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Realization of a Framework Based on Cellular Automata to Model and Simulate a Natural Disaster: Forest Fires

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Abstract : Crises (fires, earthquakes, floods, etc) often occur suddenly without prior alarm or indications. The size and impact of a crisis vary depending on its nature, the environmental circumstances, and the time and place of occurrence. Managing a crisis involves various agents/factors that affect the assessment of the crisis, its extent, and how to respond to it. To address issues related to crisis management automation, we plan to develop a system assisting management teams in dealing with forest fire. Our objective is to provide a reliable software model for evaluating a crisis, modeling it, and developing an efficient plan for tackling it. Thus, we have to design and implement a prototype that integrates the data captured from site relying on Geographical Information Systems, the reasoning and inference capability of an expert system, and the computing power of a programming language. The functionality of the system is to process quickly available information related to the crisis at hand, retrieve the impacted site database, and provide assistance with regard to: (1) identifying the parameters under prevailing environmental conditions (Wind, temperature, relative humidity, topography and fuels); (2) simulating the evolution of the crisis using specific software tools (Fiatlux, Netlogo); (3) identifying possible threats; (4) displaying important facilities, which may be highly affected; and (5) suggesting a response scenario.

Keywords: crisis management, expert systems, geographical information systems, Netlogo, fire modeling.

1 Introduction

Crisis Management is a systematic response to unexpected events that threaten the people, image and operating continuity of the organization. Cellular automata contribute to be the reliable means for such management. Cellular automata models are one approach providing a potential method to the study of natural phenomena, as well as forest fires. CA models consist of a grid of cells, each cell in one of a number of finite states. Each cell's state is updated in discrete time steps according to a set of rules. These rules depend on the state of the cell or its nearest neighbors in previous or present time steps (Malamud, Turcotte. 2000).

Catastrophic forest fires in Lebanon are a serious threat to both the unique biodiversity of boreal forests and the global carbon balance. In recent years, the Lebanese fire management policy has been unclear, ineffective and non-transparent. The current situation is even more alarming, since ongoing administrative reform and permanent changes in forest legislation lead to the dismantling of the present system of forest management in the country, not to improving its efficiency.

2 Forest Fires: Factors

A wildfire is influenced by three main elements. These are weather, topography and fuels. Each of these elements has several sub-elements.

2.1 Weather

Wind, temperature and relative humidity are the three components that comprise weather. Wind normally has the greatest effect of all the elements on fire spread and intensity as it increases oxygen supply. Fire moving with the wind burns faster than fire reversing the wind direction. After the fire reaches a certain size, it will begin to create its

own wind and burn even faster than before. Fires will generally spot in advance of the main fire in the direction the wind is blowing. Relative humidity directly affects ignition probability and fire intensity. Temperature influences fire behavior by the drying and preheating effect it has on fuels.

2.2 Topography

Topography consists of slope, aspect and terrain. Following wind, slope is the next greatest potential influence on the rate and direction of fire spread. A fire backing downslope will normally move slower than a fire advancing upslope. Taking into consideration the aspect of the slope is also necessary. Generally, south-facing slopes exhibit higher intensity and more rapid rates of spread. Terrain can also affect both intensity and rate of spread, particularly when there are either barriers or natural chimneys present. Barriers such as a log, bare dirt, or rocks, can cause a fire to slow down or even go out. Don't confuse the effect of a barrier's temporary change of a fire's direction with the actual direction the fire came from.

2.3 Fuels

Fuels are characterized by a variety of factors. These include vertical and horizontal arrangement, type, species, size and fuel moisture, both live and dead. Fires will tend to ignite more easily and spread more rapidly in fine dead fuels with low moisture contents.

3 Fire Modeling

In early explorations, a cellular automata approach to modeling the spread of fire over a terrain is developed. In this approach, we aim to be global, and study this issue in a way we reach its prevention in the future. We divided the area into a grid of small squares.
When a fire ignites in a cell, the probability of a neighboring cell igniting depends on the wind, the elevation difference and the fuel available.

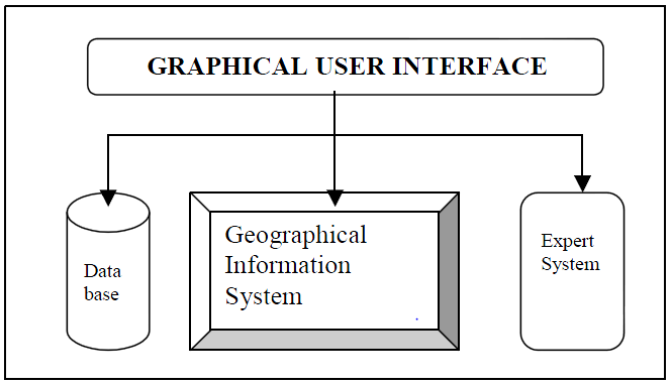

Figure 1: System Components

Figure 1 shows the major components of the system: Data base, Geographical Information System, Expert System.
As research of published literature reveals no integrated systems supporting the automated management of such a crisis, a model is to be integrated. The necessary information to build a fire simulation model may include several parameters, such as fuel, fuel moisture, slope, wind speed and direction, weather, climate, water, soil, and topography. This knowledge base and expert rules are to be collected from several agencies and individuals. Variations of these parameters greatly complicate the dynamic nature of fires.

3.1 Netlogo Model

Netlogo is a programmable modeling environment for simulating natural and social phenomena. Netlogo is particularly well suited for modeling complex systems developing over time.

It is to make the model that mostly resembles reality, thus igniting and spreading of fire relying on parameters (temperature, humidity, and wind speed and direction).
We build our model and currently work on improving it to better performance. Hereby, we can notice how fire ignites and spread when temperature is 38 degrees, and under 70% humidity. The wind is supposed north east and of 6m/s speed. In this phase of modeling, the slope and terrain are neglected as if we are working on level equated land.

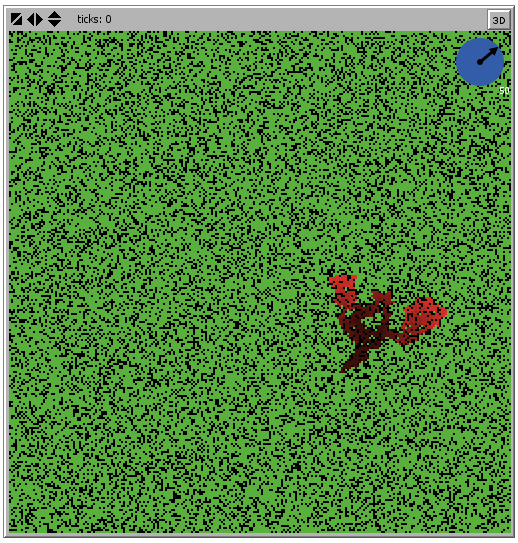

Figure 2-a: Fire ignition spot

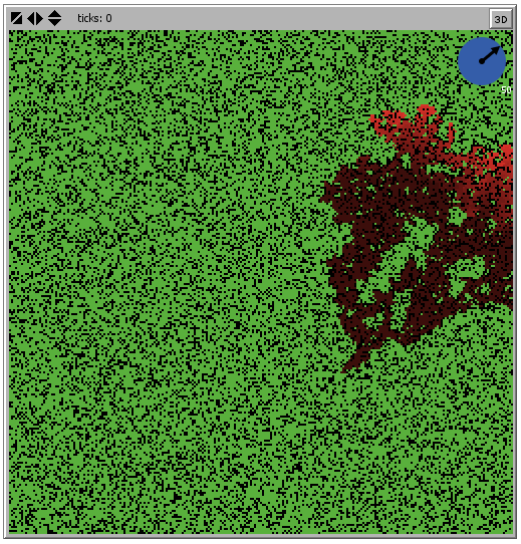

Figure 2-b: Fire spread in the direction of wind

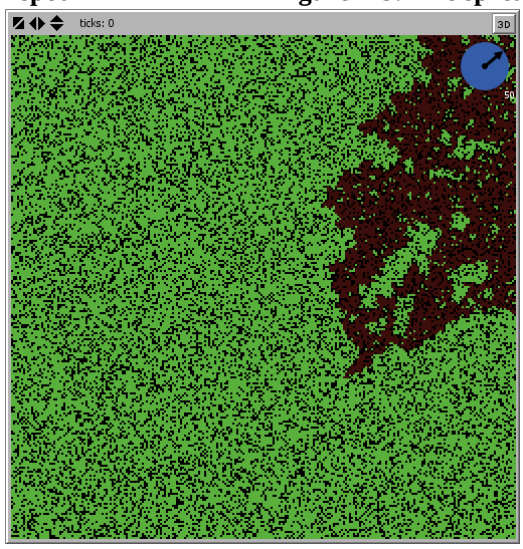

Figure 2-c: Fire stop and turn into ashes

4 Considerations and Future Work

After going deeper through our study, many considerations are to be taken for the next stage:

1 Obtain hourly weather observations from closest weather station that represents the ignition area.

2 Obtain on-site weather readings taken by first responding suppression forces.

3 Refer to forest fires history in Lebanon to scientifically model fire behavior and investigate most common ignition causes.

4 Note relevant slope, aspect, terrain and elevation features for the general area under study.

5 Document vegetation type(s) that burned within the general origin area and especially at the point of origin.

As the project advances, however, more realism and credibility of the fire model is needed based on real data coming from CNRS of Lebanon if available or other non-governmental organizations like AFDC.
Moreover, we need to use other software tools in addition to Netlogo to be capable of designing the best possible model that contribute to predict forest fire before occurrence or at least forest fire restriction in its origin.
Farsite is widely used in the Forest Service and others with an interest in wildfire science. It is part of a suite of programs, including FlamMap and Behave, that are based on first principles of fire physics. Farsite has a variety of output options including the ability to create raster files describing the simulated fire. The types of raster files include, for example, time of arrival (when does the fire reach each point in the area), flame length, fireline intensity, spread direction and crown fire activity. These can be displayed using another tool called ArcGIS. ArcView stores, displays, and updates spatial (maps) and temporal data(environmental parameters and characteristics). The Network Analyst, a component of ArcView, allows the users to solve a variety of problems using a wide selection of geographic maps.

In parallel, we have to seek more and more to define the actions and procedures to be done in case of ignition relying on experts and scientists help (Bio-chemic, Ecologic,…) to obtain a complete model.

5 Last Word

"It is no use saying, 'We are doing our best.' You have got to succeed in doing what is necessary".
- Winston Churchill –

Forest fires are the most important threat to forest and wooded area in Southern Europe.
Fires have caused extensive damage in recent years, leading to loss of human lives, affecting human health, burning properties, infrastructures and business and causing extensive environmental damage in forest and agriculture areas. Many argue that fires also contribute to global warming through the emission of CO2.
To improve Lebanon's fire management capabilities, the government urgently needs to do the following: provide the public with reliable, accurate and complete data on forest fires and their impacts on the environment; move the fire management policy into a public arena, since humans are the main cause of the country's forest fires; and clearly specify the division of responsibilities and to provide efficient cooperation among the federal agencies and regional and local authorities in fire suppression and to provide adequate financial resources and personnel training. National awareness of catastrophic forest fires in Lebanon needs to be raised, as public pressure could force the Lebanese government to change its forest fire management policies. Non-governmental organizations can play a vital role in this process by using pilot research projects to demonstrate the real scale of the problem and to analyze the causes and impacts of forest fires. Non-governmental organizations can also show how to run effective campaigns for fire prevention at local and regional levels.

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