CELL BASED GIS AS CELLULAR AUTOMATA FOR DISASTER SPREADING PREDICTIONS AND REQUIRED DATA SYSTEMS

***Kohei Arai*[1*]**

1: Department of Information Science, Graduate School of Science and Engineering, Saga University, Saga 840-8502 Japan,*
E-mail: aria@is.saga-u.ac.jp

ABSTRACT

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

Keywords: Cellular Automata, Geographic Information System, Meatasearch

1 INTRODUCTION

Satellite data utilized analysis methods need metadata searches before data retrievals (most of countries adopted ISO Metadata standard). Although there are some search engines, CS-W as well as Open search, as standard metadata search engine, there is no unified method for metadata search. In this paper, metadata search is discussed. Meanwhile, Geographical Information System: GIS is totally identical to Cellular Automata: CA which allows predictions, simulations. In this paper, Cell Based GIS as CA (it is referred to CBGISCA hereafter) is proposed.

CA approaches are widely used in disaster spreading simulations such as forest fire (wild fire), flooding, lava flow, landslide, mudflow, etc. CA approaches are simple and easy to develop, and obtain the spectacular displays or visualization. Especially for forest fire prediction, CA approaches were used by many researchers to simulate and show fire spreading for some periods.

Ioannis [1] presented the simple CA model to predict the spreading of fire in both homogeneous and inhomogeneous forests. This model is simple, although it has some addition parameters. Malamud [2] presented a forest-fire CA model by programmed simulating different fire frequencies, spatial and temporal patterns. Ecinas [3] presented a new two dimensional CA approach using hexagonal area of forest, and show the transfer of fractional burned area with different speed. The algorithm seems to be very efficient from the conventional one and it is easily implemented in any computer algebra system, allowing a low computational cost. These approaches [1][2][3] are too simple to show complex forest-fire spreading, such as tree-types, landscape and wind determination.

The other approach, introduced by Song [4], presented an improved model of CA approach with tree species, meteorological conditions and human efforts on fires are looked on as generalized “immunity” of the tree from fire. This model improved the previous model with some addition parameters, but it did not show relation between trees and probability to fire. The probability to fire is important parameter to make the model can adopt some unknown condition with simple approach.

In this paper, a new two dimensional CA approach using fire-control probability, wind characteristics and tree-types is introduced. This approach is simple and easy to develop because it uses phenomenological relationships directly. CA based forest fire prediction requires a plenty of attributed data on conditions, wind speed, wind direction, tree species, humidity, air temperature, topological feature, etc. On the other hands, GIS has databases which includes such attribution data. The proposed CBGISCA consists of 2D cells which represent geographical map, and the aforementioned attribute data. Therefore, CA based simulations can be done with reference to the attribute data effectively. Although this approach is simple, it is an alternate approach to predict forest fire spreading and shows the dangerous area in the future.
Malamud [2] presented the simple CA approach using the programmed model. This model consists of a square

grid, in which at each time step a tree is randomly dropped on a chosen site. Every 1/*fs* time steps a match is randomly dropped (*fs* is the sparking frequency). If a tree falls on an unoccupied cell it is planted. If a match drops on a tree, that tree and all non-diagonally adjacent ones are burned in a fire. The keyword of this approach is sparking frequency.

The one of important parameter in forest fire simulation is wind speed. This parameter influences the neighborhood size and sparking probability f_s. Relation of wind speed, the neighborhood size and sparking probability, introduced by Sullivan [5], is defined. It is the “bubble” convection model of wind speed influences in forest fire simulation, because this model assumes that fire component is a bubble model.

In the following section, the proposed method of metadata search engine is described followed by the CBGISCA together with the example of the proposed forest fire propagation method. Simulation results are also described. Then concluding remarks with some discussions is followed.

2 PROPOSED METHODS

2.1 Metadata search engine

CS-W, Open search is well known meatdata search engine. Cadcorp holds metadata in a centralised repository on a geospatial server, GeognoSIS. The repository is accessed through the Open Geospatial Consortium Catalog Server (Web) interface, OGC CS-W. OGC CSW Core (OGC, 2007core): this interface is recommended by the GEO/GEOSS. OGC CSW ISO Application Profile (OGC, 2007iso): this interface is identified by INSPIRE Implementing Rules (IRs) as the reference for ESDI catalog services. Meanwhile, OGC CSW ebRIM/EO is Extension Package (OGC, 2008eo). This extension package of the CSW is recommended by the GMES/ESA-HMA initiative (http://earth.esa.int/hma/index.html). On the other hand, OGC CSW ebRIM/CIM (OGC, 2007cim), OGC CSW OpenSearch Extension (OGC, 2008os) and the GENESI-DR (Ground European Network are for Earth Science Interoperations while Digital Repositories) (http://www.genesi-dr.eu/) catalog interface which is based on it.

The OGC seeks comment on City Geography Markup Language (CityGML) V1.1. There are OGC Requests Sensor Planning Server (SPS) 2.0 Reference Implementations, OGC seeks comment on candidate Earth observation profile of coverage standard, OGC Seeks Comment on candidate GeoSPARQL standard, The OGC and OpenMI Association to advance computer modeling standards, The OGC Seeks Participants for Hydrologic Forecasting Interoperability Experiment, OGC completes Water Information Concept Development Study, The OGC Announces GEOSS Workshop XLIII: Sharing Climate Information and Knowledge. It would be better that metadata search can be done in a unified way. It is also desired to determine a standard procedure for metadata search.

2.2 CBGISCA

Because geocoded earth observation satellite data can be represented on geographic maps. GIS representation is effective in such case. 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 CBGISCA. Furthermore, GIS does work as neural network then it allows predictions and simulations. In particular, disaster relief and prediction can be done with cellular automata. All the required data for disaster relief and prediction can be represented on cells and can be acquired with Web Map Services: WMS. Meanwhile, Web Geographical Map (Landscape map→Landscape object, Land-use map→Human activity influences), Forest Map (Forest type→Tropical Forest, Homogenous Forest, Hot Spots), and Weather Map (Wind, Season and Temperature) are also retrieved and downloaded from the service servers through the meataserach. 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 of geographical maps, cell based representation of maps rather than WMS.

Raster based GIS consist cells (grid) while Geo-coded earth observation data is represented on cells. Meanwhile, data required for simulation and prediction (disaster relief, etc.) is represented on cells. All these data are represented on a cell based GIS and also are used for simulation and prediction as cellular automata. GIS (ISO Standard) representation of cells, GIS based cellular automata is used for disaster relief and prediction. Meta search has to be done with unified way. Therefore, a Standard Clearing House System is highly required. Consistency of the data quality with space and time as well as among the sensors in concern

3 APPLICATIONS OF GIS ON CA FOR FOREST FIRE SIMULATIONS

3.1 Proposed cellular automata on GIS method for forest fire spreading simulation

The proposed method is two dimensional CA which uses a square grid of sites. The following four parameters are taken into account, tree-types, wind speed and direction, sparking probability and stooping probability. A number of tree-types with different probability for fire is taken into account.

The proposed forest fire model consists of a square grid of sites of which blank node, tree, and fire are considered as the status. Some trees around fire may be fired depending on the sparking probability f_s [3], and also fire may be stopped depending on the stopping probability f_c. Stopping probability f_c is a constant which depends on the tree material, species. Meanwhile, sparking probability is a variable which depends on material (species), wind speed and wind directions. Tree material (species) parameter shows possibility to be fired. Wind speed parameter defines the size of neighbors, and shows that model uses dynamic neighborhood model. Wild fire propagation direction depends on wind direction parameter.
The algorithm of Cellular Automata for forest fire simulation is represented as follows,

- We begin with a square grid of sites; there are five states:
  - s=1 → blank node
  - s=2,3,…,n+1 → tree (n different tree types). Malamud et.al [1] uses one type of tree.
  - s=n+2 → fired
  - s=n+3 → stopped or completed fired
- Determine neighborhood (size and shape) depend on wind speed and wind direction. We use the Cardioid concept.
- Trees will be fired by sparking probability f_s, if there are fire neighbors.
- Fire will be stopped by stopping probability f_c.

In the proposed method, we define n tree types that have different material. Each material has probability of fire which depends on tree type. Ohgai[6] defines the simple probability of fire depending on material as following:

S_{ij} = 1, if wooden
= 0.6, if preventive wooden
= 0, if fireproof.

In CA approach, one of the important parameters is neighborhood rules. The proposed method uses dynamic neighborhood system depends on wind parameters; wind speed and wind direction.
The number of neighbors depends on wind speed. According to Jirou and Kobayashi [7] and Ohgai[6], the relation of the number of neighbors and wind speed is expressed as equation (1):

$$D = 1.15\ (5 + 0.5\ v) \qquad (1)$$

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

$$D^* = D\ (1.5 + \cos(d)) \qquad (2)$$

where d is wind direction, D is limit of distance that written in equation 1, and D^* is new limit of distance of fire can spread.

Figures 1 and 2 show how the wind parameters determine neighborhood system in our approach. In this figure we have two variables, r and α. The first parameter is wind speed r that relates on wind speed. The second parameter is wind direction α.

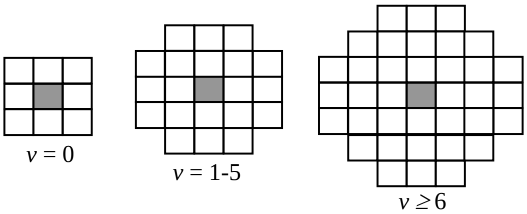


Figure 1. Neighborhood size depends on wind speed

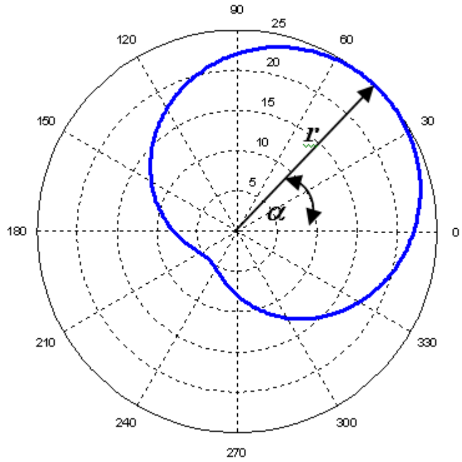
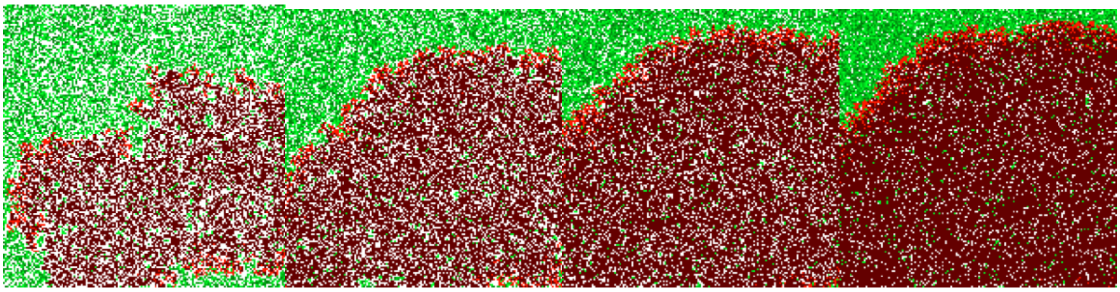


Figure 2. The Cardioid concept for wind influence

3.2 Simulation results

In this simulation three tree-types with different probability of fire are set. The probability is randomly selected. The other input parameters are density. It shows the number of trees in the observation area. We select density of around 0.6-1. Figure 3 shows the simulation results in 40 unit time steps with the different density. This simulation uses two probabilities function; sparking probability f_s and stopping probability f_c. The number of fired area which depends on sparking probability and stopping probability are shown in Figure 4. Different combination of f_s and f_c has the different joint points of the number of tree and the number of fired.



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

Figure 3. Simulation results on different density.

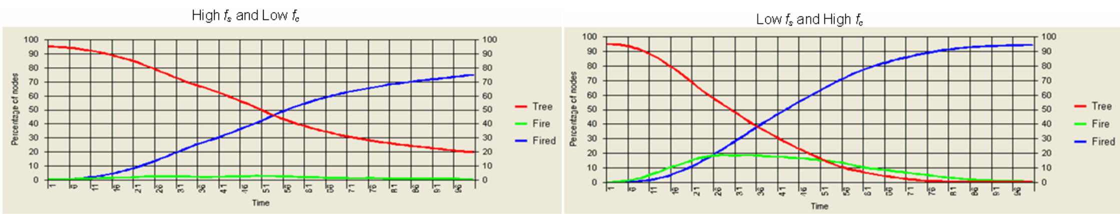


Figure 4. The number of fired area depends on f_s and f_c.

4 CONCLUSIONS

Conclusion is as follows,

- GIS (ISO Standard) representation of cells
- GIS based cellular automata is used for disaster relief and prediction
- Meta search has to be done with an unified way → Standard Clearing House System is highly required
- Consistency of the data quality with space and time as well as among the sensors in concern

In particular, the proposed CBGISCA allows flexible use of attribute data which are required for disaster prediction with reference to the geographical location information. Also prediction results can be represented in GIS display superimposing with the other attribute data. Therefore, it is easy to check a validity of the prediction results.

5 REFERENCES

[1] Ioannis Karafyllidis *, Adonios Thanailakis, A model for predicting forest fire spreading using cellular automata, Ecological Modeling 99, 87-97, 1997..

[2] Malamud, B.D., Turcotte, D.L., 2000, Cellular-Automata models applied to natural hazards, IEEE Computing in Science & Engineering, Vol. 2, No. 3, pp. 42-51, 2000.

[3] L. Hernandez Encinas, S. Hoya White, A. Martin del Rey, G. Rodriguez Sanchez, Modeling forest fire spread using hexagonal cellular automata, Applied Mathematical Modeling 31, 1213–1227, 2007.

[4] SONG Weiguo, FAN Weicheng & WANG Binghong, Self-organized criticality of forest fires in China, Chinese Science Bulletin Vol. 46 No. 13 July 2001.

[5] A.L. Sullivan, I.K. Knight, A hybrid cellular automata/semi-physical model of fire growth, Complexity International, Volume 12, 2005.

[6] A. Ohgai, Y. Gohnai, S. Ikaruga, M. Murakami and K. Watanabe, Cellular Automata Modeling For Fire Spreading As a Tool to Aid Community-Based Planning for Disaster Mitigation, Recent Advances in Design and Decision Support Systems in Architecture and Urban Planning, 193-209, Kluwer Academic Publishers. Printed in the Netherlands, 2004.

[7] Jirou K, K Kobayashi,“Large area fire”, in: Fire Institute of Japan (eds.) Fire Handbook third edition, Kyoritsu Publication Co., Ltd., Tokyo, p. 508-573 (in Japanese), 1997.