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Infrared detection of active fires and burnt areas: theory and observations

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Abstract

We have investigated the problem of fire recognition and management using hyperspectral images remotely sensed by the multispectral infrared and visible imaging spectrometer (MIVIS). Twenty near infrared bands (between 1.99 and 2.48 μm) and ten thermal infrared (between 8.2 and 12.7 μm) MIVIS bands have been utilised. The main problems addressed in this work are the fire-front and burned-area recognition and the extraction of information useful for the management of the burned area. The paper shows data gathered by the sensor MIVIS over the fire, the data processing result and is completed with a brief theoretical discussion of the involved topics. Some hints are given about the diagnostic capabilities of other hyperspectral devices. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

The monitoring and the management of the fire and other natural hazards by means of optical remote sensing instruments is an important topic that in the past has been intensively investigated [1–3,5,6,13,15,16]. The option to reliably reveal faint traces of fire and to monitor its growth has remarkable applications for the management of forests and the protection of the environment.

The remote sensing application for fire recognition and monitoring purposes should achieve the following aims [7,9]:

1. a measure of the localisation and the geographic extension of the fire-front;
2. an estimate of the fire intensity;
3. the monitoring of the burned area in order to detect traces of latent fire as well as the presence of residual vegetation not entirely burned;
4. the mapping of the burned area for the cartography and the scheduling of the restoration activity.

The recognition and the monitoring the fire locations is often approached by selecting some spectral range (e.g., the thermal infrared) that is thought to hold useful information for the proposed end [4]. Moreover the fire monitoring is often attempted by means of traditional space-borne multispectral sensors (e.g., the Landsat TM), that have a high probability to grab the fire location but

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provide a little information amount and coarse spectral resolution [8,11–14].

The main drawback of the depicted approach is due to the coarse resolution and to low data amount provided by traditional satellite sensors. Due to both the lesser resolution of the collected images and the absence of validation measurements, the utilised space-borne images are not corrected for atmospheric effects and the data are transformed to ground temperature or albedo by means of a simple and not effective lookup-table conversion [3]. Alternatively, the target temperature is retrieved using the inverse Planck's law but always the effects introduced from the emissivity are wholly neglected. We point out that neglecting both atmospheric and ground emissivity effects may originate huge errors in temperature estimates [10].

We have investigated the problem of fire recognition and management assuming that the fire may produce noticeable effects (information) in almost the entire optical spectral range. Accordingly, we have chosen to exploit the application to the concerned problem of an airborne, high-resolution hyperspectral sensor (the multispectral infrared and visible imaging spectrometer, MIVIS) that provides the user with a large amount of information about the spectral properties of the imaged target.

The main problems here addressed are the fire-front and burned-area recognition and the extraction of information useful for the management of burned areas. The paper shows the image-data gathered over a fire occurred in the Northern Italy that was casually imaged by the sensor. The data-processing result is discussed and is completed with a brief theoretical discussion of the involved topics.

It is worth noting that the high resolution images shown along this paper represent a rare scientific event and that very often fires are observed by means of space-borne sensors only.

2. Case-study

The case-study considered is a natural fire that broke out in July 1999 over a forest of the Alps mountains, in the northern part of Italy. The fire-front was imaged in the late morning (10:55 local time) by the MIVIS sensor that was flown aboard of a CASA 212 in the west–east direction from a relative ground height between 1 and 2 km. No ground truth or other ancillary measurement was acquired during the overflight and the image processing was mainly devoted to investigate the fire effects on the broad spectral range covered by this sensor.

The MIVIS is a hyperspectral airborne sensor that operates from 0.44 up to 13 μm of wavelength, with a spectral resolution ranging from about 10 nm in the SWIR (1.5 μm of wavelength) to 20 nm in the visible and 350 nm at thermal infrared wavelengths. The MIVIS collects 102 independent spectral channels (measures of monochromatic radiance), digitised with 12 bits of quantization accuracy. The broad spectral coverage, the huge volume of gathered data and the high digitalisation accuracy allowed by the MIVIS, make this sensor a valuable tool for hyperspectral investigation of the earth surface.

Fig. 1(a) shows a picture of the observed scene, obtained from the MIVIS radiometrically calibrated data. As can be seen the smoke originated by the fire strongly reduces the fire-front visibility in the entire visible spectral range.

3. Image-processing: VIS-NIR spectral range

This research has been devoted to highlight the different effects the fire produces in different spectral channels, in order to obtain useful information for monitoring and detection purposes (e.g., the fire temperature and the emissivity associated to the burnt areas).

While smoke plumes may be easily seen at a shorter wavelength (e.g., in the visible, see also Fig. 1), the short wave infrared (in the interval 1–2.5 μm) seems be able to precisely track the fire-front. This option is not easily achieved by means of thermal infrared data that due to the high temperatures involved might be saturated even in the neighbourhood of the fire-front. This phenomenon is shown in Figs. 2 and 3.

Fig. 2 shows the MIVIS image acquired in the 23rd spectral channel (at a wavelength of