Spectral Classification of Man-made Materials in Urban Area Using Hyperspectral Data

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Abstract: Hyperspectral data has a great advantage to classify various surface materials that are spectrally similar. In this study, we attempted to classify man-made materials in urban area using Hyperion data. Hyperion imagery of Seoul was initially processed to minimize radiometric distortions caused by sensor and atmosphere. Using color aerial photographs, we defined seven man-made surfaces (concrete, asphalt road, railroad, buildings, roof, soil, shadow) for the classification in Seoul. The hyperspectral data showed the potential to identify those man-made materials that were difficult to be classified by multispectral data. However, the classification of road and buildings was not quite satisfactory due to the relatively low spatial resolution of Hyperion image. Further, the low radiometric quality of Hyperion sensor was another limitation for the application in urban area.

Keywords: Hyperspectral, Hyperion, man-made materials, MTMF, spectral classification

1. Introduction

Full range of spectral information of various surface materials has been available from the imaging spectrometry since middle of 1980's. The hyperspectral images have shown clear advantage over multispectral data for the mapping of mineral and rock types, tree species, and urban land cover types that are spectally similar [1][2][3]. Urban area includes relatively complex cover types of both man-made and natural surfaces. The classification of rather complex urban cover types has been a challenging task and could be improved by using hyperspectral data [2]. The objective of this study is to analyze the capability and limitation of hyperspectral data for the classification of man-made materials in urban area using hyperspectral image data.

2. Methods

1) Study area and dataset used

Seoul metropolitan area, having 25% of total population of Korea, has very complex structures of several man-made materials, such as asphalt, concrete road, various roof types, and buildings. We used Hyperion image data of the EO-1 satellite, which were obtained over the study area on April 3, 2002 (Table 1).

Table 1. Specifics of Hyperion data used in this study.

Items	Specifics
Sensor	Hyperion Level 1R
Brightness unit	W/m^2/sr/micron
Date/Time	April 3, 2002/ A.M 11:00:08
Location	37.55N, 126.98E
Wavelength	356-2577 (nm)
Number of bands	242 (We used only 98 bands because of noise & strip.)
Pixel size	30 m
Image dimension	256C*951R
Data type	2 Signed Integers
Pixel Order	BIL
File format	HDF

2) Data processing

Figure 1 shows the overall procedure to classify the urban features from the hyperspectral data. Hyperion data used for this study shows abnormal pixels that appeared as continuous or intermittent dark strips along the scanning direction. To correct this problem, we used the algorithm developed by [5], in which those abnormal pixels were detected and corrected by neighboring pixels. After the correction of stripping effect, the hyperspectral data were processed to reduce atmospheric influences. Atmospheric correction of converting sensor-received radiance to surface reflectance was performed using Atmospheric CORrection Now (ACORN) program, which is based on MODTRAN radiative transfer model.

Because Hyperion reflectance image has more than two hundred bands, it is necessary to reduce the spectral dimension for further analysis on spectral mixture analysis. Minimum Noise Fraction (MNF) transform, which is similar to principal components transformation, was applied [4]. After we selected the MNF components of good quality, the pixel purity index (PPI) was obtained to find the most spectrally pure pixels that may corresponds to end-members. Using the PPI image and n-Dimensional Visualizer (implemented in the ENVI), we determined the end-members of several man-made materials. For spectral mapping, we used the mixture-tuned matched filtering (MTMF) algorithm. MTMF is a hybrid method based on the combination of well-known signal processing methodologies and linear mixture theory [6]. This method combined the strength of the matched filter method above with physical constraints imposed by mixing theory. The MTMF used linear spectral mixing theory to constrain the result to feasible mixtures and reduced false alarm rates [6].

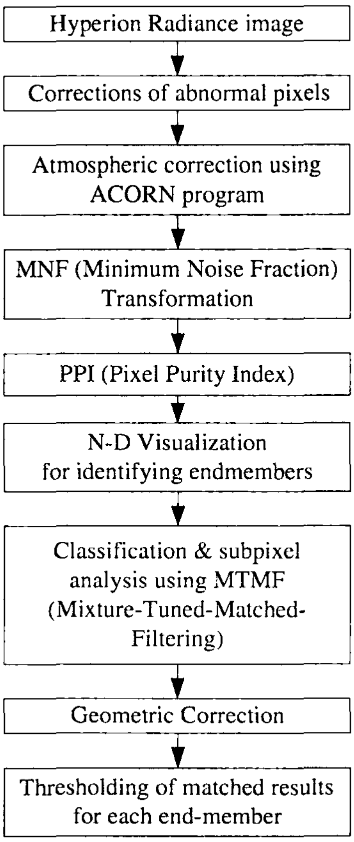

Fig 1. Processing steps of Hyperion image dataset.

3. Results

After the initial correction of stripping effect, we could acquire relatively clean image (Figure 2). However, due to other sensor noises and strong atmospheric water-absorption nature, we decided to use only 98 bands, that appears relatively clean and less noise, out of 242 original bands for the subsequent spectral analysis.

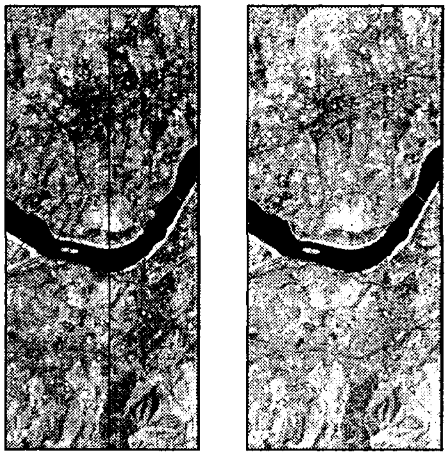

Fig 2. Striped Hyperion image (left) and corrected image (right).

The 98 bands of Hyperion reflectance image were transformed to 98 MNF components, but first five MNF components explain 32.45% of total variance structure (Figure 3).

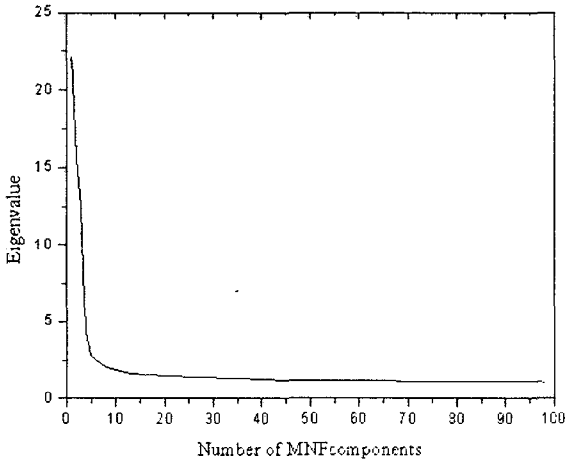

Fig 3. MNF eigenvalues of Hyperion images.

The second MNF component showed very unusual pattern of brightness gradient (Figure 4). This phenomenon was the "smile effect" referred to an across-track wavelength shift from center wavelength, which was due to the change of dispersion angle with field position [7]. Although there have been several attempt to correct this problem, the outcome was not very successful [7]. In this study, we used only first four MNF components after excluding the second MNF component.

For identifying end-members, we constructed the PPI image. The pixels of water and vegetation showed higher PPI value in PPI image because water and forest had relatively purer spectral signals than other land cover types.

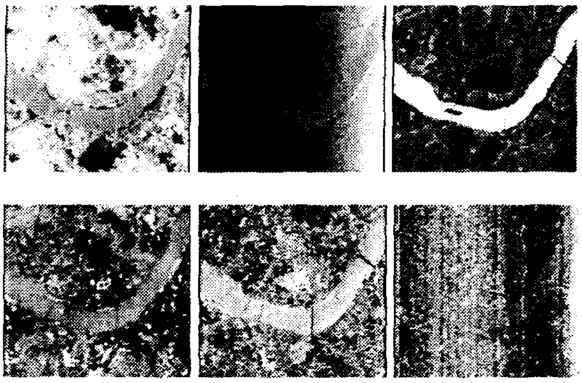

Fig 4. MNF components subset image of Hyperion (Upper from left to right: MNF 1, MNF 2, MNF 3, Bottom from left to right: MNF 4, MNF 5, MNF 6).

But a few pixels of soil, concrete road and blue roof type also showed relatively high PPI value. Using PPI and n-Dimensional Visualizer, we selected seven end-members of concrete, asphalt road, railroad, concrete building, blue panel roof, soil, shadow as figure 5. In general, asphalt road showed low reflectance, but old asphalt road was higher reflectance than fresh road because aging of asphalt was caused by reaction with atmospheric oxygen, photochemical reactions with solar radiation, and influence of heat [2]. Concrete and soil were different at VNIR wavelength. Railroad and shaded road were lower reflectance than other targets. Blue panel roof over large factories and shopping complex showed relatively high reflectance at blue wavelength.

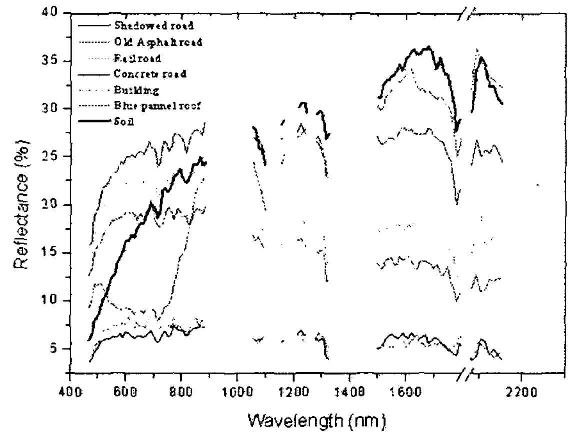

Fig 5. Selected Hyperion end-member spectra of five man-made materials.

The MTMF spectral mapping method produced the distribution and abundance of seven selected man-made materials. MTMF provides two results, relative degree of match to the end-member spectrum and the infeasibility images in which the highly infeasible number indicates that unmixing between the composite background and the target is not feasible. The final classification map of the man-made material can be obtained by selecting the highest abundance value from each end-member. Figure 6 showed the comparison between color aerial photo, natural color composite of Hyperion data, and the classification result of two end-members (blue roof and building). Blue roof, which can be recognized in both color aerial photos and Hyperion image, is relatively well classified. Also, large building area was detected for bright area at classified Hyperion image. Apartment and houses having relatively small footprint compared with the spatial resolution of Hyperion, were not well detected because of high degree of mixing with other surface materials.

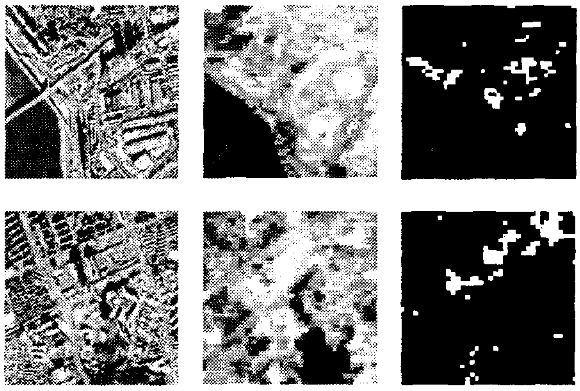

Fig 6. Color aerial image, natural color composite of Hyperion image, and classified Hyperion image of blue roof (top) and building (bottom).

Like many other urban area, Seoul imagery shows distinct shadow effect from tall buildings. Therefore, it is necessary to include shadowed portion as end-member. Although we extracted the end-member spectra of asphalt road and concrete road, the separation of these features were not very good. Considering the relatively narrow and small size of road compared with the 30m spatial resolution of Hyperion image, the result was not surprising. Better classification of man-made urban features can be achieved by using aerial hyperspectral data that has better spatial resolution.

4. Conclusions

Although Hyperion image could provide more detailed spectral information of man-made materials in urban area, it is still premature to have complete separation of such complex structure of several surface features. The spectral analysis of hyperspectral image showed a few man-made materials were effectively separated. However, due to the relatively low spatial resolution of Hyperion image small urban features, such as roads, could not be well classified. Since the end-member spectra were selected directly on the Hyperion image, the low spatial resolution problem was also augmented to the classification result. For more accurate spectral mapping of small man-made materials, it may be helpful to use the end-member spectra obtained from field spectral measurement. Further, the low radiometric quality of Hyperion image has been an obstacle to retrieve better spectral information.

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