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URBAN MAPPING USING IKONOS IMAGERY

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Abstract

In the last years the use of remote sensed images for paved surfaces investigations has been marked by a growing interest. This is mainly due to the need of more information about roads age and distress allowing a rapid updating of road databases and, consequently, to reach optimal road network management. In order to verify the applicability of the methodology already used with Multispectral Infrared and Visible Imaging Spectrometer (MIVIS) imagery for paved surfaces classification, an IKONOS image was employed.In absence of a direct correlation between MIVIS and IKONOS bands the scatter plot of band 1 (0.45 - 0.52μm) and 4 (0.76 - 0.90μm) was used to identify pixels related to paved surfaces. Interpolation line of asphalt was calculated and its slope was used as threshold value in the Spectral Angle Mapper classification procedure.

Introduction

Because of their spectral characteristic and their significant portion of urban areas, in remote sensed images paved surfaces are well-detectable territorial elements. Moreover, asphalt surfaces could be used as a tool for multi-temporal analysis.The ability to classify these surfaces, according to their composition and their condition, remains an important goal for urban areas monitoring. Currently these determinations are based on field observations, carried out in field by experts, that define the action priorities. Recent advances in remote sensing technology showed capabilities to derive aging and degradation road properties from the images. The issue has already been addressed by several authors who have used AVIRIS hyperspectral images-HyperSpectir ([1], [2]) or LIDAR data-AISA [3]. Recently, the possibility of assessing asphalt surfaces age with airborne Multispectral Infrared and Visible Imaging Spectrometer (MIVIS) was taken into account by [4] with an object-oriented processing and by [5] with field spectroradiometrical measurements and supervised classification. To assess deterioration and aging differences between paved surfaces in remote sensed images, an examination of asphalt spectra in the wavelength between 350 and 2500 nm have to be performed. In this wavelength range, asphalt reflectance is generally very low and dominated by bitumen presence which absorbs almost totally the incident solar radiation. Spectral characteristics of aggregate fraction and its size affect spectral trend only in small percentage. In fact, only after aging and wearing processes, that cause the loss of bitumen component and the outcrop of aggregate, there is a slight increase in reflectance values and the appearance of absorption peaks related to mineralogical characteristics of outcropping aggregate fragments ([2], [6], [7], [8]). Based on these considerations, paved surfaces deterioration is closely related to the decrease of bitumen on aggregate surface and, consequently, to colorimetric changes ([5], [7]). Using wavelength $\lambda = 0.46\mu m$ and $\lambda = 0.74\mu m$ from MIVIS and spectroradiometrical field data, scatter plots allow to recognize a linear distribution corresponding to paved areas. Analyzing this distribution 4 main clusters corresponding to 4 chromatic classes of Munsell (M) grey scale were recognized. In the studied areas, classes $|1<M<2|$, $|3<M<4|$, $|5<M<6|$ e $|7<M<8|$ allow to easily create Region of Interest on the images for subsequent the Spectral Angle Mapper (SAM) classification [5]. SAM classification allows to discriminate the asphalt covers and to differentiate their wears by means of relationship between asphalt color and bitumen percentage cover.

In this paper analysis of asphalt surfaces was conducted with IKONOS data in order to investigate the possibility to use low-cost satellite images.

Materials and Methods

A. Study area

The study was focused on an IKONOS georeferenced scene centered at latitude 4630471 N and longitude 273427 E (projection UTM, zone 33 North, Datum WGS-84). Image was recovered on 2007 over Rome-Fiumicino along A-91 highway (Rome Province -Italy) (Figure 1).The study area was characterized by different urban land cover and man-made materials. In particular the scene was dominated by different paved roads like highway, secondary roads and parking areas.IKONOS images have 4 bands with spectral resolution defined by 0.45-0.52, 0.52-0.60, 0.63-0.69, 0.76-0.90 μm associated to a panchromatic band (0.45-0.90 μm). Spatial resolution is 3.2 m and 0.82 m (at nadir) respectively in MS and panchromatic mode.

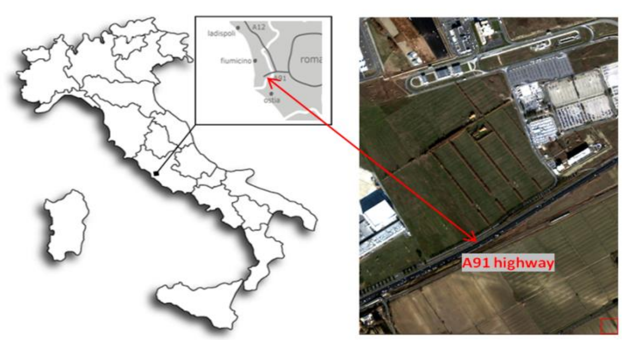


Figure 1. Case of study area (A91 highway – Rome Province)

B. Image pre-processing

On the basis of ground recognition and photo interpretation, a spectroradiometrical campaign was carried out to obtain appropriate field targets spectra. For this purpose a Fieldspec 3 (A.S.D.) spectroradiometer was used.

Measurements, in the wavelength between 350–2500 nm, were carried out in clear sky conditions between 11:00 and 14:00, with the sensor arranged with a bare fibre optic (FOV of 25) at 50 cm on the vertical of the target (about 35 cm^2). Only homogeneous targets are measured with no degradation or vegetation. To estimate the centre position of each target a Garmin GPS was used. To better characterize surfaces, 10 spectral signatures for each surface were collected; these spectra were averaged to take in to account the spatial variation of the asphalt targets. Field spectra were coupled with bitumen covering aggregate percentage values and Munsell (M) color [7] were assigned to each surfaces.To minimize the atmospheric contribution, an empirical line computation was performed. In order to transform image in reflectance values, field spectra were resampled at IKONOS wavebands (figure 2) and field and image spectra were paired. A different dataset of validation targets was used to validate the empirical line (EL) computation. The accuracy of EL computation was evaluated calculating calibration/validation regression lines and coefficients of determination for each bands (R-squared= 0.95) (Figure 3).

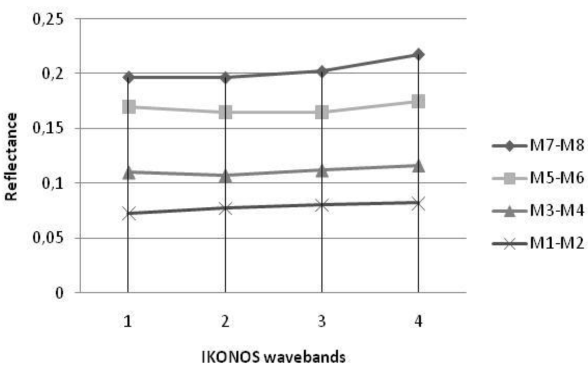


Figure 2. Asphalt field classes resampled at IKONOS bands.

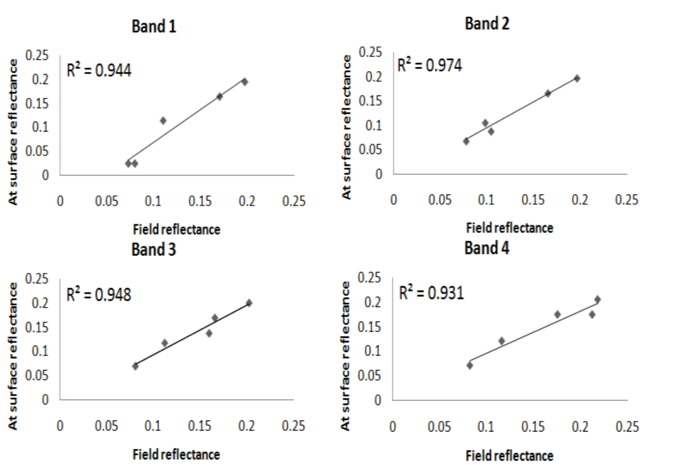
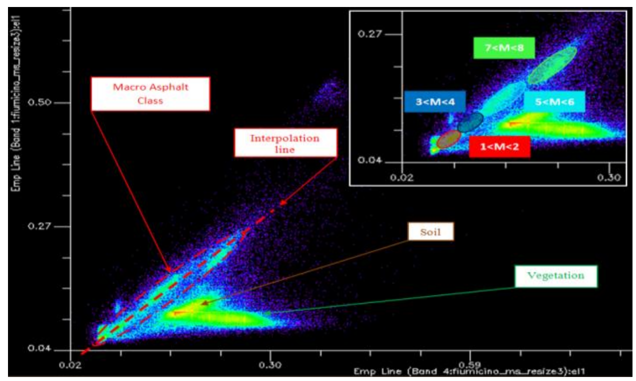


Figure 3. Regression lines using five validation targets for each of the IKONOS bands

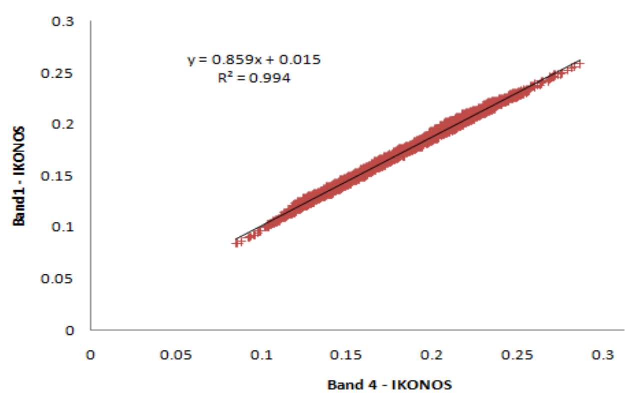
Results

Lacking a direct correspondence between bands 2 and 16 of MIVIS and those IKONOS, an analysis was conducted on scatter plot bands 1 (0.45 - 0.52µm), 3 (0.63 - 0.69µm) and 4 (0.76 - 0.90µm) in order to identify the optimal bands to define asphalt line . Analyses showed that the distribution of pixels corresponding to paved surfaces was more evident using bands 1 and 4 although their spectral ranges (respectively 0.07 and 0.14 µm) were significantly larger than those of the MIVIS bands 2 and 16 (respectively 0.023 and 0.020 µm).

In scatter plot obtained from IKONOS imagery, pixels corresponding to vegetated areas and soils were well grouped in other clusters clearly distinct from asphalt one (Figure 4(a)).



(a)



(b)

Figure 4. Scatter plot obtained by selecting 1 and 4 IKONOS bands (reflectance values) and interpolation line of asphalt (a). Distribution of values corresponding to asphalt pixels (b).

Using the scatter plot the values of asphalt class pixels were extracted as an ASCII file and processed (Figure 4(b)) and the angular coefficients (α) was computed. This value (0.86) was comparable to the values obtained in previous works with MIVIS data (α ≈ 0.68-0.85).

Taking into account field surveys observations and photo interpretation, each target was associated to a Munsell (M) grey scale class; following these indications it was possible to recognize along the asphalt line four different classes (upper right box in Figure 4(a)):

- |1<M<2| (red)
- |3<M<4| (blue)
- |5<M<6| (cyan)
- |7<M<8| (green)

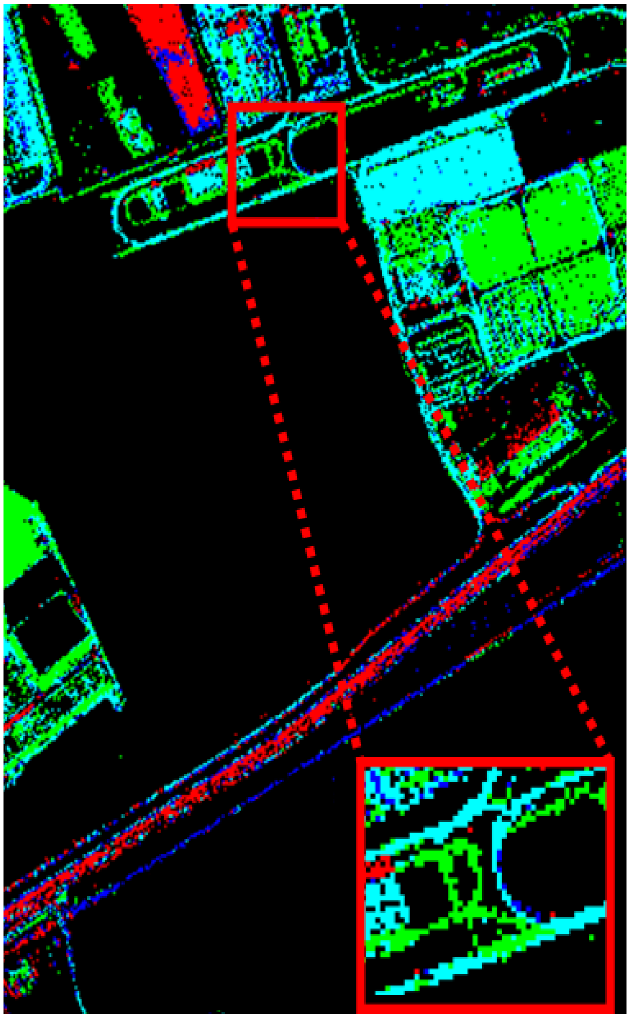


Figure 5. Image classification result: |1<M<2| (red), |3<M<4| (blue), |5<M<6| (cyan) and |7<M<8| (green). Red box shows an enlargement of road junction where all asphalt classes are represented.

Consequently, the Region Of Interest (ROI) selection for subsequent supervised classification processing was facilitated. ROIs for each class were selected (about 50 pixels), and used as calibration endmembers for Spectral Angle Mapper (SAM) classification (Figure 5).

Spectral Angle Mapper algorithm is based on a comparison of the image spectrum with a reference spectrum (endmembers or spectral libraries) and it evaluates the spectra similarity in order to enhance the target characteristics [9].

SAM attempts to obtain the angles (α) (between 0 and π/2) formed between reference and image spectrum treating them as vectors in a space with N-dimension with N equal to the number of bands ([10], [11]).

Angles α were calculated by applying (1).

$$\alpha = \frac{\cos^{-1}\sum \tau_1 \tau_2}{\sqrt{\sum (\tau_1)^2 \sum (\tau_2)^2}} \qquad (1)$$

Where:
τ_1 is the image spectrum
τ_2 is the Reference spectrum

Before SAM classification, a Minimum Noise Fraction (MNF) transformation was applied to minimize image noise. The angular coefficient of asphalt line was used as threshold value in the SAM classification procedure.

In the classified image we note that the highway are classified like newest asphalt (|1<M<2| class) on the other hand parking areas represent the most aged surfaces (|7<M<8| class) except in the north portion of the image where a recent asphalted area appears.

In order to evaluate the accuracy of classification a different set of validation ROI was create. The overall accuracy of the classified images was 98.5and a K coefficients 0.98 (Table 1).

Table 1. Confusion matrix

	Ground Truth (pixels)				
Class	1<M<2	3<M<4	5<M<6	7<M<8	Total
Unclassified	0	0	0	0	0
1<M<2	**52**	1	0	0	53
3<M<4	1	**48**	0	0	49
5<M<6	0	1	**50**	0	51
7<M<8	0	0	0	**51**	50
Total	53	50	50	50	**203**
Overall accuracy= (200/203) 98.52% *Kappa Coefficient= 0.98*					

Conclusion

In this paper IKONOS imagery was processed in order to recognize road network with the Spectral Angle Mapper procedures and to compare results with those already obtained with MIVIS hyperspectral images in different sites.

Analyzing 1 and 4 IKONOS bands was possible to define the reflectance values of different asphalt covers. The calculation of asphalt interpolation line allowed to obtain its regression equation and coefficient of determination. Using Munsell (M) grey scale, four different classes of asphalt were recognized along asphalt line. Classes |1<M<2|, |3<M<4|, |5<M<6| and |7<M<8| were recognized in the scatter plot and Region of Interest were created.

After a Minimum Noise Fraction (MNF) transformation, that allowed to minimize noise, a Spectral Angle Mapper classification was performed. The slope (α) of the interpolation linear equation of asphalt was used as threshold value in the algorithm. The classification showed an overall accuracy (Oa) of 98.5% and a K coefficients (Kc) 0.98. These values were comparable with those obtained by MIVIS data elaboration (Oa 90.5% and Kc 0.87) in previous work.

Considering the relationship between asphalt color and their wearing degree, classification results showed that IKONOS imagery could play an important role in civil engineering. Therefore, we could suggest that the method presented in this paper could supply local government authorities a tool to locate asphalt pavements that need to be checked for maintenance interventions.

Acknowledgments

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