Classification with Seasonal Variability using Harmonic Components: Application for Remotely-sensed Images of Korean Peninsula

Sang-Hoon Lee and Hyun-Ki Hong

[1]Department of Industrial Engineering, Kyungwon University, Seongnam, Korea
Tel.:+8231-750-5367 Email : shl@kyungwon.ac.kr

Abstract: Multitemporal approaches using sequential data acquired over multiple years are essential for satisfactory discrimination between many land cover classes whose signatures exhibit seasonal trends. At any particular time, the response of several classes may be indistinguishable. Using the estimates of periodogram which are obtained from sequential images, the periodicity of the process have been incorporates into multitemporal classification. The Normalized Difference Vegetation Index (NDVI) was computed for seven-day composites of the Advanced Very High Resolution Radiometer (AVHRR) imagery over the Korean peninsula for 1996 - 2000 using a dynamic technique.

Keywords : Multitemporal Classification, Seasonality, NDVI.

I. INTRODUCTION

The development of multitemporal techniques has been primarily motivated by the difficulty in discriminating between surface material types based on the spectral signatures at a single point in time. However, statistical approaches for the analysis of multitemporal remotely sensed images remain largely unexplored, and few are designed to preserve the sequence contains abundant, useful information. This study is to present observational evidence to show the potential for improved information extraction with a sequence of multitemporal data.

Analyses of the relations between AVHRR spectral measurements and vegetation related phenomena have been exceptionally successful and have encouraged great interest in the AVHRR sensor as a global vegetation observatory. The unique capacity of the AVHRR to resolve landscape at reasonable spatial resolution and high temporal resolution is critical to this type of research. Multitemporal remotely sensed data have been shown to be successful in monitoring seasonal trends in phonological processes. Multispectral reflectance data have been transformed and combined into various vegetation indices to minimize the variability due to external factors. The most commonly used vegetation index, NDVI is strongly dependent on the phonology of vegetation, and the NDVI versus time profile then reflects each vegetation's seasonal development history. The seasonality of vegetation types can be represented with a harmonic model. The parameterization of the model provides physically interpretable values with which to characterize the seasonal development of a vegetated pixel for multitemporal classification. The classification based on harmonic components reflects different sources of temporal variation.

To test the concepts, the NDVI images were computed for seven-day composites of AVHRR imagery over the Korean peninsula acquired from 1996 to 2000, and the harmonic components from this five-year sequence were estimated via spectral analysis. The effective temporal resolution of this data is reduced by cloud occurrence and sensor noise. This prevents the use of efficient statistical method based on the observations of regular time interval. In this study, the "dynamic" compositing technique [1] was used to recover missing measurements. Vegetation types were then classified, using the multistage hierarchical clustering algorithm [2].

II. HARMONIC MODEL

Many physical processes that have been sensed and displayed in the image from the land exhibit temporal variation with seasonal periodicity. The process of seasonality can be represented with a harmonic model shoes components are assumed to be only due to target characteristics. Thus, the temporal sequence of each pixel has a harmonic model according to the seasonal profile of its class.

A sample image is considered as a set of n pixels and the intensity process can be represented in the form

$$X_t = m_t(c) + e_t \qquad (1)$$

$$m_t(c) = \{m_{t,c(i)} = a_{c(i)} + A_{c(i)} \cos w_{c(i)} t + B_{c(i)} \sin w_{c(i)} t\}$$

where $c = \{c(i), i = 1, \cdots, n\}$ is an integer valued random vector related to a particular configuration of classes, m_t is a mapping vector of c into real values at time, e_t is a noise random vector at time t, and $a_{c(i)}$ is the constant mean level. The coefficients A and B are the harmonic components associated with the class *c(i)* of the *i*th pixel. In the process of (1), the class *c(i)* can be characterized using $\{a_{c(i)}, w_{c(i)}, A_{c(i)}, B_{c(i)}\}$. This set of the parameters contains temporal information that naturally combines multiple sequential data sets.

III. APPLICATIONS

For the individual observed processes of each pixel on the given image, the periodograms [3] were computed, and the main peaks in the frequency spectrum signal were selected based on Fisher's test [4] respectively. By dynamic compositing, the sequence of 243 NDVI images of 600×999 for 5 years was generated with seven-day intervals from the AVHRR data observed on the Korean Peninsula from 1996 to 2000. Only 384 pixels do not have the 1st main peak at the point corresponding to one year cycle in the frequency spectrum signal processes of NDVI image series.

The unsupervised classification using the multistage hierarchical clustering [2] was applied to the 3 band data with the mean values of 5-year's NDVI series and estimated periodogram values associated with one year period. It results in 8 classes. The results of the multitemporal classification are presented in Figs. 1 and 2. The class map shows in Fig. 1 and the Fig. 2 demonstrates the observed mean processes and estimated harmonic temporal pattern for each class respectively.

4. COCLUSIONS

Various multitemporal techniques for analyzing remotely-sensed images have been developed, but conventional approaches for multitemporal classification have usually used image data with low temporal resolution for a limited time period. An approach based on the harmonic model may be the most plausible temporal technique to analyze a sequence of the images that are acquired regularly at short time intervals for processes that exhibit seasonal trends such as vegetation activity.

References

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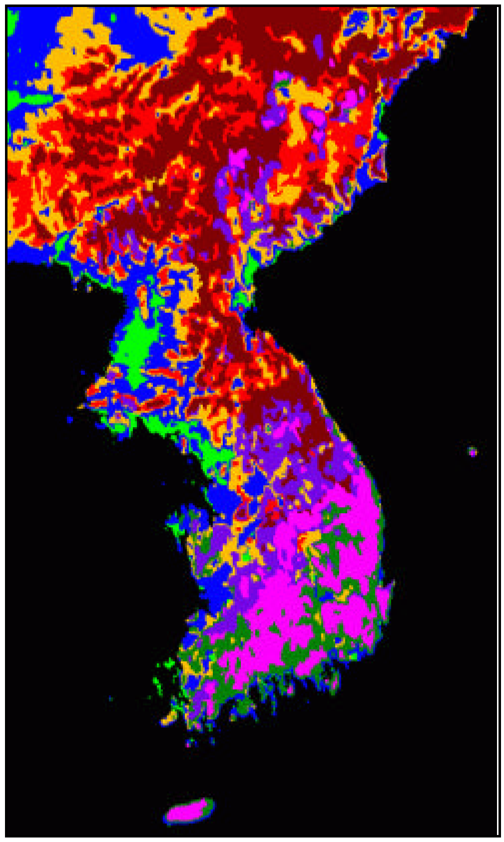

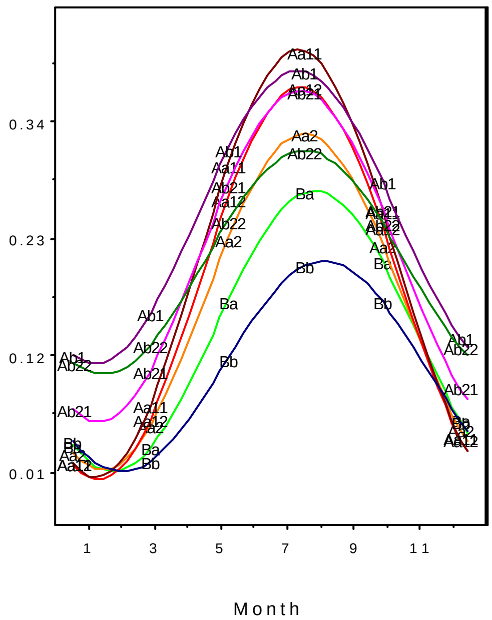

Fig. 1. Classification results: class map and estimated harmonic patterns of 8 classes

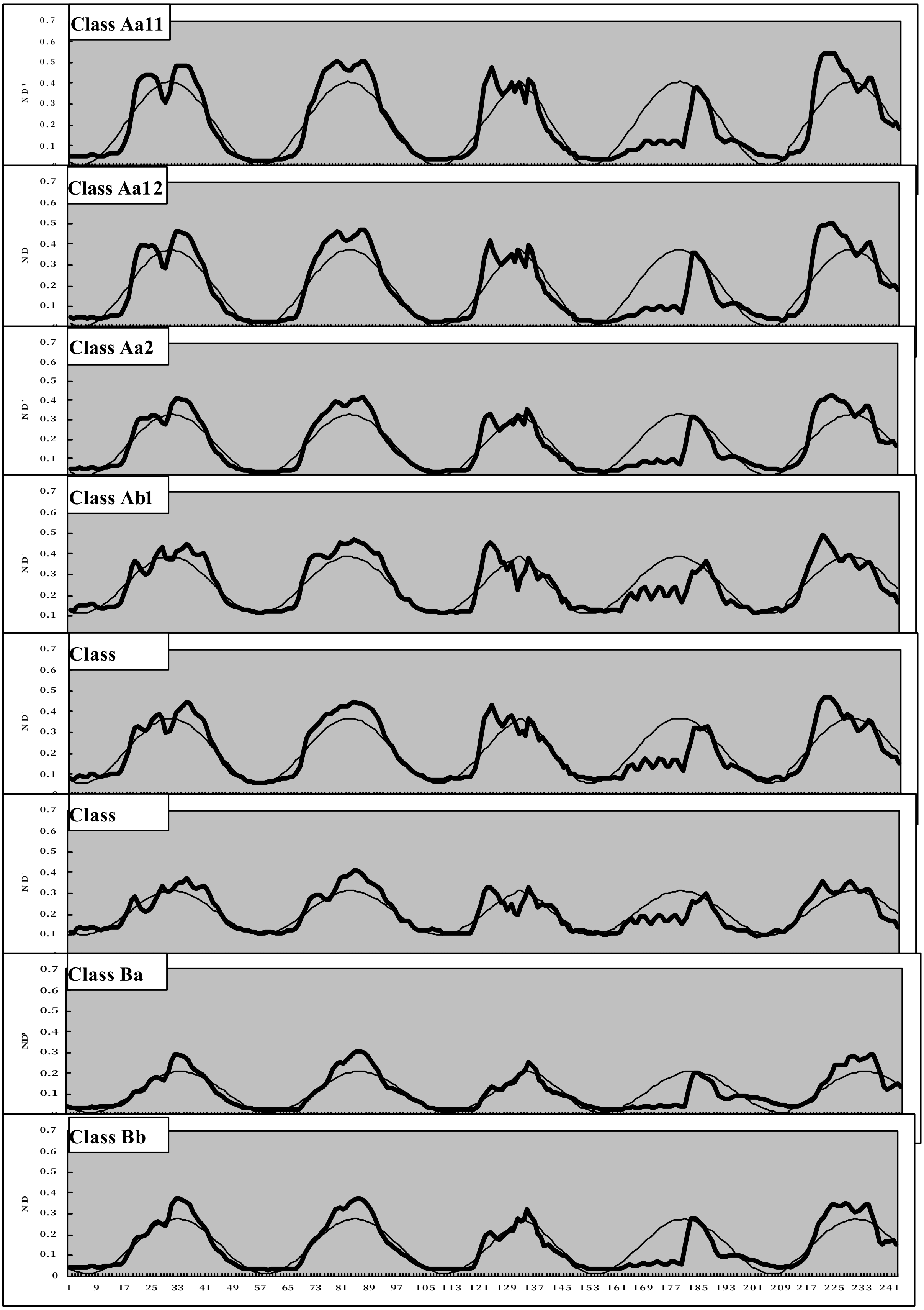

Fig. 2. Mean processes of NDVI observations (thick line) and estimated harmonic patterns (thn line) of 4 classes.