Atmospheric Correction and Target Detection in Aerial Hyperspectral Imagery

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Introduction

The use of aerial hyperspectral imagery (HSI) in remote sensing is a rapidly growing research area. Currently, targets are generally detected by looking for distinct spectral features of objects under surveillance. For example, a camouflaged vehicle, designed to blend into background trees and grass in the visible spectrum, can be revealed using spectral features in the near-infrared region of the electromagnetic (EM) spectrum.

Hyperspectral Imagery

Using a standard digital camera, light is captured at 3 distinct wavelengths relating to either red, green or blue (650nm, 550nm and 450nm respectively). These 3 greyscale images are combined to produce a colour image. In an HSI, light is captured at tens or even hundreds of wavelengths across the EM spectrum. All these greyscale images are then combined into a hypercube which has the usual x and y spatial dimensions but also a third λ dimension relating to wavelength. The data used in this project are all VNIR aerial hyperspectral images acquired from an aeroplane flying at approximately 1 km with a mounted hyperspectral sensor. Two false-colour representations of the images used are shown below:

Fig 1: Moll Harris

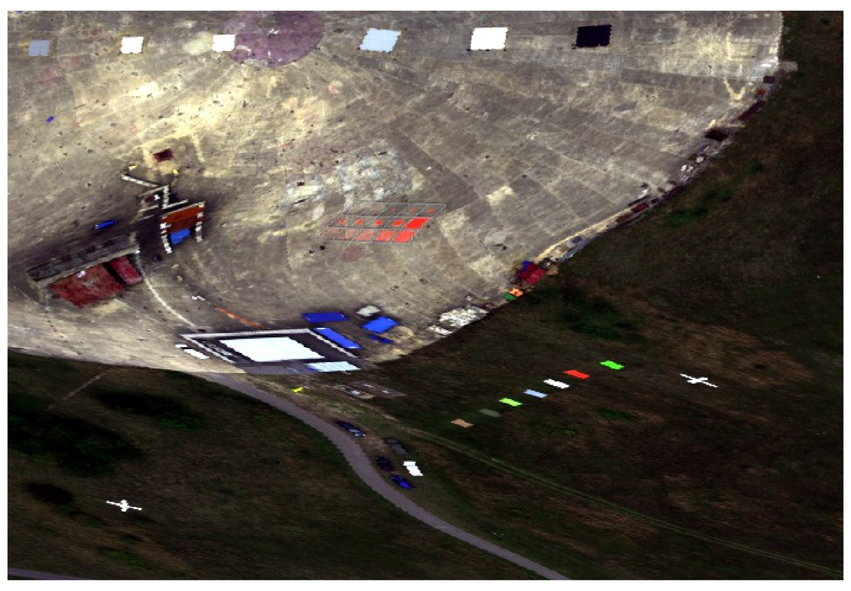

Fig 2: Porton Down

Atmospheric Correction

As well as reflectance characteristics of the ground, radiance received by an aerial imager depends on the spectrum of the incident solar illumination and wavelength dependence of the atmospheric attenuation at the location and time of measurement. A physics-based real-time atmospheric correction algorithm to convert radiance into reflectance hyperspectral image data is therefore considered crucial to development of improved spectral target detection techniques.

Atmospheric modelling with MODTRAN

MODTRAN software may be used to estimate certain key absorption and scattering parameters pertaining at the time of measurement:

- **Atmospheric Model**
- **Aerosol Model**
- **Water Vapour Content**
- **Carbon Dioxide Mixture**
- **Sensor Altitude**
- **Sensor Zenith Angle**
- **Surface Temperature**
- **Surface Albedo**
- **Date**
- **Time**
- **Latitude**
- **Longitude**

By creating a look-up table in which these parameters change, the aim is to convert the recorded radiance image into a reflectance image that can be used for improved spectral matching purposes.

Percentage Occupancy Hit or Miss Transform

As the standard Hit or Miss Transform [1] method does not allow for any target pixels to be in the background, the Percentage Occupancy Hit or Miss Transform [2] is a more robust approach to detect outliers in a scatter plot of two wavelength bands . First, the scatter plot was divided into several small cells (see Fig. 3). A new smaller image was then created. The number of pixels from the original image present in every cell of the scatter plot was counted and taken as the corresponding pixel value in the new image. To find outliers, ratios between the number of pixels in the foreground (C_{FG}; blue zone) and background (C_{BG}; red zone) were examined (see Fig. 4).

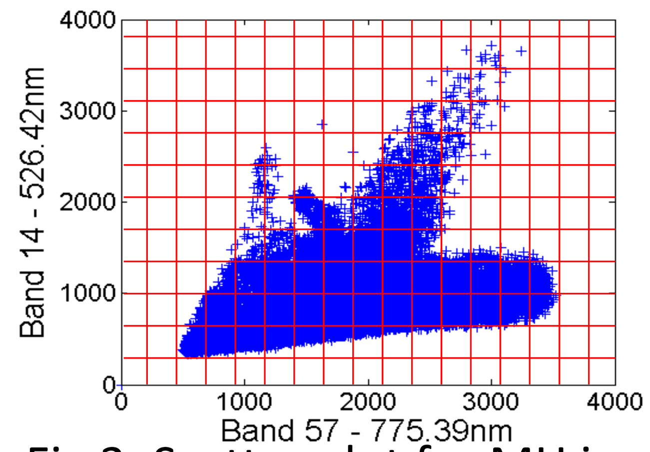

Fig 3: Scatter plot for MH image

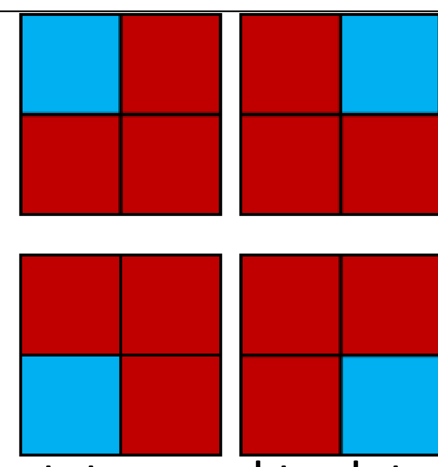

Fig 4: Four states used to detect outliers

A ratio was calculated for every pixel for both images as

$$R = \frac{\sum_{i=1}^{N} C_{FG}}{\sum_{i=1}^{N} C_{BG}}$$

where N is number of pixels in the cell. All values below a threshold were then eliminated and the remaining pixels identified as outliers. For this technique the choice of bands is very important. We have used 4 methods:

- Randomly chosen pair of bands
- 5 Randomly chosen pairs of bands; results from each pair are averaged
- Normalised Difference Vegetation Index (NDVI): use bands closest to 650 and 750 nm to distinguish vegetation
- Principal Component Analysis (PCA): using the first two PCs of the bands to create the scatter plot.

Results

To compare methods, a ground truth for each image was created. Each separate method was run on the images to produce a set of detected targets. This set was compared with the ground truth and a score calculated as:

$$Score = \frac{Hits}{Hits + Misses}$$

For every method, a cell size from 5 to 100 was used, in increments of 10. As PCA and NDVI each give the same results every time, these were both run once for each cell size. Due to the random nature of the "Random" and "5 Random" techniques, these were both run 1000 times and the average score for each cell size recorded. Results are shown below, along with 3 standard target detection approaches: Sequential Maximum Angle Convex Cone [3], Vertex Component Analysis [4] and Mahalanobis Distance [5]:

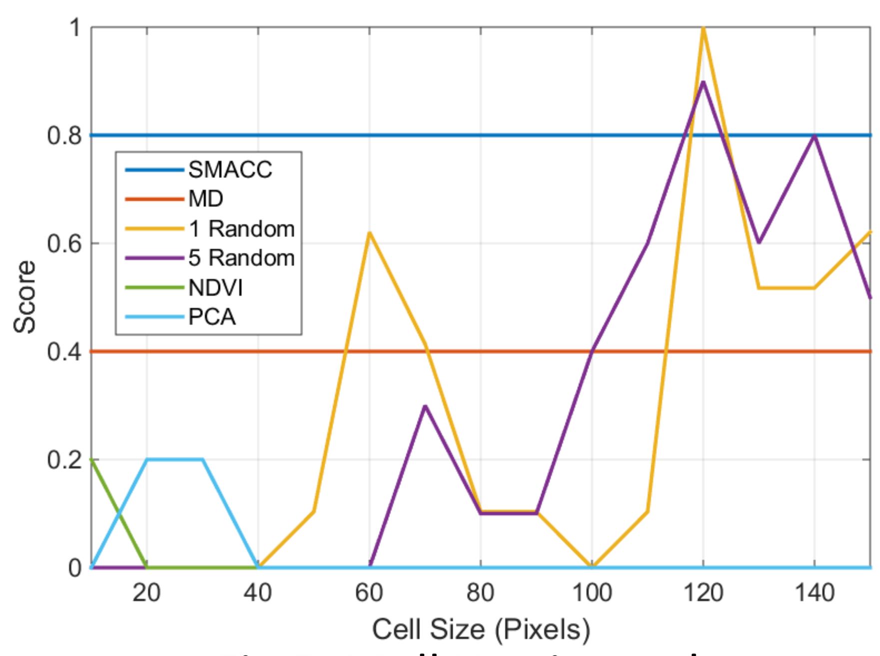

Fig 5: Moll Harris results

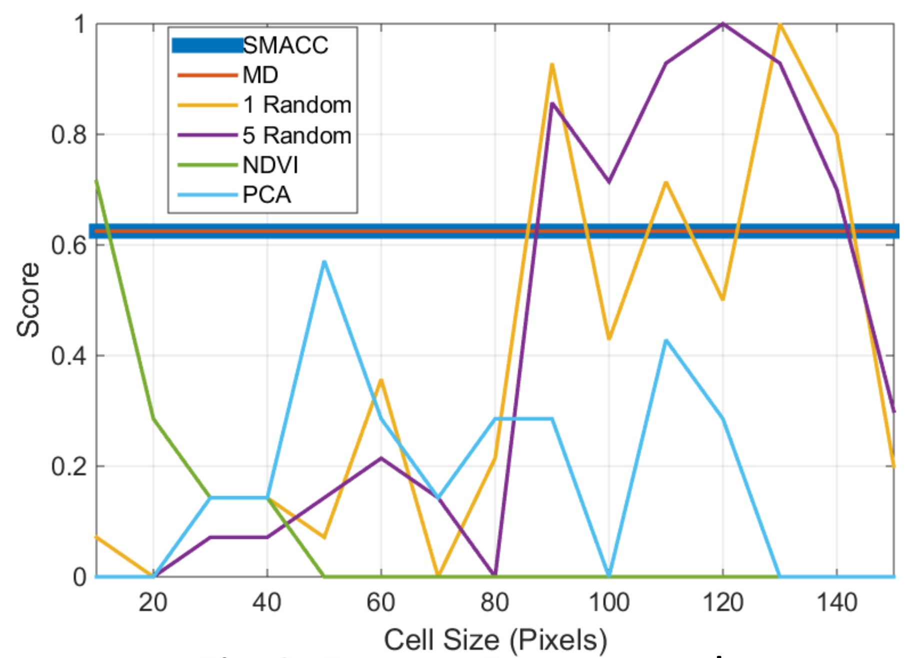

Fig 6: Porton Down results

The main object of the project was to produce an improved target detection method. Under certain circumstances this has been achieved using the POHMT with a pair of random bands selected.

[1] J. Serra, *"Image Analysis and Mathematical Morphology", v. 1.* Academic Press, 1982.
[2] P. Murray and S. Marshall, "A new design tool for feature extraction in noisy images based on grayscale hit-or-miss transforms," *IEEE Transactions on Image Processing*, vol. 20, no. 7, pp. 1938-1948, 2011.
[3] J. H. Gruninger, A. J. Ratkowski, and M. L. Hoke, "The sequential maximum angle convex cone (SMACC) endmember model," in *Defense and Security*. International Society for Optics and Photonics, 2004, pp. 1-14.
[4] J. M. Nascimento and J. M. Dias, "Vertex component analysis: A fast algorithm to unmix hyperspectral data," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 43, no. 4, pp. 898-910, 2005.
[5] P. C. Mahalanobis, "On the generalized distance in statistics," *Proceedings of the National Institute of Sciences (Calcutta)*, vol. 2, pp. 49-55, 1936.

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