H., 2003; Woodcock, C.E., 1988):

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1,N} (z_i - z_{i+h})^2 \qquad (1)$$

where γ = dissimilarities
h = spatial separation
N(h) = number of all point pairs linked by a vector h
z = a variable, here NDVI is used for its value

A useful measure of spatial variation in the values of a variable z is the semivariance, which is half the average squared difference in z values between pairs of sample points. The key to investigation of the semi-variance is the construction of a semi-variogram, which is a plot of the semi-variance, as a function of distance h. At a distance referred to as "range", the semi-variance levels off to a relatively constant value, referred to as the "sill". This implies that beyond this range, z values are no longer spatially correlated.

Figure 2. NDVI map of a part of ‘Kanto district’ of Japan acquired by ‘AVNIR-2’ on ‘ALOS’ on August 29, 2006. Small rectangular area encircled by white dotted line is almost of the same area as the NDVI map in Figure 1.

The variogram can provide the spatial structure or patterns of observed objects on the earth quantifying dissimilarity as a function of separation and direction. Here we skip the effects of anisotropy for simplified analysis.

As is shown in the following equation, we introduce two sets of parameters that represents the characteristics of variograms, that is, two ‘sills’ and ‘ranges’. By nonlinear least squares regression method, we can derive two sets of characteristic parameters of variograms which can let variograms be fitted to ‘nested spherical model’ (Wackernagel, H., 2003) :

$$\gamma(h) = \begin{cases} \sum_{k=1}^{2} Sill_k \left[\frac{3}{2}\frac{h}{Range_k} - \frac{1}{2}\left(\frac{h}{Range_k}\right)^3 \right] & for\ \ 0 < h < Range_k \\ \sum_{k=1}^{2} Sill_k & for\ \ h > Range_k \end{cases} \qquad (2)$$

where sill1, range1, sill2 and range2 are defined by non-linear least squares regression fitting of calculated semi-variances from NDVI maps to the ‘nested spherical model’ (Garrigues, S., 2006; Isaaks, E.H., 1989). We can identify the difference between two areas i.e. "range" is larger for area, which contains much natural objects such as vegetation than for area like urban area with short-range which contains many artifacts. Since it demands vast computation cost for calculation of semivariances for remotely sensed scenes, we use ordinary simple 'random sampling ' method to select sampling pixels from the target areas.

To extract interesting and important features of variograms in certain range of 'lag's where variograms would show rich vegetation characteristics, variograms and their fitted curves are calculated by nonlinear least squares regression fit to nested spherical model in the above equation. It is interesting shown in Figure that two types of rich and poor vegetation areas show their intrinsic spatial pattern in variograms. Variograms in urban areas show almost zero slope in the range of 'lag' (500m < |h| <1000m), while in richly vegetated areas have slower increase of variogram in that range.

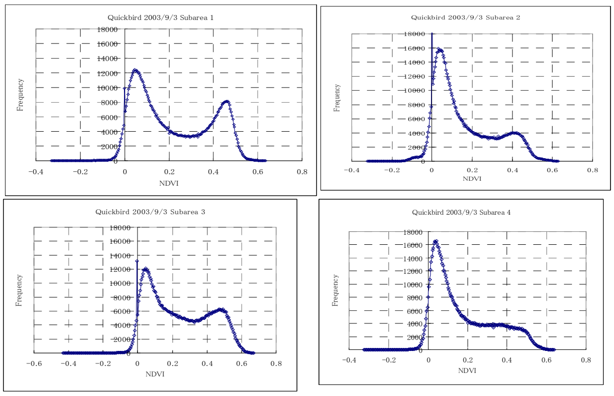

Figure 3. Comparison of histograms of NDVI values derived from 'Quickbird's multi-spectral radiance values in four sub areas divided from Figure 1. Sub areas are labelled by a1, a2, a3 and a4 sequentially from the top left to the right, then the bottom left to the right. Histograms of sub area 1 and 3 show the characteristics of richly vegetated areas.

Though the NDVI map can indicate the degree of vegetation at each point or pixel and the vegetation distribution shown in Figure 1 and 2, it seems to be difficult to estimate rather global context of vegetation coverage in larger area.

Let us divide the area of 5.2km x 5.3km in Figure 1 into four sub-areas labelled by a1, a2, a3, and a4 for further exploration of spatial characteristics of NDVI maps.

The labelled areas a1, a2, a3 and a4 correspond to upper left, upper right, lower left and lower right of the area in Figure 1, respectively.

Comparison of the histograms of NDVI values in four sub-areas is shown in Figure 3 and the distinctive characteristics of vegetation distributions for each sub-area reveals the importance of histograms as a whole.

Figure 4 shows the similar aspects of histograms of NDVI values acquired by AVNIR-2 on the ALOS with the spatial resolution of 10m coarser than Quickbird.

In spite of the difference of sensor spatial resolution and other properties between ALOS and Quickbird, it is found that the semi-variogram's attribute, longer 'range' value seems to have nearly common feature between the two.

Here the comparison of semi-variograms of NDVI values by Quickbird in four sub-areas is shown in Figure 5. The semi-variograms by ALOS also shows the similar characteristics to

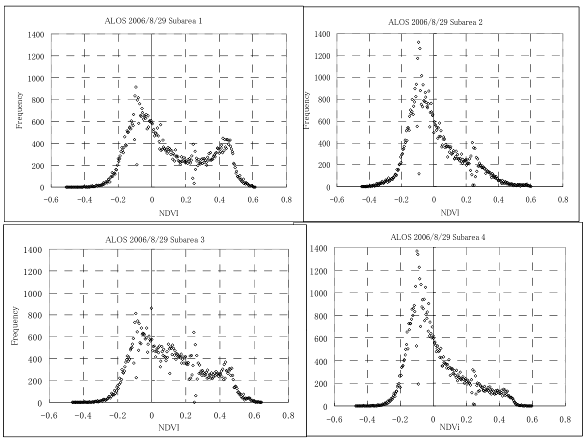

Figure 4. Comparison of histograms of NDVI values derived by 'ALOS AVNIR-II' sensors in four sub-areas. The distribution of NDVI values by 'ALOS' looks shifted to lower NDVI values by about 0.15.

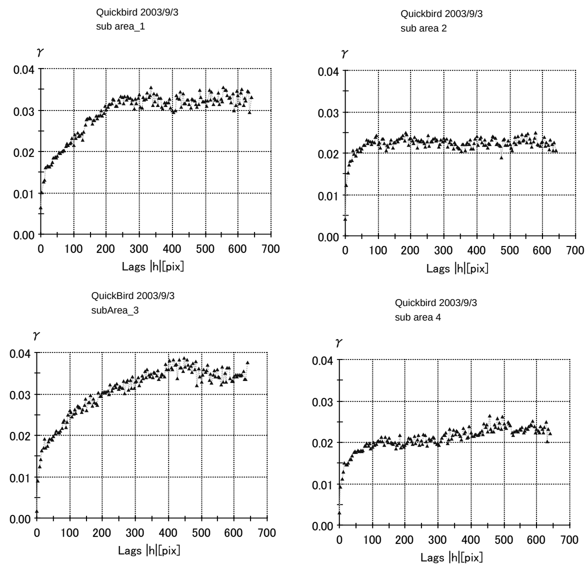

Figure 5. Comparison of semi-variograms of four sub areas divided in a similar way to Figure 2. The features of semi-variograms manifest the differences in both 'sill' and 'range' between high-density vegetated sub-areas and low-density ones.

that by Quickbird.

As seen in Figure 5, it is undoubtedly difficult work to determine the attributes of semi-variograms without any ambiguity.

So as to mitigate the ambiguity in determining those 'sill' and 'range' values, the method of fitting semi-variance data to 'nested spherical model' in equation (2) has been employed by a non-linear least squares regression. Figure 6 shows the fitting

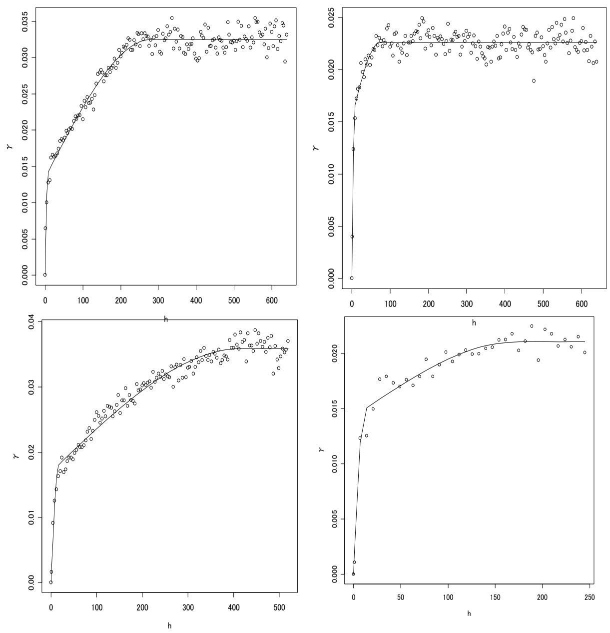

Figure 6. Fitted curves of semi-variograms to a combined spherical model with two 'sills' and 'ranges' in four sub-areas. Urban areas which contain less vegetation show a short value of semi-variogram's 'range' and fluctuating semi-variances around the 'sill' of semi-variograms as seen in sub-areas 'a2' and 'a4'.

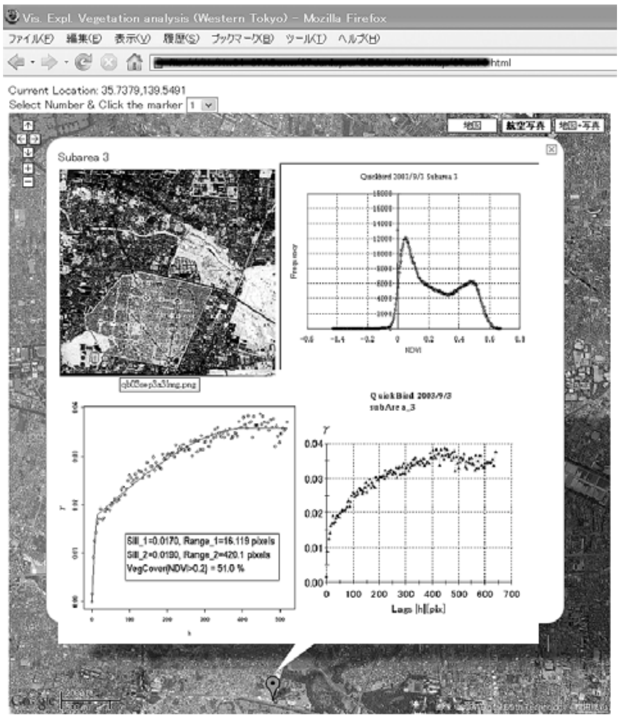

Figure 7. A snapshot of a browser image on the display as an example of map-based Web application that shows 'Google maps' as a background and an overlaid set of NDVI map, histogram and a semi-variogram for sub-area whose center is indicated by a marker.

results by each curved line among scattered plots in each sub-area.

4. EFFECTIVE USE OF SPATIAL DATA

Since the release of Google Maps API in 2005 enables us to integrate Google's maps with geo-located data such as current NDVI maps etc., it will be certainly easier for us to utilize and explore spatial data for various analysis of geo-spatial properties from earth observing satellite data.A tentative map-based Web application is now constructed and it is realized that this type of Web application might become useful tool for obtaining the specific features from various geo-statistical results such as NDVI maps, histograms, semi-variograms and its analysis etc.Figure 7 shows one of the examples of Web application linked to Google Maps.It is furthermore expected that more several visualized results can be displayed in a multi-layered manner and become a powerful tool for exploration of spatial characteristics of various objects on the earth.

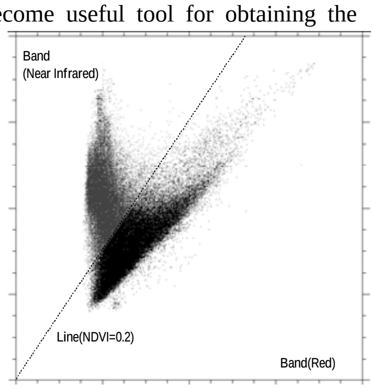

Figure 8. Scatter-plot of near infrared vs. visible red radiance values of 'Quickbird' sensor in a sub-area on September 3, 2003. A crossing line of plotted area indicates the threshold value of NDVI of 0.2 for calculation the percentage of vegetation coverage in the sub-area.

It is demonstrated in Figure 9 that one of the attributes of semi-

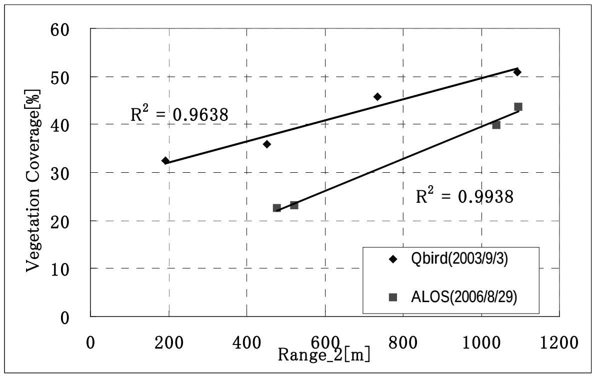

Figure 9. Correlation of vegetation coverage with longer 'range' value of semi-variogram of four sub-areas acquired by both 'Quickbird' and 'ALOS'. Unit of horizontal axis is converted to meters from their pixels. The threshold values of NDVI for calculation of vegetation coverage are 0.2 for 'Quickbird' and 0.12 for 'ALOS', respectively.

variograms, 'range' shows fairly strong correlation with a vegetation coverage ratio to the entire sub-area. In order to obtain the threshold value of NDVI which decides whether the pixel belongs to vegetation area, a scatter-plot of near infrared vs. visible red radiance values is available shown in Figure 8.
It seems to be appropriate that the threshold value of NDVI for ALOS data might be 0.12 smaller than that for Quickbird.

5. CONCLUSION

It is concluded that satellite data with high spatial resolutions is utilized effectively for vegetation analysis by the current visualization method and an interesting relation between vegetation coverage of the selected area and the variogram's attributes of NDVI maps have been found by the present geo-spatial analysis

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