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Measurements of physical parameters of laboratory forest fires by bi-spectral infrared imaging

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EXTENDED ABSTRACT

During the last decade, infrared (IR) sensors have proved to be a useful tool in forest fire fighting. The first applications came from satellite sensors originally devised for meteorological applications, like the Advanced Very High Resolution Radiometer (AVHRR) onboard the NOAA satellites[1,2]. Now, a new generation of specific fire satellites is planned that promises early fire outbreak detection and monitoring[3]. The success of satellite IR sensors has encouraged many forest services to use ground-based IR sensors for fire detection[4], typical devices being IR cameras placed on rotary platforms on lookout towers. These ground-based applications have been confined nearly always to fire detection, but IR sensors can provide much more information on fires. This information may be very useful to get a better understanding of fire properties and behaviour, in particular by providing inputs and experimental validation for the theoretical models of fire spread. This paper focuses on the problem of how to get quantitative information on relevant physical parameters of forest fires by using IR cameras.

Traditionally, physical information on forest fires is obtained laboratory fires with thermocouples and by measuring the fuel mass loss. This is a very labour-demanding task, that requires to deploy

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previously a grid of sensors in the fire regions, as well as to perform pre- and post-fire fuel inventories in order to derive heat release from mass loss and heat of combustion of the fuel. In contrast, IR cameras provide fast, spatially resolved measurements of radiated power, without any pre-fire of after-fire work. If camera measurements of other fire parameters proved feasible, it would greatly simplify the experimental study of fires and improve or knowledge of them, by making possible large-scale field studies that now are impractical.

However, quantitative measurements of fires using IR cameras face important difficulties, related mainly to the complex spectral structure of fires. In this work it is shown that some of these difficulties can be overcome by using bi-spectral images of fires (i.e., images in two different spectral bands that are simultaneous and co-registered) and applying them classification techniques, a standard tool for the analysis of satellite multispectral images.

Images of laboratory forest fires were acquired by a bi-spectral imaging system made up by two cameras that operate in the medium infrared (MIR) and thermal infrared (TIR) bands. The cameras are computer controlled so that they provide simultaneous images calibrated in brightness temperatures, that can be co-registered with subsequent processing. The MIR-TIR scatterplot of these images can be used to classify the scene into different fire regions (background, ashes, and several ember and flame regions). This region identification is useful to locate the fire front, to point out places of re-ignition and to determine the rate of spread. Geo-referencing makes possible to measure areas of the classes and to calculate the power emitted in the MIR and TIR bands by the different classes in a field fire (see an example of results in Figure 1). Additional geometric and spectral corrections make possible to estimate the total power radiated by the fire in the whole spectrum. Time integration provides total energy radiated per unit area. Estimated values for both magnitudes are compared to those for total power and total energy release derived from heat of combustion and fuel consumption. Fires with several different fuel loads have been studied, to check the consistency of the method.

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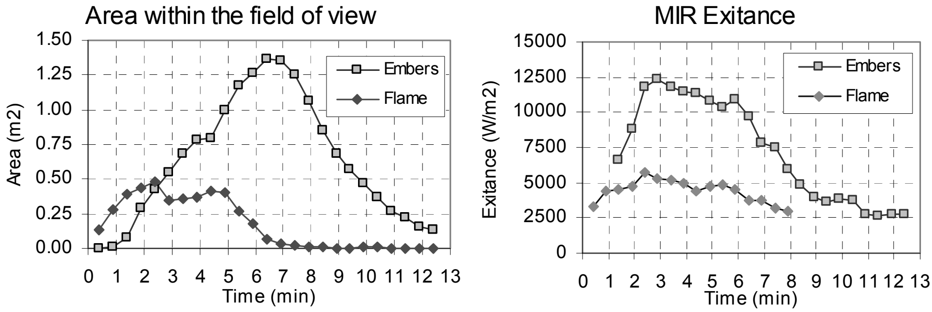

FIGURE 1: (Left) Areas of the classes "embers" and "flame" within the FOV of the bi-spectral imaging system. (Right) Average exitance of those classes.

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