AN AGENT-BASED ALGORITHM FOR FOREST FIRE DETECTION

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ABSTRACT:

For remote sensing image analysis, it is necessary to use spatial information surrounding pixels, in addition to spectral information of them. Several works have been done in this field. On the other hand, autonomous agents, a newly explored area of research in image processing, can operate directly in the two-dimensional lattice of a digital image and provide an attractive abstraction to encapsulate local and intelligent processing. Our purpose is to study the potential of agents to be applied in processing of remote sensing imagery. Therefore, in this paper, we present an agent based approach for forest fire detection. It utilizes the tests used in MODIS version 4 contextual fire detection algorithm to determine agent behavioral responses. To do so, a collection of distributed autonomous agents will operate at the individual pixels of the image divided into 10×10 pixel blocks. Performance of the proposed algorithm is compared with MODIS version 4 contextual fire detection algorithm and ground-based measurements. The results show good agreement between the algorithms and field data.

1. INTRODUCTION

Recently, processing methods of remote sensing imagery are closer to computer vision and require the knowledge of spatial structures and relationships among image contents, in addition to spectral information. Spatial information of a pixel, whether textural or contextual, relates a pixel to its surroundings (Kiang, 1999). How classification accuracy of remote sensing imagery increases by incorporating spatial information has been investigated in lots of literatures (e.g. Jackson et al., 2002; Tso et al., 2004; Qian et al., 2005). On the other hand, autonomous agents for image segmentation consider local neighborhood information of image pixels, but in comparison to conventional methods, agent-based approaches have some advantages such as being adaptive to the locality, reliable in performance, less sensitive to the noise and easy to represent and implement repeated again and again in literatures (Maes, 1995; Liu et al., 1997; Keshtkar et al., 2005). Intelligent agents are new paradigm of modern Artificial Intelligence (AI) research in computer science (Maes, 1995). Agents have been widely used in diverse fields such as traffic management, network monitoring, robotics control, electronic commerce and computer vision (Demazeau, 2003). Recently, some efforts have been made to use agent-based methods in remote sensing (Stiteler IV et al., 2002; Pigeon et al., 2002; Ettabaa et al., 2004; Riadh et al, 2006). In this paper, we propose the application of agents to the classification of remotely sensed imagery. We have defined one class of agents responsible for labeling fire regions. Our purpose is to detect forest fire pixels in MODIS data acquired over Kerman shah province, Iran. Local stimuli of agents are based on the tests used in MODIS version 4 contextual fire detection algorithm (Giglio et al., 2003). This algorithm works on the basis of statistical characteristics of a local area, an average and a standard deviation of pixel values surrounding a pixel (Giglio et al., 2003; Byun et al., 2005).

2. EXISTING FIRE DETECTION ALGORITHMS

According to the ECE/FAO database on forest/other wooded land fires in Iran (1982-1995), the number of fires per year is 130 and the average area burnt per year is 5400 ha (Allard, 2003). The use of remote sensing is now an important method for monitoring forest fires, especially in vast and remote areas. For this purpose, MODIS imagery from the Terra with continuous near daily coverage can be a good candidate. Traditionally, there have been there kinds of forest fire detection methods in remote sensing (Liu et al., 1997); the spectral method, the spatial method and the temporal method. The MODIS Science Team developed the contextual fire detection algorithm based on spatial method. It is planned to be fully automated for the production of daily, global fire information (Kaufman et al., 1998). In comparison with original version (Kaufman et al., 1998), MODIS version 4 contextual fire detection offers superior sensitivity to smaller, cooler fires and has yielded fewer blatant false alarms (Giglio et al., 2003). The algorithm is divided in the following steps (Giglio et al., 2003):

a) Cloud and water masking
b) Identification of potential fire pixels to eliminate obvious non-fire pixels
c) Background characterization using the neighboring pixels to estimate the radiometric signal of the potential fire pixel in the absence of fire
d) Tentative fire detection using a series of contextual threshold tests
e) Sun glint, desert boundary and coastal false alarm rejection.

It uses MODIS geolocation product, reflectance values in 0.65μm, 0.86μm and 2.1μm and brightness temperature values in 4μm, 11μm and 12μm.

3. AN AGENT-BASED APPROACH

An intelligent agent is a physical or virtual entity, which is capable of acting in an environment, here an image and competing directly with other agents (Riadh et al, 2006). Autonomous agents operate directly in the two-dimensional lattice of a digital image (Maes, P., 1995; Liu et al., 1997; Keshtkar et al., 2005) and provide an attractive abstraction to encapsulate local and intelligent processing (Duchesnay et al., 2003). Their behavioral responses are triggered by their local stimuli whenever stimuli satisfy certain constraints. The agents may self-reproduce, move to adjacent locations or vanish, in response to the image characteristics of their local neighboring regions (Liu et al., 1997).

4. DATA AND METHODS

4.1. Remote Sensing Data

The remote sensing data used in this paper is an image acquired over Iran in summer 2006 by NASA's Terra satellite. We used the image taken on 27th September of 2006 (figure 1, table 1).

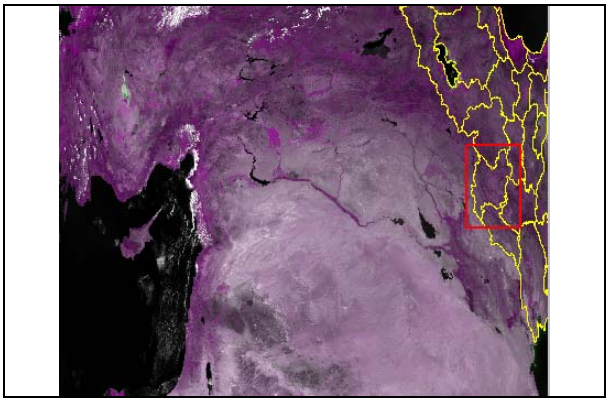

Figure 1. MODIS imagery on July 27, 2006 used in this study

Num	Date	Time (GMT)	
		Start	End
1	2006-07-27	08:13:19	08:16:16

Table 1. Specifications of MODIS image used

In figure 1, the selected window shows our study area, Kerman shah province. Before fire detection, reflectance values for visible and NIR bands and brightness temperature values for MIR and TIR bands are computed using MODIS level 1B 1 km earth view data product. The bands used in our study are listed in Table 2.

Band number	Band width (μm)
1	0.620 – 0.670
2	0.841 – 0.876
7	2.105 – 2.155
21	3.930 – 3.989
22	3.930 – 3.989
31	10.780 – 11.280
32	11.770 – 12.270

Table 2. MODIS bands used in this study

4.2. Proposed Method

The algorithm used in this study is based on agent concept and MODIS version 4 contextual fire detection. In the proposed method, a collection of distributed autonomous agents will operate at the individual pixels of the given image and execute a number of reactive behavioral responses based on tests used in MODIS version 4 contextual fire detection algorithm (Giglio et al., 2003). The agents sense the local stimuli from the image by means of evaluating the intensity of neighboring pixels and active their behaviors to detect fire pixels simultaneously from different parts of the image. It is worth noting that life span of agents, their self-reproduction and diffusion modes (directional/non directional) are pre-defined. The algorithm is as follow:

1. At first, the image is divided into 10×10 blocks.

2. After cloud and water masking (Giglio et al., 2003), in each block, the pixel with maximum ΔT=T4-T11 is detected. It is because, once a forest fire breaks out, brightness temperature in 4 μm (T4) changes significantly compared to the changes in 11 μm (T11).

3. Thereafter, we define a class of agents, fire. Initially, N agents are inhibited in the detected pixels, where N indicates the number of the aforementioned pixels.

4. An agent will leave a marker at a pixel if the tests used in version 4 contextual MODIS fire detection algorithm i.e. step b-e are satisfied, otherwise the agent will diffuse to adjacent pixels within a neighboring region of radius rd (life span is set to Δ). If the fire size exceeds a pixel, it will be necessary to check the neighborhood of the considered pixel .The number of offspring agents reproduced at an active fire pixel is set to s. The directions for an agent to self-reproduce within a neighboring region of radius rsr are determined randomly.

Num	Region	Date	Area (ha)	Spatial coordinate of fire		Time (Local)	
				Latitude	Longitude	Start	End
1	Eslam Abad Gharb	2006-7-27	10	34:05:00 N	46:31:00 E	14:00	20:00
2	Salase Babajani	2006-7-27	1	34:41:16 N	46:13:12 E	16:30	17:20
3	Gilane Gharb	2006-7-27	20	-	-	17:00	20:30

Table 4. Specifications of ground based measurements

5. RESULTS

The developed algorithm is applied to the given image in the defined window. Figure 2 shows the initialization of agents. The attribute values for agents are given in table 3. The results (figure 3(a)) were compared with version 4 contextual MODIS fire product (figure 3 (b)) and ground-based observations collected with GPS by Forest, Range and Watershed management organization (table 4). The MODIS image was observed in the morning at 08:13:19 - 08:16:16 GMT July 27, 2006. According to ground-based observations, the fire events took place in the afternoon. As a result, it is likely to miss fire events duo to limited satellite sampling. Nonetheless, both algorithms have detected one of the reported fires (fire num. 1). It was reported to be an active fire in the afternoon (i.e. approximately 3 hours later). This proves how the evolution of the distributed autonomous agents identifies fire pixels optimally.

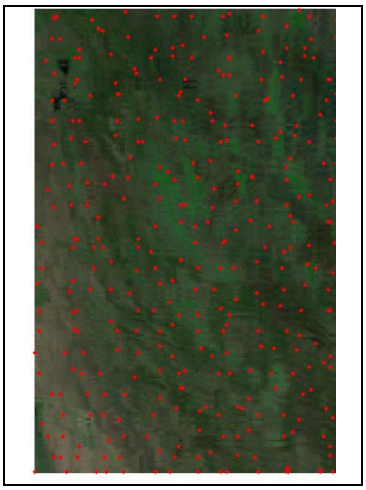

Figure 2. Initialization of agents (t=0)

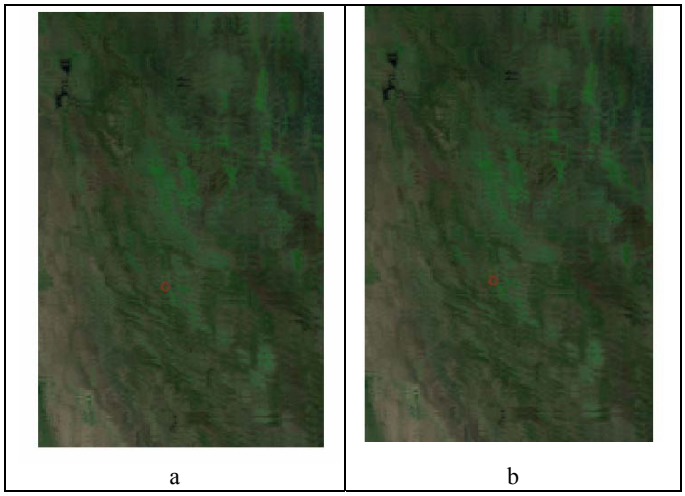

Figure 3. Results of a) the proposed algorithm, and b) MODIS fire product

Attribute	Description	Value
r_d	Radius of diffusion region	2
r_{sr}	Radius of self-reproduction region	1
Δ	Life span of agents	5
S	Number of offspring agents	2

Table 3. Attribute values for agent behavioral responses

6. CONCLUSION

The proposed fire detection algorithm has been implemented and tested with MODIS data acquired over Kerman Shah Province in Iran on July 27 2006. The results were compared with version 4 contextual MODIS fire product and ground-based observations. It implies the agent concept has potential to be applied in the processing of remote sensing imagery, here detecting the fire pixels. In other words, this algorithm incorporated spatial information surrounding the pixels in all steps to reduce commission error in comparison to using the conventional MODIS fire detection algorithms. As a result, using an agent based method, it is possible to have a framework to track fire development with more accuracy. It is also explicit that additional algorithm enhancements may be made in the future.

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