EXTRACTION OF ACTIVE FIRE LINE AND MAP USING AVIRIS IMAGERY

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ABSTRACT

Fire managers who respond to wildland fire outbreak will need intelligent information regarding the state of the fire such as location, direction and active fire perimeter for better fire management. The Infrared Interpreters, who visually examine the infrared imagery to provide intelligent information, usually undertake the task of drawing the active fire map by hand. Vegetation indices like Normalized Difference Vegetation Index (NDVI) and Normalized Difference Burn Ratio (NDBR) have only been used to calculate and map vegetation characteristics, ascertain portions of an area that have been burned thereby providing burn severity classification. These indices have the potentiality of being extended to extract active fire line and fire map but have not been exploited. In this study, we propose a technique of extending their use to extract active fire line as well as active fire map. Image processing tools like multi-band image gradient and image dilation were developed to extract active fire line and fire map using AVIRIS imagery. The extracted fire line was refined by B-spline curve fitting and dominant fire pixels obtained from the multi-band image gradient. The smooth curve may be used as an input for a model that estimates direction of propagation of fire and also for visualization of the evolution of active fire front. We show results of extracted active fire line and fire map with San Bernardino Mountain Fire, AVIRIS imagery of 1996.

1. INTRODUCTION

Incidents of wildland fire occur all over the world. They are sometimes naturally ignited by lightning and sometimes by man. Wildland fire provides a natural process of maintaining the ecosystem. It also servers as a means of reducing the excessive fuel accumulation in the wildland. Plants and animals depend on this process for regeneration. On the other hand, its effect (of wildland fire) can be catastrophic. It brings about destruction of human livelihood and forests. It also produces trace gases and gives rise to green house effects.

To help reduce the risk of wildland fire destruction or spread to unwanted areas, its progression has to be monitored and controlled. A good monitoring scheme should be equipped with information about location of the fire, its perimeter and some measure of speed of propagation. The ability of the fire mangers to effectively monitor or suppress the spread will be incapacitated when these pieces of information are not available. Some semi-empirical based models like BEHAVE and FARSITE have been proposed for predicting fire dynamics. These models work reasonably well but they rely on the availability of a set of input parameters which must be known a priori. Furthermore, their use is impracticable for regions where terrain and local weather information are not immediately known. These systems and their associated subsystems are discussed in (Burgan and Rothermel, 1984) and (Andrews, 1986).

The Normalized Difference Vegetation Index (NDVI) defined by near infrared (NIR) and visible (Red) spectral bands, has been used to characterize the state of greenness of vegetation. Healthy vegetation absorbs most of the visible light that is incident upon it and reflects a huge fraction of the NIR light and vice versa. This difference shrinks as the health of the vegetation deteriorates. The Normalized Difference Burn Ratio (NDBR) is being used to quantify burn severity. It is similar to NDVI but uses NIR and Shortwave infrared/Midwave infrared (SWIR/MWIR) spectral bands. The use of this set of bands provides a good contrast between healthy and burned vegetation. These indices may be used as essential tools to classify remote imagery for extracting active fire line and map.

We hereby propose a non-parametric technique which exploits the combinatory use of the vegetation indices, NDVI and NDBR to provide a useful constraint for extracting active fire front, burn scar and fire map. This will ameliorate the task of IR Interpreters who usually generate such maps by hand. The output may be used as an input to a model that extracts the direction of fire propagation in order to visualize active fire fronts as they evolve.

2. PROCEDURE

The flowchart of our proposed method is shown in Figure 1 below. The procedure starts with the computation of vegetation indices, NDVI, NDBR and the magnitude of multi-band spatial image gradient. By applying suitable thresholds along with image dilation to NDVI and NDBR, burn scar and fire maps are extracted. Using an operation similar to **AND** *gate* logic to process NDVI and multi-band gradient magnitude image, the active fire line is then estimated. The fire line is *raw* and has some discontinuities inherent in the extraction process. Hence, it is dilated and fitted using B-spline to create a realistic active fire line that might be used as input to a model that generates normals and ultimately estimates the direction of propagation of the fire front.

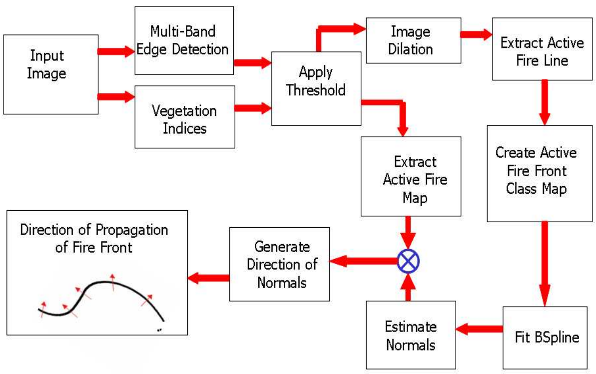

Figure 1. *Overview of active fire line and map extraction procedure.*

2.1. Multi-band Edge Detection

Edge detection routines exploit the contrast between fire pixels and background by highlighting regions of rapid intensity or radiance changes. Edges were extracted by computing the magnitude of spatial gradient of multi-band imagery. Gradient of a three-band color image field was described in (Lee and Cok, 1991) and (Saber *et al.*, 1997). Our approach extends this three-band algorithm to over 150 spectral bands for AVIRIS spectral bands 70 - 224. Bands lower than 70 were not used to avoid the influence of smoke. Sobel operators were used to implement the image gradient. The gradient magnitude was thresholded using the technique discussed in (Ononye *et al.*, 2004). The resulting gradient magnitude was further post-processed by dilation to connect broken edges to create a good edge map.

2.2. The Vegetation Indices

The two vegetation indices used to generate the active fire map and burn scar were Normalized Difference Vegetation Index (NDVI), and Normalized Difference Burn Ratio (NDBR). They are defined as

$$NDVI = \frac{R_{nir} - R_{red}}{R_{nir} + R_{red}}; \qquad NDBR = \frac{R_{nir} - R_{swir}}{R_{swir} + R_{red}}$$

where R is the reflected radiance in the $red/nir/swir$ spectral band. NDVI characterizes the state of vegetation while NDBR gives the measure of burn severity. For unhealthy vegetation, R_{red} value increases and NDVI value drops and ultimately becomes negative when the vegetation has been burned. Similarly, NDBR < 0, for burned vegetation.

2.3. Extraction of Active Fire Map

Although, NDVI and NDBR tend to be negative for a given burned and area, NDBR provides a better mapping tool for burned area. With NDBR image, a sign change technique was used to classify burned and unburned areas. This approach was used to extract the burn scar. A zero-crossing operation was applied to the derived burn scar image to extract the active fire perimeter. With NDVI, a zero-crossing was also used to derive the fire perimeter. An image dilation was used to convert the NDVI to a bilevel image. This image will provide a good constraint for extracting direction of fire propagation which is not discussed in this paper. Information about image dilation as a tool for image processing is given in (Gonzalez and Woods, 2002).

2.4. Extraction of Active Fire Line

The post-processed magnitude of spatial gradient image may be binarized or left as a bilevel image with gray scale value of 255 denoting the active fire pixels and 0, otherwise. The fire perimeter image deduced from NDVI was also converted to the same form. This sets the stage for an image operation similar to logic **AND** *gate* to be applied to the two images to extract the active fire line. In other words, a pixel is deemed to be a point on the fire line if the gray scale values of that pixel in fire perimeter and edge map images are 255 or 1 for binary case. By applying this operation to the entire image, the active fire line was extracted.

The extracted active fire line at this stage is *raw* and in digital form. To generate a more realistic fire line that would be used as input for active fire propagation estimation model, the curve was processed and fitted with a B-spline.

3. RESULTS

We tested our approach with AVIRIS data sets of 1999 San Bernardino mountain fire and the performance of our technique is demonstrated in Figures 2 through 5. Extraction of active fire map from NDBR is shown in figure 2. In this figure, the NDBR image is shown in (a). The burn scar image derived from applying the sign change discussed previously shown in (b). A zero-crossing technique was used to derive the active fire perimeter shown in (c) from the result in (b).

In Figure 3, the result of fire perimeter extraction from NDVI image is shown. The NDVI image is shown in (a). In (b), the fire perimeter extracted by zero-crossing procedure using the NDVI image as the input is shown. A bilevel image that distinguishes burned region from the unburned is shown in (c). The burned region is in black while the unburned is white. This image was generated by dilating the NDVI image.

The performance of the **AND** *gate* operation using processed NDVI and gradient magnitude images to extract active fire line is shown in figure 4. The fire perimeter which was derived from NDVI is shown in (a). The multi-band image gradient magnitude computed using Sobel operators is shown in (b). A suitable threshold technique was used to suppress the background thereby accentuating the fire area. The extracted active fire line through an **AND** *gate* operation is shown in (c). This fire line is *raw* and in digital form at this level and will therefore need to be processed. This leads to the results shown in Figure 5. The raw result of the fire line is also shown in (a). A B-spline, geometric tool, was used to fit points on the fire line. This is shown in (b) as an image. It is also plotted in (c) using ArcView GIS 3.3. At this stage, the fire line may be used as an input to a model for estimating the direction of fire propagation.

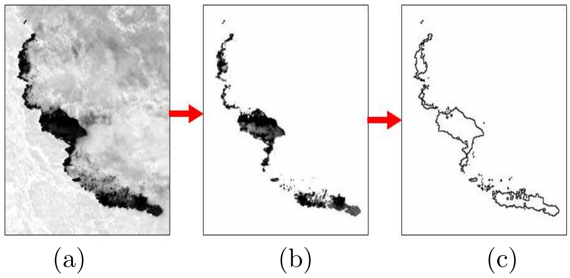

Figure 2. *Extraction of active fire map from NDBR: (a) NDBR image, (b) burn scar image and (c) active fire perimeter.*

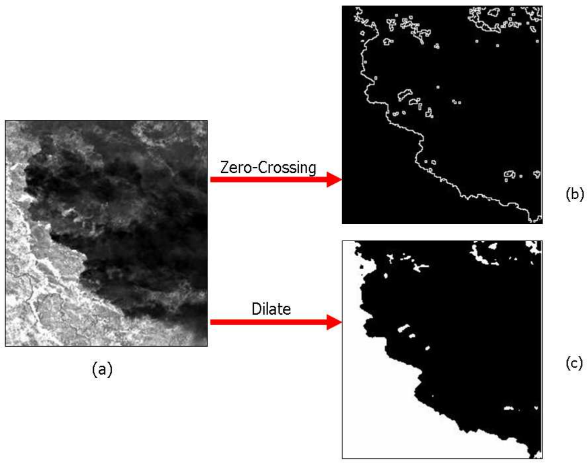

Figure 3. *Extraction of fire perimeter from NDVI: (a) NDVI image, (b) fire perimeter derived from result in (a) using zero-crossing and (c) bilevel image derived from NDVI by dilation.*

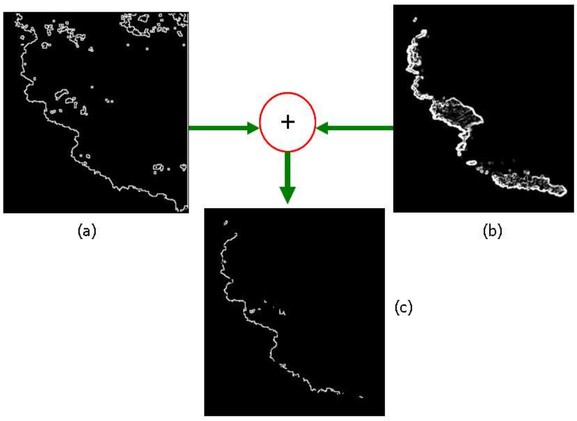

Figure 4. *The* **AND** *gate operation: (a) fire perimeter from NDVI, (b) magnitude of spatial multi-band gradient and (c) extracted fire line in raw form.*

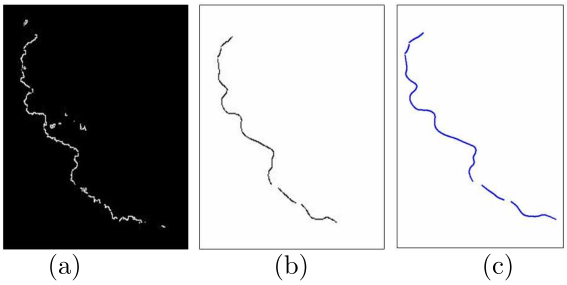

Figure 5. *Fitting B-spline to the extracted raw fire line: (a) extracted raw fire line, (b) display of fitted active fire line with B-spline as an image and (c) active fire line fitted with B-spline and displayed in Arc-View.*

4. CONCLUSION

We have developed a useful tool that automatically extracts the active fire line from remote imagery. The technique also generates fire maps or perimeter. These results were realized by employing tools such as image gradient and dilation developed from known images processing techniques. The technique will ameliorate and quicken the tedious task of IR Interpreters who currently rely on visual observations to manually generate such maps.

This proposal is being extended to a model that estimates the direction of propagation of fire using the extracted fire line as input and knowledge of the burned area to constrain the propagation direction. The performance of this extension will be evaluated with imagery from different sensors and will be reported in a later conference.

Acknowledgements

This work was sponsored by NASA Grant NAG5-10051 and NSF Grant CNS-0324989. The AVIRIS images used were provided by the AVIRIS Data facility.

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Biography

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