HYPERSPECTRAL IMAGE ENHANCEMENT USING THERMAL BANDS: A METHODOLOGY TO REMOVE BUILDING SHADOWS

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Hyperspectral sensors are becoming more widely applied for observation of Earth surface with high spectral detail and this is confirmed from the increasing number of such sensors in these last years.

Among the range of applications of hyperspectral data, this work has been focused on urban environment, where they are very useful to provide detailed maps of urban land cover. In particular, an important application is Urban Thermography, representing an effective methodology for LST (*Land Surface Temperature*) retrieval and Urban Energy Balance Models [1].

For remote sensing observation of urban areas, an inherent issue of high spatial resolution remote sensing images is building shadows. A frequent problem in urban environment is measuring the real spectral property of pixels in building shadows for which shadow detection is the first step.

In this study, the authors propose a method to reduce the effect of building shadows on urban environment, starting from the *Simulated Reflectance* algorithm developed for Airborne Thematic Mapper (ATM) images [2]. The simulated reflectance can be derived from the relation between irradiance, thermal emittance, spectral reflectance and albedo based on a simplified energy conservation model of solar radiation incident on a land surface.

This algorithm considers an imaging sensor system with two broad spectral bands: one is a panchromatic spectral band (visible to near-infrared) recording the reflected solar radiation M_r, which depends on the reflectance ρ ($M_r = \rho E$) and the other one a broad thermal band recording the band thermal emission M_e. The sum image of the two bands should be equivalent to the incident irradiance on land surface E reduced by the radiation balance B, the general formula is:

$$E - B = M_r + M_e = \sum_{i=1}^{n} w_i \,\mathrm{RefBands_i} + \sum_{j=1}^{m} w_j \,\mathrm{ThermalBands_j}$$

where the first term on the right side of equations considers a weighted sum of the n reflective bands of a specific sensors and the second term is generated by the weighted sum of the m thermal bands. All the spectral bands are expressed in radiance values.

The simulated spectral reflectance of band i is defined by:

$$\rho_{\mathrm{sim}}(\lambda)=\frac{M_r}{M_r+M_e}=\rho(\lambda)\frac{E(\lambda)}{E-B}=\frac{\mathrm{RefBands}(\lambda)}{\sum_{i=1}^{n}w_i\,\mathrm{RefBands_i}+\sum_{j=1}^{m}w_j\,\mathrm{ThermalBands_j}}$$

where λ is the spectral wavelength and $\rho(\lambda)$ spectral reflectance refereed to a specific wavelength.

This methodology allows to suppress topographic effect and it has the advantage of conserving surface albedo information.

In the beginning, simulated reflectance demonstrated its advantages on enhancement of shaded area on relief territories. It highlights sparse vegetation on shaded slopes and it permits to discriminate between rocks unit that looks uniform with a normal colour composite. Among the wide range of applications, the methodology has already been applied to Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) multi thermal images in which different lithologies were detected and better defined [3]. However, the method carries the disadvantage of a reduction of the spatial resolution in the thermal band (90 meters).

With the increasing hyperspectral flights above urban areas, this technique can be very effective to detect features under building shadows and to highlight the surface that is shaded by these building.

As shown in figure 1, the first test on an Airborne Hyperspectral Scanner (AHS) testing image above Madrid (acquired during summer 2008) shows the enhancement of the image after the simulated reflectance processing: the topographic effects of buildings have been suppressed with spectral properties of various ground objects enhanced.

The general formula has been adapted considering this airborne sensor characteristics (table 1):

$$E-B=M_e+M_r=\sum_{i=1}^{63}w_i\,\mathrm{AHSRefBands_i}+\sum_{j=1}^{17}w_j\,\mathrm{AHSThermalBands_j}$$

$$\rho_{\mathrm{sim}}(\lambda)=\frac{\mathrm{AHSRefBands}(\lambda)}{\sum_{i=1}^{63}w_i\,\mathrm{AHSRefBands_i}+\sum_{j=1}^{17}w_j\,\mathrm{AHSThermalBands_j}}$$

The weights have been calculated using the solar radiation curve: the average height of a spectral band in the solar radiation curve is measured and then multiplied by the band width.

Another advantage of the technique is shown in classification. An image before and after the simulated reflectance was classified using a supervised neural network to identify four classes: vegetation, building, asphalt and bare soil [4]. The accuracy (with the same net structure and learning process) using the simulated reflectance bands as input has increased more than 4% (table 2) in comparison with that obtained using the original image.

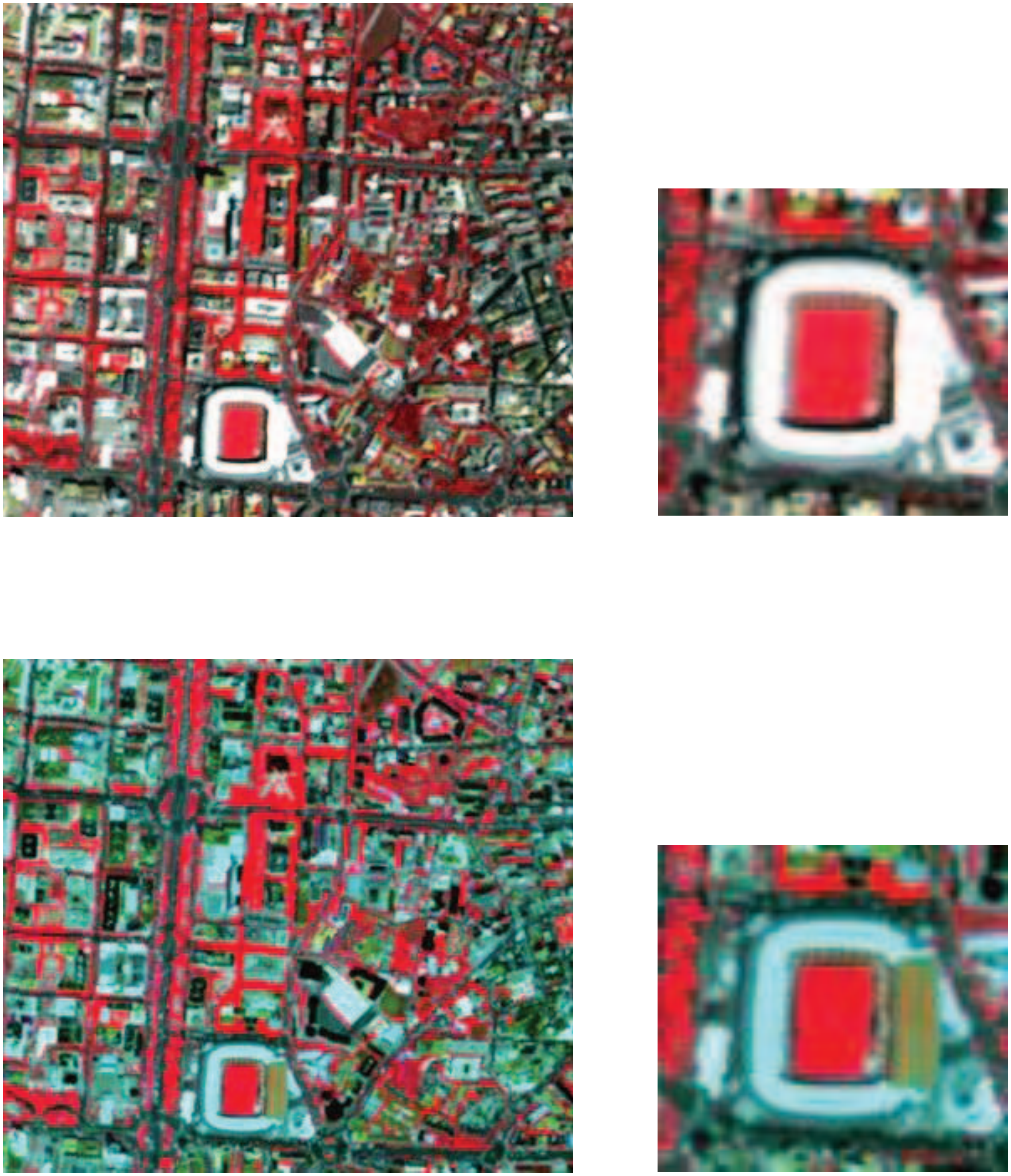

Figure 1: AHS false colour composite 14-8-5 RGB obtained with the original image (above) and simulated reflectance image (below). On the right side, the spectral detail of a stadium enhanced by the simulated reflectance is highlighted.

Wavelength Range (µm)	**Bands**	**Number of Bands**	**Band-Width (FWHM, µm)**
0.441-1.018	1-20	20	0.03
1.491-1.650	21	1	0.2
2.019-2.448	22-63	42	0.0013
3.03-5.41	64-70	7	0.3
7.95-13.17	71-80	10	0.4-0.5

Table 1: AHS spectrometer characteristics

	Original Image	**Simulated Reflectance Image**
Overall Accuracy	92.48 %	96.00 %
Kappa Coefficient	0.8988	0.9461

Table 2: table shows the increased classification accuracy using a supervised neural network with a simulated reflectance image

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