Urban Change Monitoring using Spectral Mixture Analysis - Case study of Daegu Metropolitan City

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Abstract

Metropolitan cities in Korea are constantly developing and to keep up with changes is an important task for urban planners. Because of their various spatial, spectral, temporal resolution and their low costs, satellite images offer a valuable source of informations for urban monitoring. The method for urban change detection using spectral mixture analysis (SMA) to multi-spectral, multi-temporal Landsat TM(Thematic Mapper) images will be described in this paper.
The SMA calculates the proportion of different endmember for each pixel, which are defined by the user, and provide as a result so-called fraction images. These fraction images are then used to detect those areas, where construction activities have taken place. The fraction images are precisely analyzed and changed areas should be detected, where the urban proportions of one fraction image have significantly changed compared to that of other urban fraction image, resulted from satellite images acquired earlier.
A case study was performed for the areas of Daegu Metropolitan City, using Landsat TM images acquired in June 1987 and June 1997. After the change detection procedure using Landsat TM images, the KOMPSAT EOC images will be used to analyze, what kind of changes has occurred in this location, and this will be the next step after this paper.

Key words : SMA, Endmember. Urban Monitoring

Introduction

The metropolitan cities in Korea are faced with increasing populations and this is a major reason for many major city problems such as increasing pollutions, demand of land, etc, and the future urban development will be confronted with the lack of land. This is a reason for the need of urban monitoring and for the sustainable and planned development of urban region. The ecological monitoring of urban region is a essential task for the urban planner. This task requires a system, with which the city planner monitor and manage the urban areas. The GIS(Geographic Information System) is accepted as a powerful tools for this purpose, because they can handle the large volumes of diverse geographic data for the urban area management. However, due to the rapid changes which occurs in urban areas, regular monitoring is very important to provide GIS with up-to-date informations. Unfortunately, the conventional methods such as field survey are time-consuming and cost-intensive, so that they cannot provide the essential information for the city planner in timely manner and this is a important burden for the decision makers, because they are not equipped with the newest information.

Updating of urban area can be restricted to those areas where the changes have actually occurs. In this sense the task of updating can be devided into two parts, namely where has the change occur and what kind of changes have taken place in this area. This paper focuses on the first part of the questions.

We will use digital Earth observation satellite data in order to answer the first question, because they have an advantage, relative lower cost, regular coverage of interesting site. The lower resolution will be overcome with the later development of techniques.

Spectral Mixture Analysis

There are various change detection methods for analysing satellite images - e.g. principal component analysis, regression analysis, image rationing or comparing image indicies. In 1989 has Singh summarized these methods in two categories, namely.

1. comparative analysis of independently produced classifications for each of the image
2. simultaneous analysis of multi-temporal image.

The spectral mre analysis(SMA) is one of the method, which is under second category and normally used to analyse hyperspectral satellite images. The SMA calculatne the proportion of different land cover components for each pixel, as defined by the user as endmembers. The endmembers are defined by their spectral signatures, and there are diverse selection methods such as the use of laboratory data, the use of training area, direct selection of pixel vectors within the image or the combination of these methods. The maximal number of endmembers are limited by the number of spectral bands of the used satellite images, which means in this study 7 maximal endmembers can be selected, because the Landsat TM images has 7 bands. In many cases the number of endmembers are less than the number of available bands. To decide the number of endmembers the principal component can be used, because the number of components, which show the meaningful information equals the smallest number endmembers needed to generate a linear mixture model.

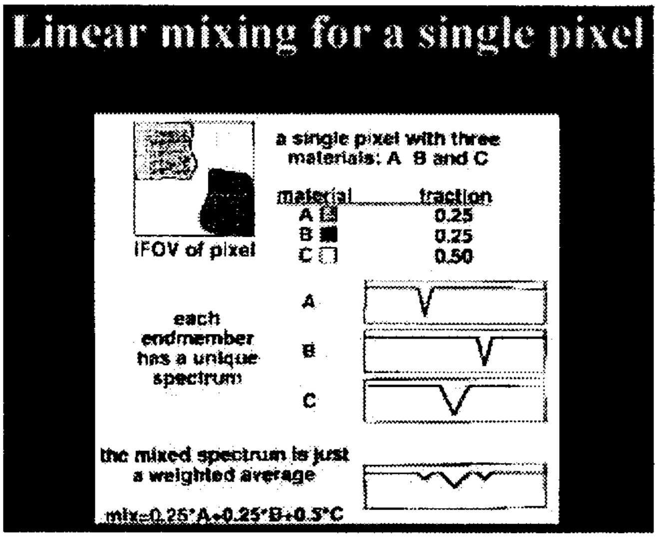


Fig. 1. Linear Unmixing for Single Pixel

Once the number of endmembers are decided, the fraction of each endmember in each pixel can be calculated using the equation for unmixing (Adams et al 1989):

$$DN_c = \sum_{n=1}^{N} F_n \bullet DN_{n,c} + E_c \quad (1)$$

where

$$\sum_{n=1}^{N} F_n = 1 \quad (2)$$

with

DN_c : radiance in channel c

N : Number of endmembers

F_n : fraction of endmember n

$DN_{n,c}$ radiance of endmemnber n in channel c

E_c : error for channel c of the fit of N spectral endmembers

Equation (1) calculates the radiance values of each pixel in each channel to the equivalent proportion () of each endmember as defined by the endmember (). It is assumed that, every pixel is a linear combination of endmembers, it means the spectral signature of each pixel can be generated by the combination of spectral signatures of every endmembers. The results of SMA are so-called fraction images which show the proportion of each land cover component within each pixel.

In order to perform change detection multitemporal fraction images of one land cover component, namely artificial surfaces, can directly be compared.

Case Study

In order to verify the availability of the proposed SMA method for the urban change detection, the whole Daegu Metropolitan City was selected as a study area. The small 3 area will be studied specially, because a large construction activities were taken place at that areas. The area A(Chilgok) and C(Siji) contains a large construction of residence, which were developed between 1988 and 1996. The area B(Sungseo) were developed as a industry zone. For the urban growth monitoring these three areas will be considered because of their changes during 1987- 1997.

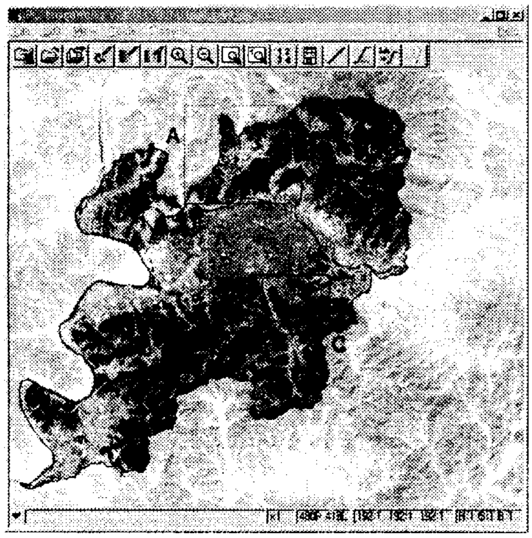


Fig. 2. Study Area

Two Landsat 5 mages were available for the study, acquired at 23, June 1987 and 18, June 1997 The six reflective bands(B1, B2, B3, B4, B5 and B7) covering the visible light and parts of near and middle infrared from the 7 available bands were used for the analysis. The two Landsat TM 5 images were acquired at the same month of the year, and this is important for the minimization of artifacts of seasonal variation for the study.

The Landsat image, which was acquired at 1997, was rectified using 13 Ground Control Points and the total RMS error was 0.537892. The 1987 image was rectified using 14 Ground Control Points and the total RMS error was 0.589361. The work flow for the detection of changed area is showed in Figure 3.

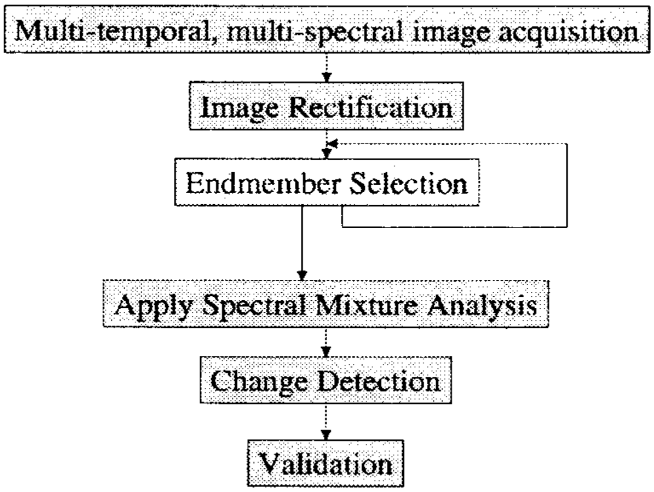


Fig. 3. SMA Change Detection Work Flow

The image rectation for the Landsat TM image, which was acquired at 18, June 1997, was performed using the rectified KOMPSAT EOC image and the rectification for the Landsat TM image, which was acquired at 23, June 1987, was performed using rectified 1997 Landsat TM image.
To decide the mum number of endmembers the principal components analysis were applied for each Landsat images. The results shows that the first three components cover the over 99% of the variation in both cases. The endmembers selected for the analysis represent Water (Blue), Mountains(Green), Artificial Surfaces(Yellow) and Rice Field(Sienna).

Table 1. Principal Component Analysis Results Principle Component Analysis for

Landsat TM 1987. 06.23

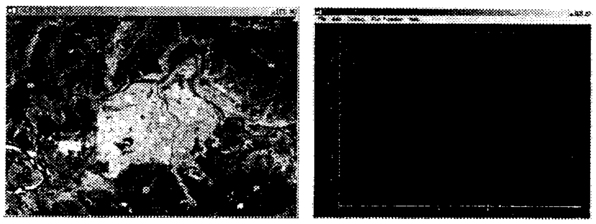
Eigenchannel	Eigenvalue	Deviation	%Variance
1	1700.6099	41.2385	62.31%
2	926.2089	30.4337	33.94%
3	78.9337	8.8845	2.89%
4	13.8306	3.7190	0.51%

5	8.3180	2.8841	0.30%
6	1.1922	1.0919	0.04%

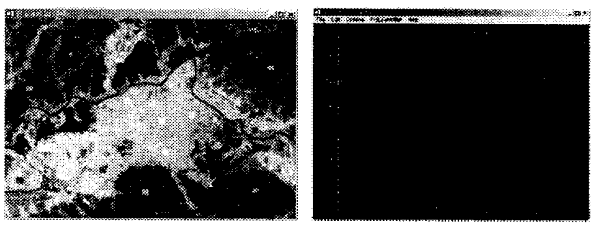
Landsat TM 1997. 06.18

Eigenchannel	Eigenvalue	Deviation	%Variance
1	1677.6420	40.9590	67.56%
2	732.6498	27.0675	29.51%
3	57.1681	7.5610	2.30%
4	8.6603	2.9428	0.35%
5	6.3836	2.5266	0.26%
6	0.5030	0.7092	0.02%

The endmember selection was performed using pixel vector in the image. The endmember water was selected from river and lakes and the artificial surfaces were in the city center and industry zone. The vegetation was taken from mountains and the rice field was selected separately from vegetation, because they have some similar characteristic with urban area. Figure 4 shows the selected endmember and their spectral plot.



1987



1997

Fig. 4. Selected Endmembers and their Spectral Plot(Left:1987, Right:1997)

The SMA was performed on the two images resulting in four fraction images per acquisition date. Figure 5 shows the fraction images for 1987and 1997. In contrast to the original image bands the fraction images do not represent spectral characteristics but can be as continuous thematic layers.

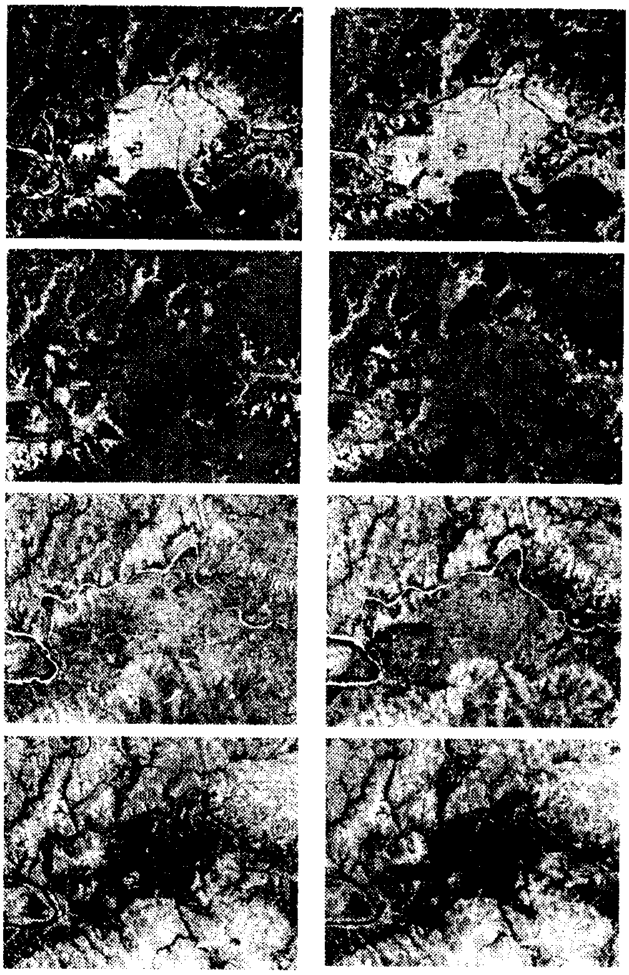


Fig. 5. Fraction Images(Urban, Field, Water and Vegetation)

Change Detection

In order to detect new built up areas the fraction images for artificial surfaces of 1987 images was subtracted from that of 1997. The result is a kind of change map. Only areas of significant change are represented by big numbers(bright areas). The change detection for artificial surfaces was carried out for the whole city of Daegu. The analysis resulted in a change image which indicates those areas where building activities have taken place according to real development. Figure 6 shows the changed areas. The areas, which are bright, can be interpreted as a area, where during 10 years lots of building activities have been occured. Specially in the area Sungseo, Chilgok, Jisan and Kyungsan many developing activities have occurred and in this areas we can see also bright area in the change map.

Results and Discussion

The method to detect the areas where the building activities have taken place using spectral mixture analysis were introduced in this paper. Due to the limitation of the spatial and spectral resolution of the Landsat TM images the small changed areas could not be detected. But the most large changed areas were detected and this result are important for the next step of the study, namely updating the topographic informations using high spatial resolution satellite images like KOMPSAT. To update the topographic informations for the GIS, there are two questions to answer:

1. Where has a change occurred, and
2. What kind of change has occurred in this location.

The study in this paper offers an acceptable way for the answer of the first question and will be further studied.

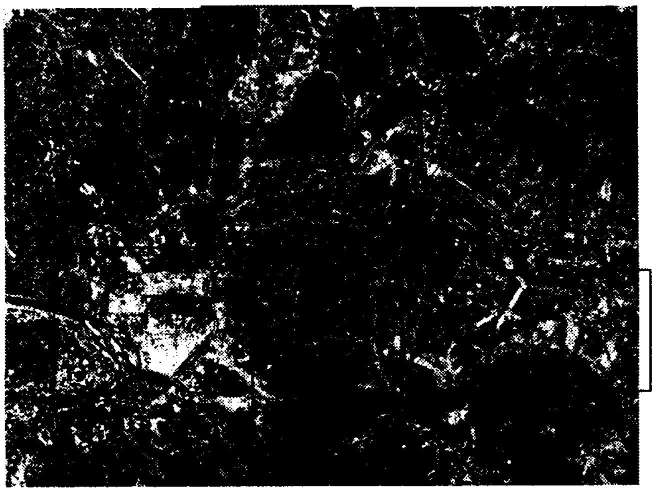


Fig. 6. Change Map of Daegu

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