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Cellular Automata on GIS Method for Forest Fire Spreading Simulation

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Abstract

A method for prediction and simulation based on the Cell Based Geographic Information System (CBGIS) as Cellular Automata (CA) is proposed together with required data system systems, in particular metasearch engine usage in a unified way. It is confirmed that the proposed CBGIS as CA has flexible usage of the attribute information that is attached to the cell in concern with location information and does work for disaster of forest fire spreading simulation and prediction.

Keywords: Cell Based Geographic Information System (CBGIS), Cellular Automata (CA)

1. Introduction

Because geocoded earth observation satellite data can be represented on geographic maps, GIS representation is effective in such case cases. CA, on the other hand, is effective for estimation and prediction phenomena and is based on cells. Therefore, geocoded data can be treated as cell wise data, which results in CBGIS as CA. Furthermore, GIS work works as a neural network, allowing predictions and simulations. Disaster relief and prediction can be done with cellular automata. All the required data for disaster relief and prediction can be represented on cell s and can be acquired with Web Map Services: WMS. Meanwhile, the Web Geographical Map (Landscape map→ Landscape object, Land Land-use map→ Human activity influences), the Forest Map (Forest type→ Tropical Forest, Homogenous Forest, Hot Spots), and the Weather Map (Wind, Season, and Temperature) are also retrieved and downloaded from the service servers through a metasearch. WMS provides geographical map data with the information lossy algorithm while WCS (Web Coverage Service) data is represented as a set of cells. Therefore, CBGISCA uses WCS type types of geographical maps, cell-based representation representations of maps rather than WMS.

2. Proposed Forest Fire Prediction

The proposed method is a two-dimensional CA that uses a square grid of sites. It can be superimposed on GIS. The following four parameters are considered: tree-types, wind speed and direction, sparking probability, and stooping probability. Several tree-types with different probabilities for fire are also considered. The proposed forest fire model consists of a square grid of sites of which blank node, tree, and fire are the status. Some trees around a fire may be fired depending on the sparking probability *fs* [1], and fire may be stopped depending on the stopping probability, and fire may be stopped depending on the stopping probability fc. The stopping probability fc is a constant that depends on the tree material and species. Meanwhile, sparking probability is a variable which depends on species, wind speed, and wind direction. The tree species parameter shows the possibility of burning. The wind speed parameter defines the size of the neighborhood and shows that the model uses a dynamic neighborhood model. The wildfire propagation direction depends on the wind direction parameter. The CA algorithm for forest fire simulation is represented as follows:

It begins with a square grid of sites. There are five states:

s=1 → blank node

s=2,3,…,n+1 → tree (n different tree types). Malamid *et al.* [2] use one type of tree. s=n+2 → fired
s=n+3 → stopped or completed fired

It is determined the neighborhood (size and shape), depending on wind speed and wind direction, using the Cardioid concept. Trees will be fired by the sparking probability fs if there are fire neighbors. Fire will be stopped by the stopping probability fc. In the proposed method, Ohgai *et al.* [3] define tree types made of different materials. Each material has a probability of fire that depends on the tree type. It is defined the simple probability of fire depending on material as the following:

Sij = 1, if wooden

= 0.6, if preventive wooden

= 0, if fireproof.

In the CA approach, one of the important parameters is neighborhood rules. The proposed method uses a dynamic neighborhood system depending on wind parameters, wind speed, and wind direction. The number of neighbors depends on wind speed. neighbors depend on wind speed. According to Jirou and Kobayashi [4] and Ohgai *et al*. [3], the relationship between the number of neighbors and wind speed is expressed as Equation (1):

$$D = 1.15\,(5 + 0.5\,v) \tag{1}$$

where v is wind speed (m/s) and D is the limit of the distance in which the fire can spread. Sullivan and Knight [5] use the bubble concept while we use the "Cardioid" concept for definition of the influence of wind direction on the neighborhood system. This is the proposed model in the CA approach for forest fire simulation. This is an original method which differs from the Sullivan and Malamud model models. The new limit of the distance in which fire can spread is represented as Equation (2):

$$D^* = D\,(1.5 + \cos(d)) \tag{2}$$

where d is wind direction, D is the limit of the distance that is written in equation 1, and D* is the new limit of distance of fire can spread. There are wind parameters determine the neighborhood system, r and α. The first parameter is wind speed r that relates to wind speed. The second parameter is wind direction α. Figures 1 and 2 show how the wind parameters determine the neighborhood system in the proposed approach.

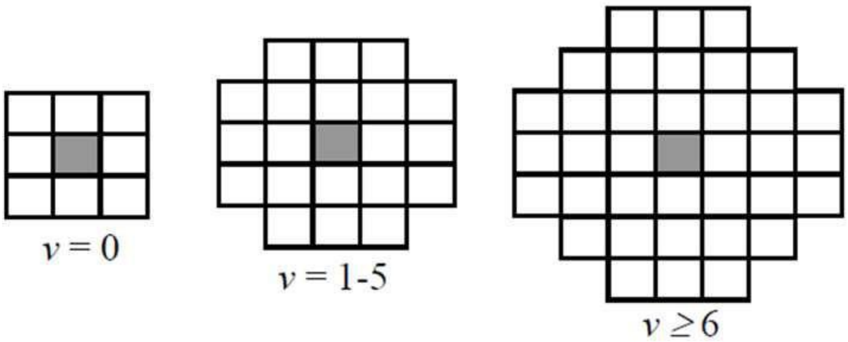


Figure 1. Neighborhood size depends on wind speed.

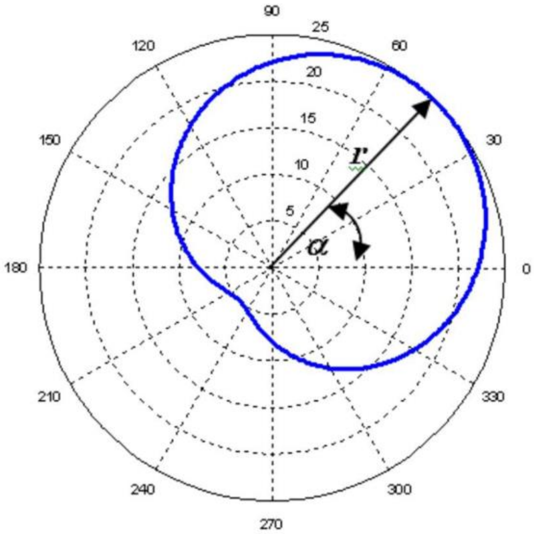
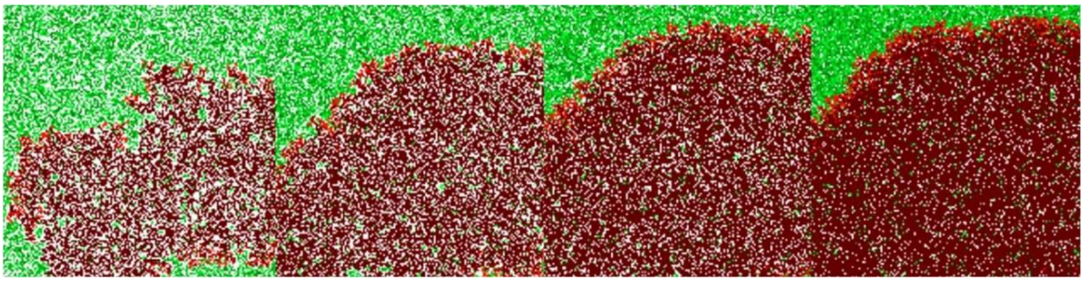


Figure 2. The Cardioid concept for wind influence.

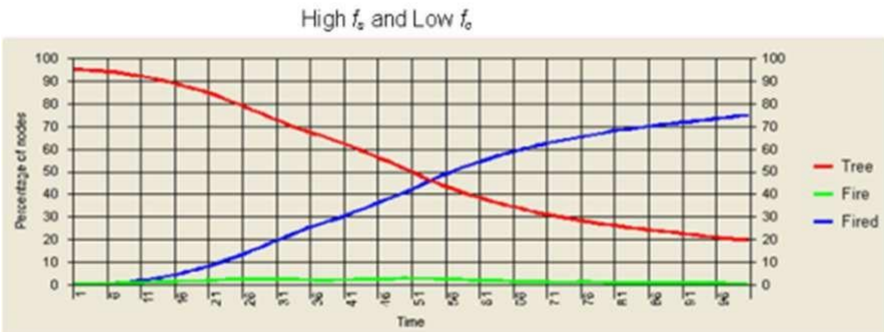
3. Experiment

In this simulation three tree-types with different probabilities of fire are set. The probability is randomly selected. The other input parameter is density, the number of trees in the observation area. It is selected a density of around 0.6-1. Figure 3 shows the simulation results in 40-unit time steps with different densities. This simulation uses two probability functions: sparking probability fs and stopping probability fc. The number of fired areas, which depends on sparking probability and stopping probability, are shown in Figure 4. A different combination of fs and fc has different joint points at the number of trees and the number of fired areas.



Density=0.6 Density=0.7 Density=0.8 Density=0.9

Figure 3. Simulation results on different density



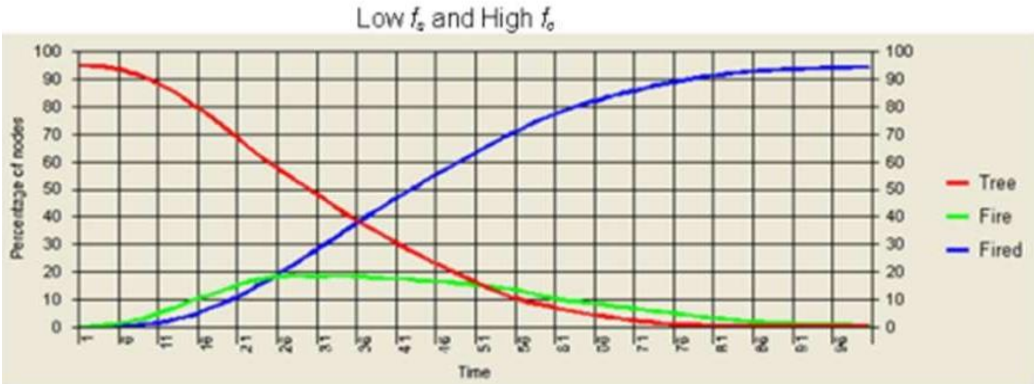


Figure 4. The number of fired area depends on fs and fc.

4. Conclusions

In conclusion, the proposed method allows the flexible use of attribute data that are required for forest fire disaster prediction with reference to geographical location information. Also, the prediction results can be represented in a GIS display superimposed with other attribute data. Therefore, it is easy to check the validity of prediction results.

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