Applications of hyperspectral Remote Sensing in urban regions

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Abstract
This paper examines the potential application of hyperspectral remote sensing for the analysis of complex urban scenes. Urban areas go through phenological changes (just the same way as a vegetation cycle), that have a spatio-temporal dimension, which is important to understand for various applications and land management related issues. However the study of urban areas is a complex process since they are characterised by the presence of numerous surface materials in relatively small regions. The features in these urban scenes contribute to the reflected radiance and are difficult to detect by coarse sensors.

Hyperspectral sensors have the highest potential for mapping complex urban ecosystems mainly attributed to their fine spectral resolution. This study uses Hymap data which has 124 spectral bands.This paper describes the compilation of a spectral library of urban surface materials, which is then used for calibrating an airborne hyperspectral image of a selected scene in Perth, Australia. The spectral library was also used for identifying pure pixels in the image, identification of image derived endmembers, and for spectral unmixing to decompose this image into abundance of individual surface materials. A georeferenced map showing the distribution of surface materials was generated.

Introduction
Urban areas are typified by intricate mixtures of materials ranging from concrete, wood, tiles, bitumen, metal, sand, and stone. The Spatial distribution of these materials is not regular and is compounded by rapid temporal changes that occur in the urban landscape over a very short period of time. Besides they have a high object density which leads to errors in the multispectral classification (Hornstra et al, 1999). Hyperspectral sensors with their high spectral resolutions carry contiguous information about the urban landscapes and enable quantification of surface features, particularly for classifications based on the material composition. The creation of spectral library for urban surface materials can assist in the sub-pixel analysis and has the potential to diminish some of the limitations posed due to spatial resolution. Hyperspectral imagery has been widely used for vegetation studies and geologic mapping but very little has been done for urban surface (Bing et al, 1998). This paper examines the potential to use hyperspectral remote sensors for the classification of urban features.

Study Area and Data Collection
An urban area in Perth, Western Australia was selected for investigation. Image data was obtained by HyMap, an airborne imaging spectrometer developed in Australia. HyMap data is available in 124 contiguous bands over the 450-2500 nm wavelengths, with a spatial resolution of 5-metre (Cocks et al, 1998). The HyMap was most appropriate for this study due to its superior signal to noise ratio and high spatial and spectral resolutions.

Methodology and Analysis (Fig. 1)
A laboratory spectroradiometer (FieldSpec) was used to measure reflectance of urban surface materials over the 450-2500 nm wavelengths. Samples of building materials were collected including bitumen, concrete, tiles, roofing material, brick, etc. For each sample 10 scans were taken and averaged. The spectra were imported into the ENVI

image analysis software for compilation of a 'Spectral library'. Of the 124 bands in the HyMap image, 6 bands in the major water absorption regions near 1450 and 1930 nm were found to be bad bands. These 6 bands were excluded and the remaining 118 bands retained for further analysis. The spectral library consisting of 2150 nm bands was resampled to the 118 HyMap bands. The reflectance image was first classified with the Spectral Angle mapper (SAM) algorithm in ENVI. For this classification the entire spectral library (70 endmembers) was used and the classified image produced abundance of pure pixels matching the library endmembers. The result of SAM revealed that nearly 70% of the image was unclassified. Several library endmembers did not match any pixel spectra. This result showed that

1) The image contains many mixed pixels
2) There may be other pure pixels for which no library spectra were available

The next step of the analysis was to determine the endmembers from the image itself and to use these for:
1) Identifying all pure pixels in the image
2) Unmixing the mixed pixels

The image was first transformed using the minimum noise fraction (MNF) transform, in order to remove noise in the data, determine the inherent dimensionality of the image, and to speed up the subsequent computer processing. The forward MNF with rotation was used and eigen values greater than 1 were retained. The pixel purity index (PPI) was run on the MNF image to separate the pure pixels from the mixed pixels. The PPI was run with 2000 iterations using a threshold of 3 standard deviations. The n-dimensional visualizer was then used with the PPI image to extract image end-members. The image end-members were compared to the library spectra to identify some of the end-members. Several image end-members were not identified since their library spectra were not available. The image derived end-members were exported into a spectral library. The SAM classifier was run again with the image derived spectral library. Linking the new SAM image and the PPI image showed that the SAM did identify all pure pixels in the image. The reflectance image was finally unmixed using ENVI`s linear unmixing procedure and the image derived spectral library. The resulting image produced classes showing abundance of the image derived endmembers.

Comparison of unmixing and SAM results with true colour RGB image of the scene showed that the unmixing and SAM procedures showed accurate locations of natural and man-made materials.

Results
The main findings were that :

- There are more endmembers in an urban scene compared to vegetated or agricultural landscapes
- Not all urban endmembers can be easily represented in a laboratory spectral library.
- Useful to derive image endmembers and use it for unmixing or spectral matching.
- However laboratory spectral library is still useful for identification of image derived endmembers.

The detailed spectral analysis carried out in this study reveals that complex urban scenes can be analysed accurately with hyper-spectral imagery. Further work is continuing and will look at the use of spectral techniques of derivative analysis, as well as use of neural networks for quantitative analysis and classification of heterogenous urban images.

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