Land Cover Classification on the Korean Peninsula Using Multi-temporal MODIS and GOCI Data

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ABSTRACT: Land cover data are required in the analysis of environmental processes and problems for improving or maintain living standards at current levels. They are used in an important ways in climate change studies and analysis and monitoring of ground state changes. In this study, we propose a land cover classification method by characterizing multi-temporal pattern in Modis and GOCI NDVI time series data. We applied it to the Modis and GOCI multi-temporal data over the Korean Peninsula and compared the classification results. Since many parts of the satellite image data are unobserved or have malicious information, data restoration process is essential to estimate the accurate temporal characteristics. In this paper, an adaptive reconstruction system is employed to reconstruct a series of NDVI time series at real-time intervals. Then, a harmonic analysis is applied to the reconstructed NDVI data for classification of the land covers. The vegetation type of the surface varies with time and has seasonal variation characteristics. The time series of vegetation with seasonal characteristics can be modeled by using harmonic function. In this study, multi-periodic harmonic models were used: the four cycles (1 year, 6 month, 3 month, 1 month cycle). Classification was carried out using the reconstructed NDVI data of MODIS and GOCI for 5 years from 2012 to 2016. The results show that the proposed methodology can be usefully employed for land cover classification and change detection over the Korean Peninsula using MODIS and GOCI time series data.

1. INTRODUCTION

Remote sensing is a very useful tool to provide quantitative and qualitative land-cover information as a cost-effective means through image processing techniques. Various Image processing techniques to extract land use/cover information from satellite imagery have been developed for the last several decades. Land cover data are needed in the analysis of environmental processes and problems for improve or maintain living standards at current levels. They are used in an important ways in climate change studies and analysis and monitoring of ground state changes such as natural resource management, urbanization and desertification. Classification is one of the powerful techniques to provide Earth‘s surface information.

Multi-temporal classification techniques characterizing temporal profiles have an advantage over spectral approach having the inherent difficulty in discriminating surface types based on the spectral signatures at a specific time. In this study, a land cover classification method by characterizing multi-temporal pattern observed in the time series data using a multi-temporal harmonic model is exploited. The physical process of multi-temporal data generally shows the characteristics of a time-series phenomenon with seasonal trends (Brims, 1991; Bloomfield, 1976; Jakubauskas *et al.*, 2001). For this reason, the temporal patterns of land cover through temporal profile is better analysed in the time domain (Reed *et al.*, 2006). Harmonic analysis has been utilized in many applications such as seasonal changes over a long-term period (Bradley *et al.*, 2007). In harmonic analysis, a complex time series can be transformed into sum of a series of sinusoidal waves (Davis, 1986). Multi-temporal classification approach was successfully applied to AVHRR time series data over the Korean Peninsula (Lee. 2003).

Multi-temporal remotely-sensed data have been shown to be successful in monitoring seasonal trends in phonological processes. Especially, reflectance data from Moderate Resolution Imaging Spectroradiometer (MODIS) that is deployed on the Terra and Aqua satellites are obtainable globally on a daily basis and have been shown to have considerable potential for land vegetation studies at a regional and global spatial scale. The GOCI, launched in 2010, has a 2500 km × 2500 km field of view and eight multispectral bands,

including visible and near-infrared bands. The GOCI has spatial resolution of 500 m and temporal resolution of eight-time a day (Ryu *et al.*, 2012). The GOCI also has a considerable potential to understand land covers at reasonable spatial resolution and high temporal resolution and to be utilized for land vegetation studies. MODIS and GOCI are very useful data resources for monitoring land cover from short term to long term. In this study, we propose a land cover classification method by characterizing multi-temporal pattern in MODIS and GOCI NDVI time series data and compare the classification results over the Korean Peninsula.

Since many parts of the observed image data are unobserved or have malicious information, data restoration process is essential to estimate the accurate time-series characteristics. In this study, an adaptive reconstruction system is employed to reconstruct a series of NDVI time series at real-time intervals. Series of incomplete NDVI time series images for five years observed from the Korean Peninsula from 2012 to 2016 was reconstructed by adaptive system into a complete time series of daily intervals. The NDVI time series data were obtained using MODIS and GOCI system. The actual area of the pixel is 250m × 250m in MODIS and an image over the Korean Peninsula has a size of 2590 × 4380 pixels. As for GOCI, it has a size of 1210 x 2190 pixels, each covering 500 m x 500 m.

Then, an adaptive harmonic analysis method was applied to the reconstructed NDVI data to classify the land covers. In this study, four adaptive harmonic models were used, where the four cycles used were 1 year cycle (/ 365), 6 month cycle, 3 month cycle, 1 month cycle. Seasonal characteristics of vegetation type are four factors of harmonic function: mean, wavelength, period, and a wavelength phase. The estimated harmonic components are used as feature vectors for land cover classification.

2. Classification Method

2.1 Data Reconstruction

Satellite data inevitably contain disturbances caused by atmospheric effects and surface anisotropy scattering, which result in unobserved or bad-quality values. They impede estimation of an accurate harmonic model for a certain period of time. In this study, for high-quality data stream, we perform dynamic compositing, which is a feedback system consisting of dynamic synthesis, Bayesian MAP estimation and adaptive harmonic model estimation (Lee, 2008). Dynamic synthesis is a process of continuously recovering unobserved or bad-quality data using an adaptive quadratic polynomial model. The adaptive reconstruction system can generate a completely reconstructed image in real time at a given unit period. In addition, it is possible to analyze the characteristics of surface vegetation change in real time using the harmonic factor estimated every unit period.

2.2 Classification algorithm

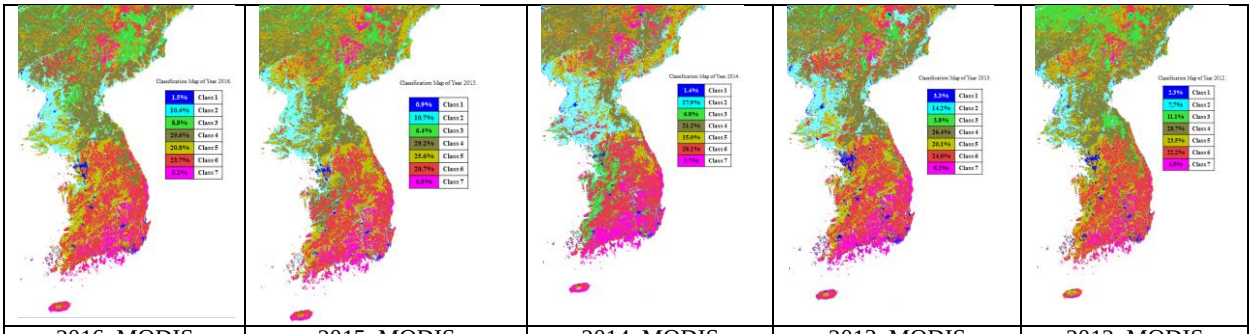
Harmonic analysis is a mathematical procedure to break complex waveforms into sum of comparatively simple sinusoidal components and an additive term and analyze them by comparison with a sinusoidal variation (Bloomfield 1976, Jakubauskas *et al.* 2001). Each of these components represents a periodic pattern of a phenomenon with a unique set of amplitude, period, and phase angle and accounts for a certain percentage of the total variance in the original time-series data set (Davis 1986). A complex model of multiple periods would be more proper to represent inter-annual and inner-annual variations of surface parameters, resulting in characterizing a complex curve. This study proposes a multi-periodic harmonic model, which is expressed as the sum of a series of sine waves.

The time series of vegetation with seasonal characteristics can be modeled by using four factors of harmonic function: mean, amplitude, frequency and phase. In terms of the temporal characteristics in the vegetation process, the average values of the overall greenness are the mean intensity level over the period, the amplitude reflects the range (size of the wave), frequency is the seasonal periodicity, and the phase represents the initiation time of variation. Vegetation types can be distinguished by the parameters of the harmonic components. Thus the estimated harmonic

components are used as feature vectors for land cover classification.
In this study, a multi-stage hierarchical clustering technique was employed for unsupervised classification (Lee, 2003). The multi-stage algorithm consists of two stages. In the first stage, local segmentor, region-growing segmentation is performed by employing a hierarchical clustering procedure with the restriction that pixels in a cluster must be spatially contiguous. In the second stage, global segmentor, hierarchical clustering is carried out for the segments resulting from the previous stage without spatial constraints for merging. The local segmentation can be considered to be a stage to reduce the obscurity in the image pattern, whereas the global segmentation a classification stage in which the image is grouped into meaningful regions.

3. Results and Discussion

In this study, the proposed algorithm was applied to MODIS and GOCI NDVI sequential images of daily intervals over the Korean Peninsula for five years from 2012 to 2016. In MODIS, the actual area of the pixel is 250m × 250m and one image has 2590 × 4380 pixels. A single GOCI image has 1210 x 2190 pixels, each having a size of 500 m x 500 m.
First, data reconstruction was performed in MODIS and GOCI NDVI time series to build the high quality data stream. Then multi-periodic harmonic analysis was applied to the reconstructed MODIS and GOCI data. For adaptive harmonic analysis, four adaptive harmonic models were used: a one-year cycle (period), a six-month cycle (period), a three-month cycle (period), and a one-month cycle (period). The parameters of harmonic components are estimated from the reconstructed NDVI time series at the end of each year.
The estimators of multi-periodic harmonic components are evaluated for the selection of meaningful elements to classify land-cover types. In this study, a feature vector is composed of the mean value, the amplitude of the one-year period, the phase of the one-year period and the amplitude of the half-year period based on the values of the estimators.
The classification results of MODIS and GOCI NDVI data for 5 years from 2012 to 2016 are compared in Fig. 1. Classification map is consisted of seven classes and the percentage shown in the legend represents the area occupied by each class. Classifications results of MODIS GOCI data show similar distributions of vegetation each year. In this classification, the first class (Class 1) corresponds to the urban area, and the northern part of the peninsula has the second, third and fourth classes (Class 2, 3 and 4). The vegetation types of the fifth, sixth and seventh classes (Class 5, 6, 7) are mainly distributed in the southern part of the Korean peninsula. The average intensity level in the southern region is higher than in the northern region, but the northern region has higher amplitude.



2016 MODIS	2015 MODIS	2014 MODIS	2013 MODIS	2012 MODIS
2016 GOCI	2015 GOCI	2014 GOCI	2013 GOCI	2012 GOCI

Fig. 1. Classification Map using 4 Harmonic Components for MODIS and GOCI NDVI of Year 2016-2012

Fig. 2 shows the harmonic patterns of vegetation for each class of MODIS and GOCI NDVI data for 5 years from 2012 to 2016. Comparing these results with those of MODIS, the distribution of vegetation types doesn't show any significant difference, but the mean intensity level is lower in GOCI and the amplitude is slightly higher in MODIS.

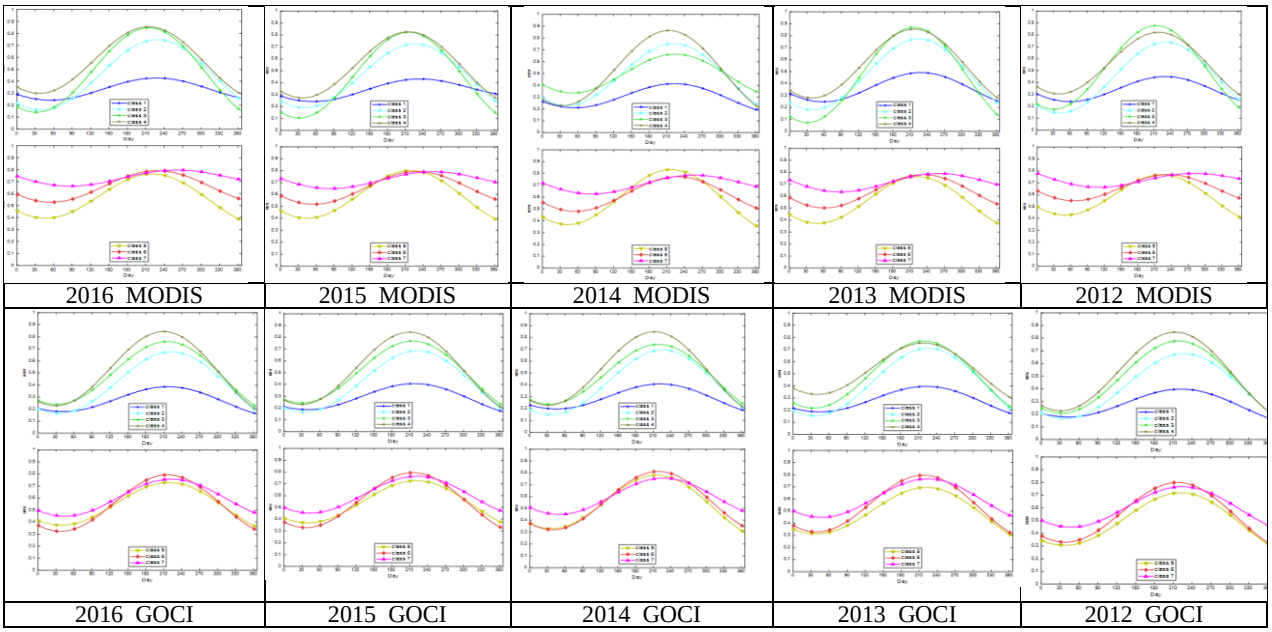


Fig. 2. Harmonic pattern for each class of MODIS and GOCI classification map

4. Conclusions

Classification is a very useful technique for extracting land-cover information in analysis of remote sensing data. Time series analysis provides a better approach to explore vegetation phenology and dynamics for monitoring land-use/cover change than spectral-based change detection techniques. In this study, multi-temporal classification method based on harmonic model is tested for a sequential of remote sensing data collected regularly at short time interval. Harmonic analysis of time series data provides an appropriate approach for monitoring inter-annual land-cover change since temporal variation with seasonal periodicity can be well represented with harmonic components. The results obtained in the study suggest that harmonic analysis can be utilized efficiently in analyzing MODIS and GOCI NDVI time series for land-cover change detection.

Classification was carried out using the reconstructed NDVI data of MODIS and GOCI for 5 years from 2012 to 2016. Comparing the results, while the distribution of vegetation types did not show any significant difference, the average intensity level was lower in GOCI than in MODIS, and the wavelength was measured to be slightly higher in GOCI. The results show that the proposed methodology can be useful for land cover classification and change detection over the Korean Peninsula using MODIS and GOCI time series data.

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