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Invited Papers

Design of Near Real-Time Land Monitoring System over the Korean Peninsula

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ABSTRACT

To provide technological foundation for periodic and real-time land monitoring over the Korean peninsula where the land cover changes are prevailing, the Land Monitoring Research project was initiated as one of five core projects within the Intelligent National Land Information Technology Innovation Project operated by the Korean Land Spatialization Group (KLSG). This four year project can be categorized into two research themes with nine sub-projects. The first research theme is dealing with the real-time data acquisition from aerial platform and *in-situ* measurements by ubiquitous sensor network (USN), ground video camera, and automobile-based data collection systems. The second research theme is mainly focused on the development of application systems that can be directly utilized in several public organizations dealing with land monitoring over the nation. The Moderate Resolution Imaging Spectroradiometer (MODIS)-based land monitoring system that is currently under development is one of such application systems designed to provide necessary information regarding the status and condition of land cover in near real-time.

Keywords : land monitoring, remote sensing, *in-situ* sensing, MODIS, real-time

요 약

국토모니터링기술개발 핵심과제는 지능형국토정보기술혁신사업단의 5개 핵심과제 중 하나로서 토지피복변화가 빈번한 한반도 전역의 국토변화를 주기적/실시간으로 모니터링하기 위한 기술적 기반을 제공하고자 한다. 이 과제는 크게 두 개의 연구주제를 포함하고 있는데, 첫 번째 주제는 공중 및 지상에서 실시간으로 국토모니터링을 위한 자료 획득을 다루고 있다. 디지털항공사진 및 항공 LiDAR 자료를 실시간으로 획득하기 위한 영상시스템과 USN, 지상 비

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디오 영상, 차량탑재 센서를 통한 지상자료획득 시스템을 개발하여 공중원격탐사자료의 한계를 극복하기 위한 자료획득시스템을 개발하고자 한다. 두 번째 주제는 국토모니터링을 담당하고 있는 공공기관에서 직접 채택 운영될 수 있는 여러 활용시스템을 개발하고 그에 필요한 제반 처리기술을 개발하고자 한다. MODIS위성자료를 이용한 국토모니터링 시스템은 그러한 활용시스템의 하나로서 준 실시간으로 한반도 전역의 토지피복 상황을 모니터링하기 위한 기술을 포함하고 있다.

주요어 : 국토모티터링, 원격탐사, 지상센싱, MODIS, 실시간

1. Introduction

The monitoring of land cover changes is essential part for land use policy as well as for environmental conservation. Due to the rapid urbanization and industrialization, the Korean peninsula has been very vulnerable to land use and land cover changes during the last several decades. In addition, land cover status in this region has been also sensitive to environmental perturbations such as natural disasters like flooding and forest fire. Furthermore, it has been very difficult to obtain reliable information regarding the land use and land cover status in North Korea because of the confined political situations. There have been only a few studies related to the land cover status in North Korea (Lee *et al.*, 1999; Kim *et al.*, 2007).

Although it has been a great concern to monitor the spatial extent and distribution of land use and land cover changes over this heavily populated region, there is no single standard and operational system for land monitoring over the nation. There have been a few attempts to derive land cover and land use information from satellite remote sensor data (Lee, 1994; MOE, 2001; Chung *et al.*, 2006). However, these attempts were limited to at one-time approach and did not furnish continuous monitoring scheme.

Land use and land cover change detection has been a major subject in remote sensing since the first earth observing satellite was launched (Green *et al.*, 1994; Muchoney and Haack, 1994). Since remote sensor data from earth observing satellites can be obtained repeatedly over the same area, they have been very useful to monitor and analyze land cover changes in various regions on earth. While the demand of reliable and consistent land monitoring system is increasing over the Korean peninsula, there has not been an operational system that can provide continuous monitoring tools for detecting, tracking, and predicting various land surface parameters of interest. The objectives of this paper are to introduce the Land Monitoring Research (LMR) core project within the umbrella of the Korean Land Spatialization Group (KLSG) and to describe the near real-time land monitoring system over the Korean peninsula that is one of sub-projects within the

LMR core project.

2. Overview of the Land Monitoring Research core project in KLSG

2.1 Backgrounds

The Korean peninsula has been under the increased level of land cover changes because of the high demand of land developments for urbanization and industrialization, natural disaster, and environmental changes. Although it has been a very crucial to have a suitable monitoring system at national level for continuous and reliable monitoring of land cover and land use changes, there is no such a domestic system in operation. During the last decades, developments of airborne and space-borne remote sensing technologies made it available to acquire necessary data for land monitoring over the wide geographical area. Furthermore, recent advancements in *in-situ* sensing and telecommunication technologies have expanded the possibility of obtaining a reliable national-level land monitoring system that needs comprehensive sets of diverse data sources.

As one of five core projects in the Intelligent National Land Information Technology Innovation Project operated by the Korean Land Spatialization Group (KLSG), the Land Monitoring Research (LMR) project is designed to provide technological foundation for periodic and real -time monitoring of the national land. This core project aims to develop technologies for improving efficiency and effectiveness of decision making

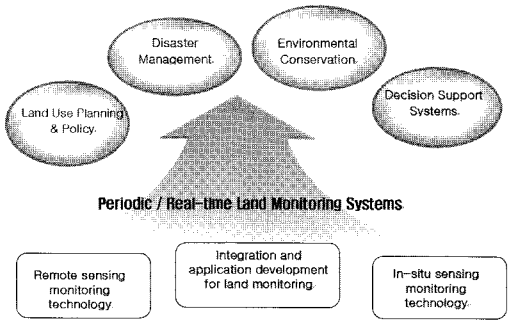

Figure 1. Overall objectives of the Land Monitoring Research Core Project in KLSG

process in various fields such as national land management, environment conservation and disaster management. Figure 1 shows ultimate objectives of this core research project. Research categories are basically divided into three groups of 1) data acquisition and information extraction by remote sensing technology, 2) data acquisition and information extraction by *in-situ* sensing technology, and 3) application developments. Throughout these technological developments, periodic and real-time land monitoring systems can be built for the national land use planning and policy, disaster management, environmental conservation, and various decision support systems.

2.2 Research themes

Primary research themes of the LMR project were originally established by the strategic initiative prepared by the government. There are several monitoring targets that vary by spatial and temporal scales. Major monitoring targets include land cover /land use, topography, urban structures (building, road), forest, agriculture land, natural disasters

(flooding, forest fire), and water body. Although the LMR core project may not cover all these monitoring targets, its research and development was designed to include diverse topics ranging from fundamental theoretical aspects to particular application developments.

The LMR core project started in September, 2007 and will last until June, 2011. During the first year (September 2007~August 2008), land monitoring research plans were established and several pilot studies were performed to derive essential technologies and applications that are suitable for the land monitoring for Korea as well as for the other parts of the world. Table 1 shows the 2nd year research projects that were re-designed after the careful evaluation of the first year research and developments.

The first theme of the LMR core project is related to the data acquisition for land monitoring. Recent advancements in remote sensing technologies provide several types of spatial data by digital aerial camera, LiDAR, synthetic aperture radar (SAR), and multi- and hyper-spectral scanner. Since the acquisition of these airborne and space-borne data is currently in operational stage and most of them are currently available in Korea, the data acquisition sub-projects are mainly related to other than remote sensing methods. There is only one sub-project that is related to remote sensing data acquisition system. Some applications like disaster management require real-time aerial image for the on-site maneuvering (i.e., relief operation, forest fire control). The first sub-project in the data acquisition theme is to develop a system to obtain geo-referenced aerial images and LiDAR in real-time. This system mainly use unmanned aerial vehicle (UAV) as a platform for the small format digital camera. Several subsystems and data processing algorithms are under development and they include data communications between a aircraft and a mobile receiving station, sensor stabilization techniques, and real-time geo-referencing methods.

The other three sub-projects in the data acquisition theme are related to *in-situ* sensing technologies. Although aerial and space remote sensing images have been primary data sources for land monitoring, they are not adequate for continuous and real-time monitoring of some surface features due to the limitation in temporal and spatial resolution. In other cases, the information extracted from remote sensing data may not be accurate enough. *In-situ* measurements have been an important part to calibrate remotely sensing data, to assist image classification and interpretation results, and to assess the accuracy of the products of remotely sensed data. In this core project, three sub-projects are dealing with the development of techniques for real-time data acquisition for land monitoring by USN, ground-based video images, and vehicles-based sensing system, which have been used to monitor structures (Pyeon *et al.*, 2006). These *in-situ* data acquisition projects are utilizing very advanced technologies of USN, wireless networking, and physical or environmental sensors and intending to provide necessary information that are not easily available from aerial and spatial remote sensing methods.

The second theme of the LMR core project is mainly to develop data processing methods and

Table 1. Research themes and sub-projects for the second year of the Land Monitoring Research core project.

Themes	Sub-project	Contents
Data acquisition	1) Real-time airborne data acquisition systems	- UAV based aerial sensor system design - data communication - sensor stabilization - mobile receiving station - real-time georeferencing
	2) Ground based in-situsensor network	- USNfor land monitoring - ground and sub-surface land monitoring data acquisition - geotechnical parameter mapping
	3) CCTV-based monitoring system	- ground-based video image data acquisition - integration of different video image format - real-time supply networking of video images
	4) Automobile-based monitoring system	- mobile ArcSAR system - public transportation based data acquisition and mapping system - environmental data mapping - video image collection
Data processing and Applications	5) Change detection methods based on aerial data	- automatic extraction of surface features - Lidar change detection - change detection by aerial digital image - change detection by multisensor data fusion
	6) Portal system for land monitoring information service	- design & implementation of portal system - integration with other government operating land information services
	7) Renewal system for updating existing digital map	- Automatic & semi-automatic extraction of 3D terrain data - orthoimage based map updating - user-specific map updating system
	8) Watersheds monitoring support system	- automatic parameter extraction for watershed management - real-time data provider for water-related models
	9) Land & environmental monitoring system of the Korean peninsula	- near real-time MODIS based monitoring system without receiving station - MODIS based change detection algorithms - integration of remote sensing and in-situ measurement - soil moisture mapping

application systems that can be implemented in operational uses for wide range of land monitoring fields. Automatic and semi-automatic extraction of changed surface features is main target for

the research and development of a sub-project that includes change detection techniques with digital aerial photographs, LiDAR data, and multi -sensor data fusion. Another key objective of this project is to develop a state-of-art applicable monitoring systems for the practical uses by government agencies and public organizations that are actually in charge of land monitoring operation in Korea. These land monitoring application systems includes the portal system for land monitoring information services, the renewal system for updating existing digital map, the watersheds monitoring support system, and the land and environmental monitoring system of the Korean peninsula. The second theme also includes the integration between remote sensing and *in-situ* sensing technologies. However, since it is somewhat early stage to implement the *in-situ* sensing techniques, particularly for the land monitoring purposes, the integration of these two technologies has not been well established and requires a great amount of research efforts before any practical application.

Primary outcomes expected from the LMR core project include new algorithms, processing modules, and practical application systems that are mainly to enhance societal benefits to the nation by providing suitable and reliable information for various land monitoring practices. Therefore, the research works are conducted with the careful analysis on the technical requirements in which most public agencies need for their land monitoring operations.

3. Korean Peninsula Land Monitoring System Based on MODIS Data

Medium and high resolution satellite data may not be suitable for near real-time land monitoring system over the large geographic area because of the longer than about twenty days of revisit cycles. The near real-time monitoring system over the whole territory of the Korean peninsula should be based on the high temporal resolution satellite data. Low spatial resolution satellite images can provide with a short revisit cycle (usually one day) and low cost or without charge for monitoring in public sectors. As one of such monitoring system based on satellite remote sensing data, AmericaView (http://www.americaview.org/, 2008) can be a good specimen for the Korean Peninsula Land Monitoring System that we will implement. AmericaView is a nationwide program of using remote sensing data for large area land monitoring as well as for the practical uses of local agencies. Figure 2 shows TexasView that provides the visualization viewer within AmericaView program. The TexaxView shows similar functions that illustrate concrete characteristics of our system when the systems will have been embodied.

The Korean Peninsula Land Monitoring System was designed to process raw data of daily MODIS images, to produce Level 1, radiance images, and adequate products for land monitoring purposes in Level 2. MODIS is a key instrument of Terra and Aqua satellites launched by NASA in 1999 and 2002, respectively. MODIS images

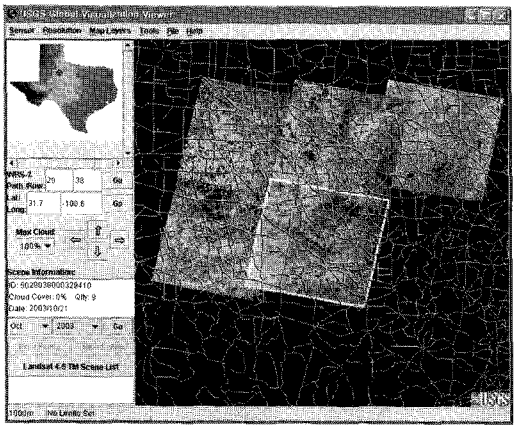

Figure 2. Example of large area land monitoring system: TexasView within AmericanView, which uses remote sensing data for land monitoring (http://www.americaview.org/, 2008).

are composed of 36 bands from 0.4 ~ 14.4 μm with three spatial resolution, 250, 500 and 1000 m. Since MODIS images are provided for free without any license restrictions, users with an receiving system can receive the image data directly from the satellites or users can access the data through diverse sources of existing receiving stations. Our system is designed to obtain daily MODIS data through high speed internet, such as Korea Research Environment Open NETwork (KREONET), in near real-time from existing domestic receiving stations. Therefore, daily MODIS images will be continuously entering to the system and the system is producing radiance data and other products for land monitoring. Since MODIS images are acquired and receiving with high temporal resolution, two times from each satellite in a day, the MODIS images are practically provided to the system in near real-time.

Figure 3 illustrated the composition and generation of land products based on the daily MODIS images. For the processing of MODIS data from level 0 to level 2, our system modified the

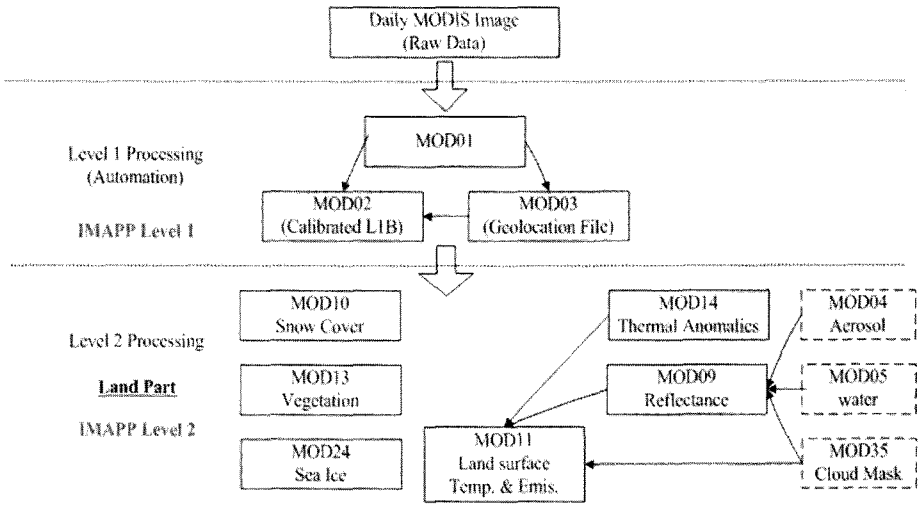

Figure 3. Sequence of MODIS data processing for regional land monitoring

International MODIS/AIRS Processing Package (IMAPP) and the operational EOS processing software developed at NASA. IMAPP is mainly used for the processing from level 0 to level 1 as the basic function. Actually, IMAPP was developed by Space Science and Engineering Center (SSEC) at University of Wisconsin-Madison, and it was also modified from EOS processing package (http://cimss.ssec.wisc.edu/imapp/, 2008). For the level 2 products, we are currently concentrating on the MODIS reflectance data (MOD09) that are probably the most widely used product to extract meaningful information regarding several land cover parameters. Since the MODIS surface reflectance product algorithm, Product Generation Executive (PGE) provided by NASA Goddard space flight center, was mainly developed for global scale observation, it may not be quite effective and accurate for regional and local application. The NASA's original algorithm will be analyzed and enhanced for the application over the Korean peninsula in our system.

Figure 4 shows the comprehensive architecture of the proposed near real-time land monitoring system over the Korean peninsula. The system composed of four modules: basic image processing, MODIS processing, monitoring processing and vector processing. Basic image processing module includes general functions like image display, preprocessing, enhancement, and classification. MODIS processing module include all the procedures from data acquisition to level 2 processing that are shown in Figure 3. Monitoring processing module is the implementation of change detection algorithms for various land monitoring functions that include land cover change detection, forest fire (Son *et al.*, 2006), flooding, and crop monitoring. Vector processing module is for the integration of change information extracted from images with GIS vector data for visualization and practical uses for the general users.

Among the four modules in the proposed system, monitoring processing part includes algorithms for land monitoring such as change detection, local fire detection and land cover classification algorithms etc. These algorithms are under development with the system. The change detection algorithm is based on the temporal profiles which are accumulated reflectance information. Since MODIS images have the high temporal resolution,

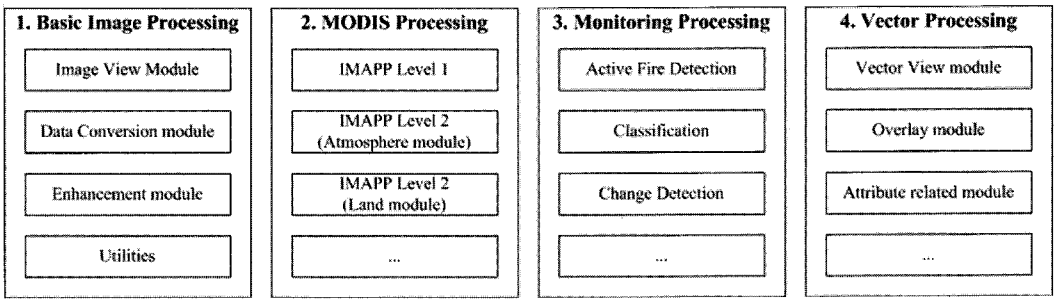

Figure 4. Architecture of the proposed land monitoring system for near real-time monitoring of the Korean peninsula.

comparison of reflectance variation will be the most advantageous method for the long-term land monitoring. Reflectance of a pixel is accumulated within a year, and the reflectance within a year has a specific pattern depending on land cover as shown in the bottom graph of Figure5. For instance, reflectance of near infrared band shows unique temporal pattern within a year according to land cover: vegetation, bare soil, water, city, crop field. Each year has the temporal pattern of reflectance that can be compared with each year to detect changed area. The change detection algorithm implemented in our system is based on the temporal profile method. The manifest changed area such as urbanized area and deforested area shows large differences from the previous temporal pattern.

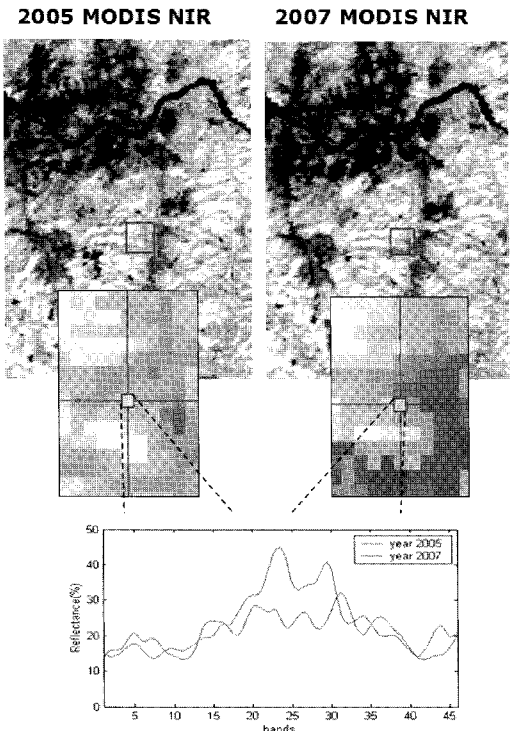

Figure 5. Change detection using temporal profile method

4. Conclusions

Considering the nature and frequency of land cover changes over the Korean peninsula, the government supported research and development projects are very significant to deliver necessary technologies for the effective management of the nation's territory. The Land Monitoring Research project initiated as one of five core projects in the KLSG should answer the fundamental questions, such as spatial content of urbanization and deforestation, flooding damage over North Korea, timely detection of illegal development, content and frequency of forest fires, change of agricultural crop cultivation, etc··· Although recent advancements in remote sensing and *in-situ* sensing technology have enormous capability to gather necessary information for land monitoring, it has not been fully adopted and applicable to real-world situations. Therefore, the LMR core project should include research themes of not only methodology development but also aggregation and application of existing technologies. Therefore, the research and development works should begin with the careful analysis on the technical requirements in which the land monitoring organizations need.

It is often very crucial to provide monitoring data without delay. In particular, the current status and condition of land cover over the whole territory of the Korean peninsula should be

maintained continuously. Development of the near real-time land monitoring system using MODIS data is designed to meet such requirement. Although the spatial resolution of MODIS images may not be quite appropriate to observe detailed land cover phenomena, the high temporal resolution of the image can provide necessary information for timely land monitoring over the peninsula. Technical enhancements of MODIS data processing algorithms, which are originally developed for global applications, can have a great potential to be applicable to wide range of land monitoring practices over the nation as well as many other countries.

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