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Application of cellular automata technique for prediction of growth pattern through Java programming

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ABSTRACT

Cellular Automata (CA) is an effective simulation technique to study the dynamics of urbanization in rapidly growing cities, from different perspectives of planning and development. CA technique is convenient for encoding spatial structures like built up, agricultural land, waste land, industrial land, plantation etc. The information so generated by CA encoding would not only serve as baseline data but also help in providing predictive scenario to categorize the areas for sustainable urban development. Geographical Information System (GIS) is used to view and analyze data from a geographic perspective. The spatial representation of an object and its related attributes are merged into a unified data file. The paper demonstrates the futuristic view of the study area for the year 2020. The result includes statistical details of built up growth (63.64%) of the area under consideration.

Keywords: Cellular Automata, Supervised Classification, Growth Pattern, Prediction Model.

1. Introduction

Fast growing cities are becoming a cause of concern for all developing countries of the world due to haphazard and rapid urbanization. Urbanization has led to serious issues like loss of agricultural land, metamorphosis of hill slopes, unauthorized / slum development along river banks, availability of waste disposal sites, hike in land values, and other related problems. In the emerging scenario it is essential to have updated information on urban growth pattern and its impact on the environment. The growth of these metropolitan cities is likely to continue and therefore there will be a need to design proper City Development Plan (CDP) and managing or improving the existing infrastructure facilities.

Urban growth modeling can assist urban and regional planners to foresee impacts of their actions and policies (Wegener, 1994). To date, various urban growth models are developed by using the simple vs. complex, aspatial vs. spatial views of urban phenomena. For more than a decade, research focus has been on developing a model using Cellular Automata (CA) technique as it can handle the spatial complexity of the urban change process. This model is receiving more attention due to the capability for managing spatial and temporal dimensions, using bottom-up approach, relying on geospatial data and capacity to couple with raster-based Geographic Information System (GIS) as well as with other approaches such as agent-based or multi-criteria evaluation (Batty, 1998).

The computer representation of geographical space in current GIS technology is essentially static. Therefore, one important research focus in geocomputation aims to produce models that would combine the *structural* elements of space (geographical objects) to the *processes* that modify such space. Such models would free us from static views of space (as centuries of map-making have conditioned us) and to emphasize the dynamic components as an essential part of geographical space. Cellular automata (CA) models consist of a simulation environment represented by a grid of space (raster), in which a set of transition rules determine the attribute of each given cell taking into account the attributes of cells in its vicinities. These models have been very successful in view of their operationally, simplicity and ability to embody both logics- and mathematics-based transition rules. In this paper LANDSAT data (2008) is taken as the base map for understanding the current Land Use / Land Cover (LULC) status. Model based on cellular automata technique are proposed herein to replace the conventional tools.

A. Cellular Automata Technique

CA is discrete dynamical system that model the complex behavior based on simple, local rules animating cells on a lattice. In the simplest forms of CA, space is represented by a uniform M-dimensional grid of cells (e.g. M=1, M=2), with each cell containing some data. Time advances in discrete steps and the laws of the "universe" are expressed through a rule (or “finite state machine” = FSM) dictating how, at each time step, each cell computes its new state given its old state and the states of its K closest neighbours (K = key parameter). Thus, each CA’s behaviour is determined by a uniformly applied rule governing local unit behaviours.

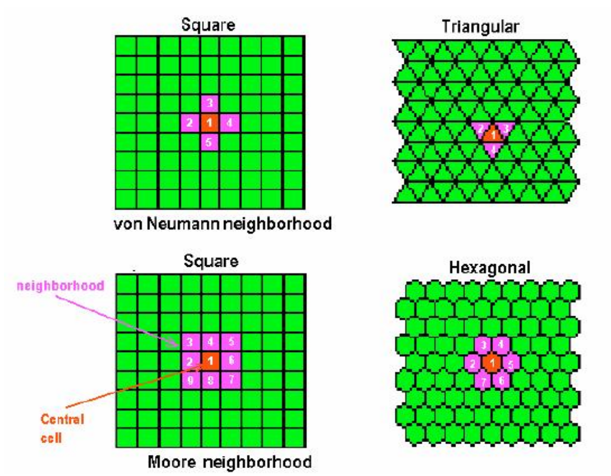


Figure 1: Central and neighboring cells representing 2D cellular automata

The main feature of CA is regularity and homogeneity. CA can be defined as a structured collection of identical elements called cells. The basic computational unit in cellular automata is called a cell and such cells are in fact nonlinear dynamic systems. The neighborhood is a concept representing the set of cells that are directly interacting with the central cell. The central cell is depicted in red while surrounding cells in the neighborhood in magenta (Figure 1). The structure is given by the choice of lattice. Such lattices are 1-dimentional, 2-dimentional and, less used, 3 or more dimensional.

B. A conventional cellular automaton consists of

1. A Euclidean space divided into an array of identical cells.
2. A cell neighborhood.
3. A set of discrete cell states.
4. (d) A set of transition rules which determine the state of a cell as a function of the states of cells in the neighborhood.
5. Discrete time steps, with all cell states updated simultaneously.

C. The algorithm used in CA is as follows

{

For every cell

{

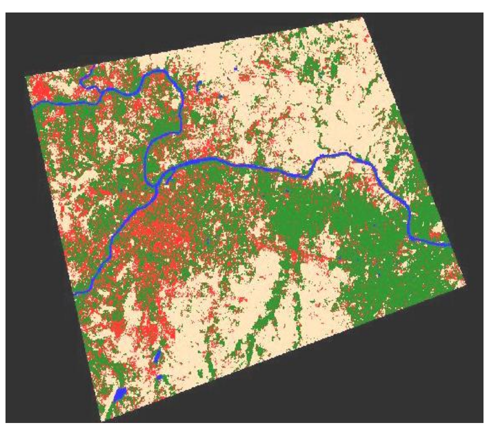
If cell is the same state as its group made by several adjacent neighbor cells Keep the state of the cell unchanged or else choose the majority cells' value

}

}

2. Methodology

The LANDSAT satellite imagery has been downloaded for Land use - Land cover supervised classification. This image is classified in four land use classes, namely: barren land, water body, built-up area (built-up, road/rail) and vegetation (Figure 2).



Red: Built up, Green: Vegetation, Blue: Water body/river, Yellow: Barren land

A. Supervised classification

In supervised classification, the analyst, based on the prior information on the spectral characteristics of these classes, 'trains' the computer to generate boundaries in the feature space within which each class should fall.

Then each pixel lying within a class boundary is assigned to that class. Typical supervised classification involves three steps (Lillesand and Kiefer, 1987).

1. The training stage, wherein the multi- spectral parameters are extracted for various classes from the training sites identified in the image.
2. The classification stage, wherein, each pixel is assigned to a class to which it most probably belongs, and
3. The output stage – the presentation of the data is in the form of maps, tables, graphs, etc.

Since it is important to analyze different urban land use classes that change over time, built up and transportation routes were chosen as the most dynamic factors. Land uses such as agricultural areas which would impose more constraints on urban growth pattern, were classified as other land use classes. Nonetheless, this area has been considered to be changed to housing throughout the simulation. Water bodies represent comparatively fixed land use types, which are assumed not to grow or change the location over the short time period. Therefore, the simulation was configured to ensure that urban area can grow in any direction without limitations except for river, water bodies and steep slopes along hills, in which urban growth is assumed to be difficult. For predicting urbanization, CA technique has been performed on various land use land cover classes.

B. Working principle

The CA model in general works by

1. Simulating the present by extrapolating from the past using the image time-series,
2. Validating the simulations via the remotely sensed time-series of past conditions and through the available collection of field observations,
3. Allowing the model to iterate to the year of choice in future and
4. Comparing model outputs to an autoregressive time-series approach for annual conditions

3. Practical Demonstration

A. CA rules for Pre-defined Land Use/Land Cover classes

1. Builtup area

If there are more than 3 pixels of build up around either Open land, or Dense vegetation, or medium dense vegetation or agriculture then open land or dense vegetation or medium dense vegetation will convert into built up area.

2. Water body

No change in waterbody

3. Vegetation

1. If there are more than 3 pixels of agriculture around either Open land, or Dense vegetation, or medium dense vegetation then convert it in to Agriculture.

2. If there are more than 3 pixels of agriculture around builtup then no change in to builtup

4. Barren land

1. If there are more than 3 pixel of open land around dense vegetation then converted it in to open land
2. If there are more than 3 pixels of built-up around open land then no changes in built-up.

B. Cellular Automata algorithm Process

1. Define the Land Use/Land Cover classes for input multi date classified images
2. Generation of the user interface using Net beans 5.5.1.
3. Define the file format for input image.
4. Set the transition rules for defined classes for the algorithm.
5. Provide image input and run the algorithm.
6. Validation of the rules and subsequent changes in the transition rules to get final output.

C. Step to run Prediction model by using cellular automata algorithm

1. Step 1: Enter the old classified image and the year of older classified image.
2. Step 2: Enter the new classified image and the year of new classified image.
3. Step 3: Choose which color represents which classification class.
4. Step 4: Calibrate iteration computes number of iteration/decade.
5. Step 5: Select the year of which Urban sprawl is to be predicted.
6. Step 6: Compute the City sprawl for the selected year.
7. Step 7: Verify city growth in percentage as an output of the simulation model.

8. Step 8: View the predicted image as an output image of the simulation model.

D. Flowchart followed in Cellular Automata Algorithm

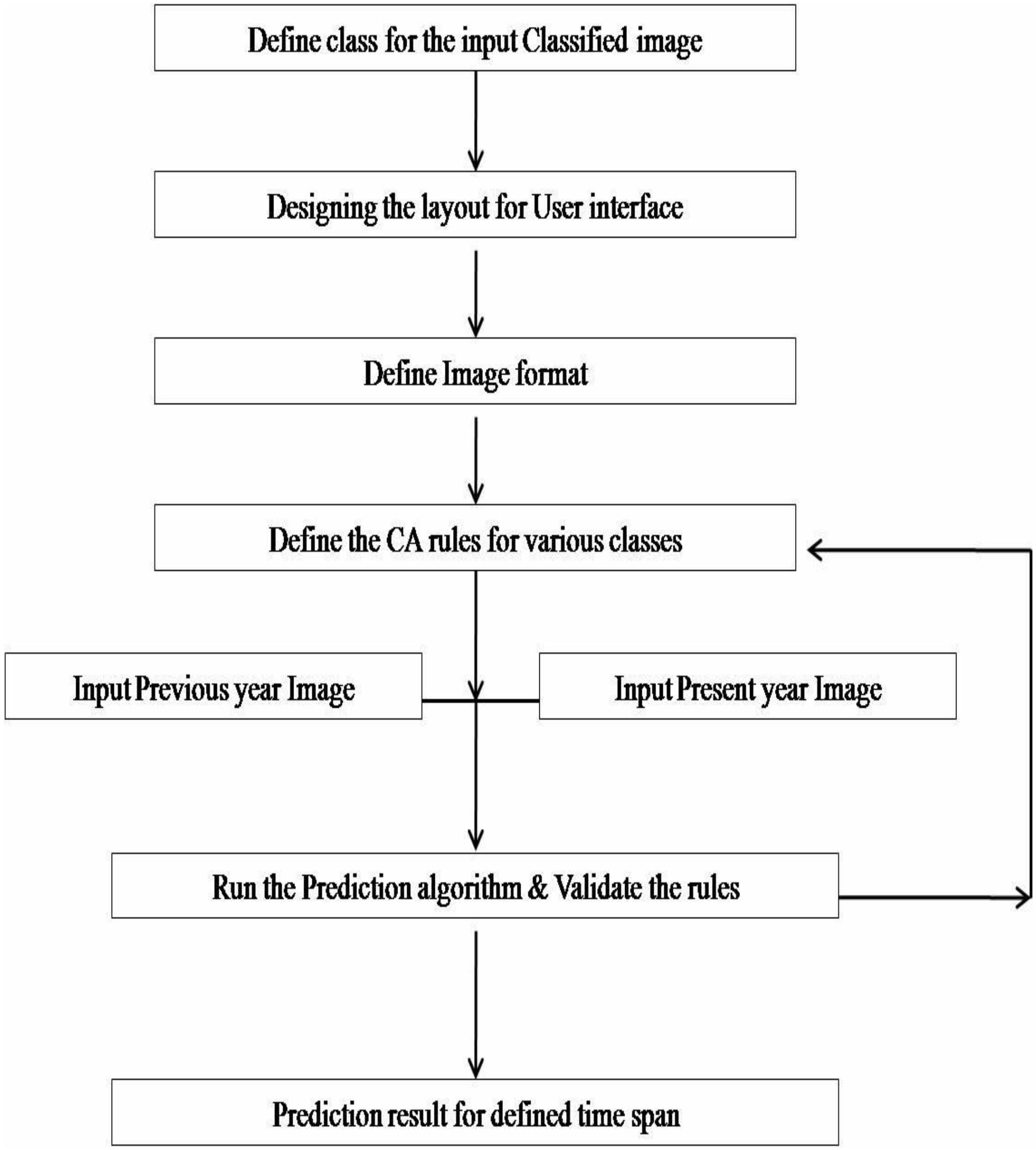


Figure 2: Flowchart for Cellular Automata algorithm

E. User Interface of Cellular automata algorithm

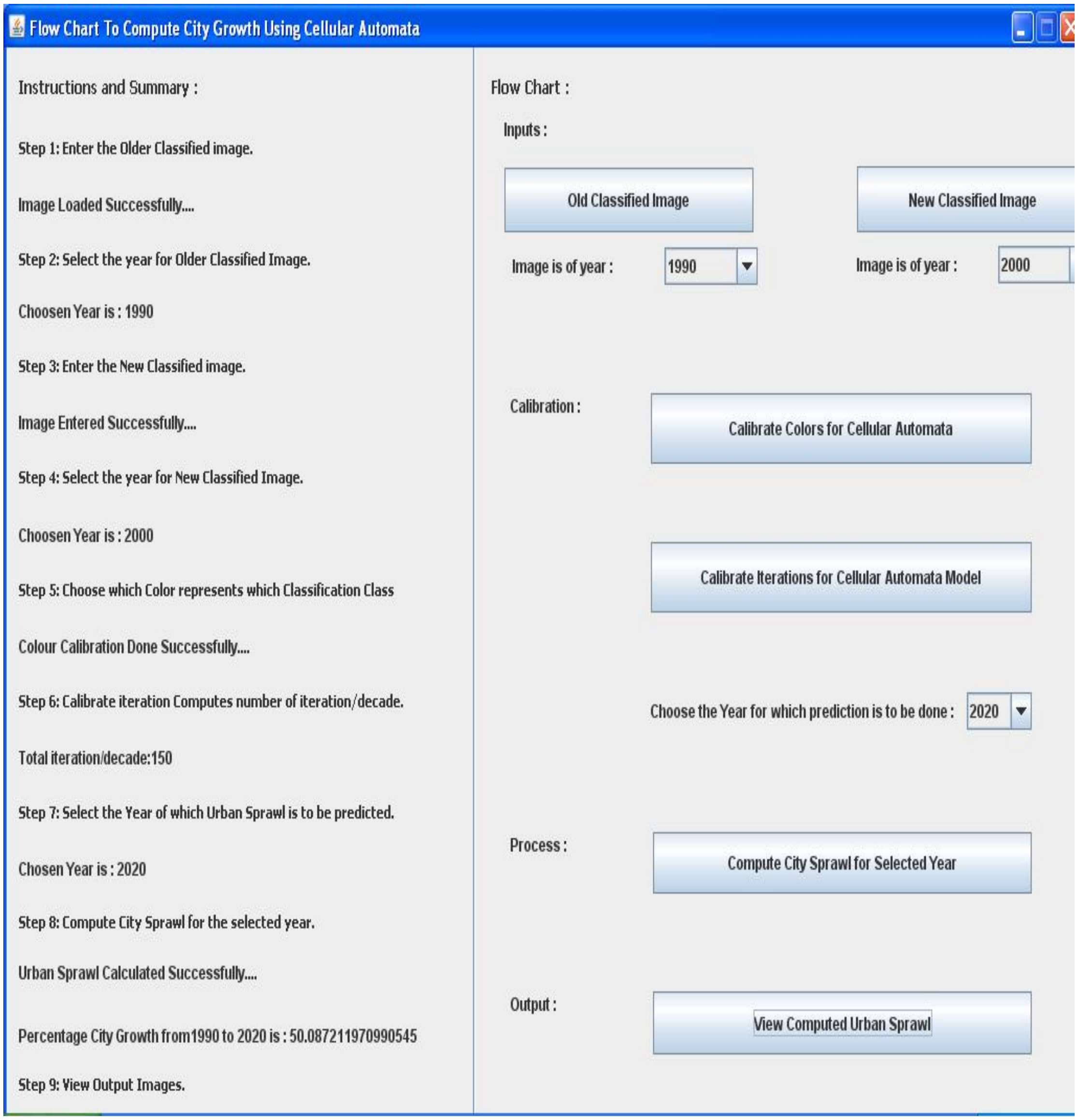


Figure 3: User Interface of Cellular automata algorithm

4. Prediction Model

Prediction Model is implemented with the help of JAVA programming language (Figure 5). Input for this model is classified images of two different years in bmp format. For processing of prediction logic in JAVA, bmp format is mandatory. Along with classified images, their representative and color code opted for different classes (Figure 6) should be provided as input to this model. Prediction model takes these classified images of different years for finding out the trend in the built up area. With the help of this trend, the software predicts the future growth of any area. It also prints growth of area in percentage for selected year.

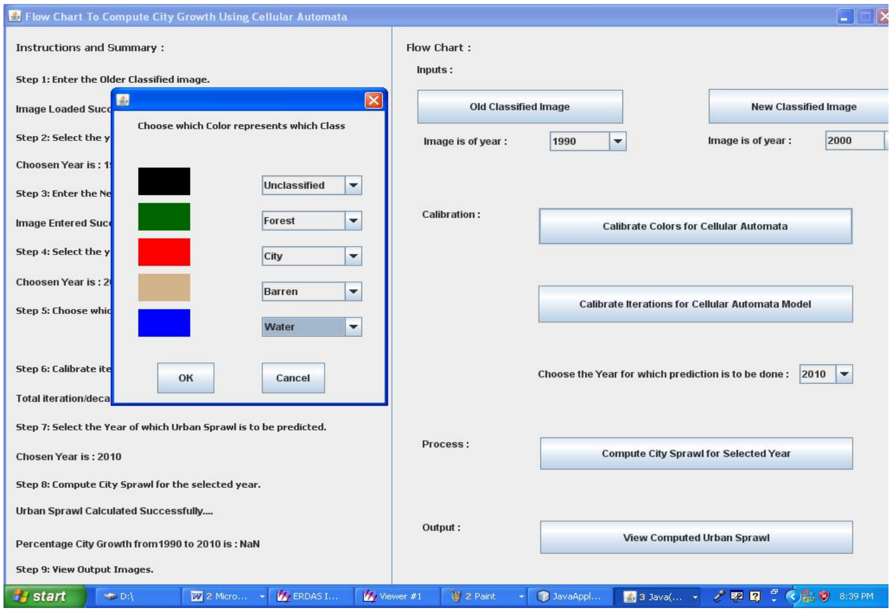
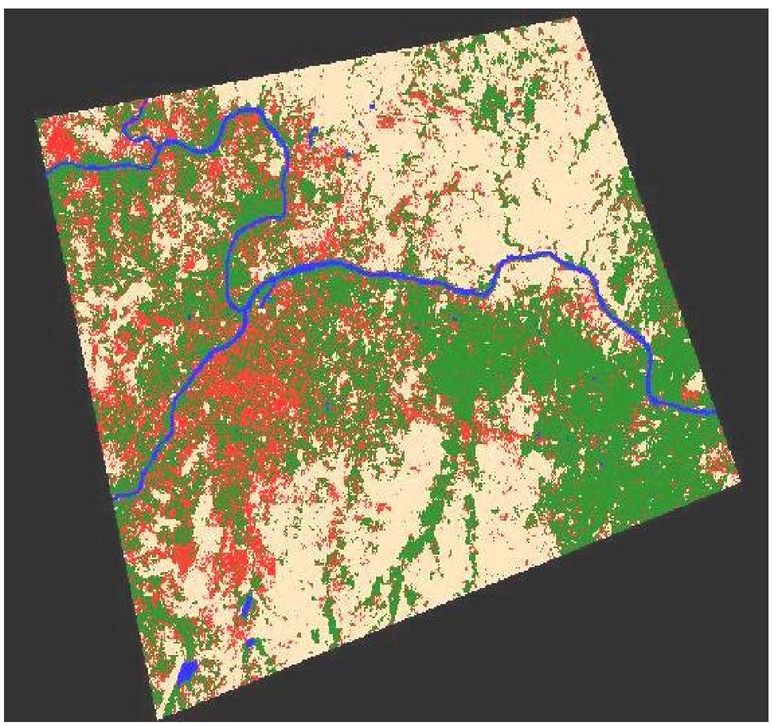


Figure 4: Color indication used for various land use – land cover classes

A. Output generated by prediction model

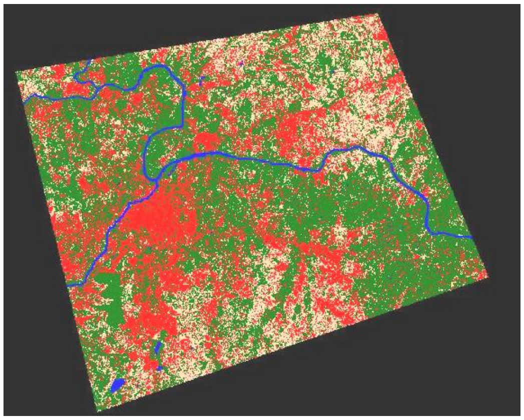
1. Image of year 1990

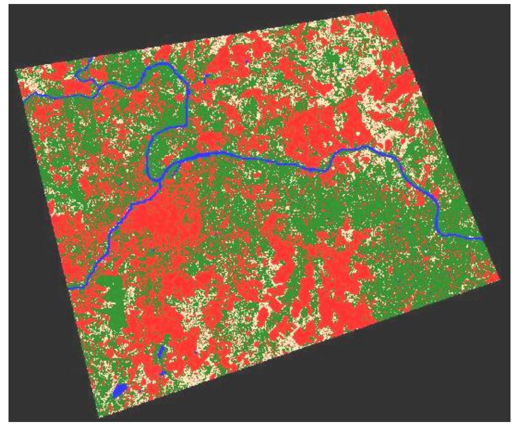


Red: Built up, Green: Vegetation, Blue: Water body/river, Yellow: Barren land

Figure 5: Land use/Land cover pattern of the year 1990

2. Image of year 20003. Predicated image of year 2020





Red: Built up, Green: Vegetation, Blue: Water body/river, Yellow: Barren land

Figure 6: Land use/Land Cover pattern of the year 2000

Figure 7: Predicted Landuse/Landcover pattern of the year 2020

5. Discussion and Conclusion

The growth pattern study using satellite imagery provides reliable and accurate information, which is cost and time effective. It also offers a holistic view of large areas for better assessment / monitoring of land use - land cover occurrence and distribution pattern. Hence, CA and GIS techniques are useful tools for assessing the growth pattern which is one of the important components for planning and development of the city. In present research, the predictive model generated for the year 2020 has shown increased urbanization up to 63.64% out of the total area available through LANDSAT image. A customized solution for the future prediction of growth pattern using cellular automata could be useful for decision making and planning the strategy of the growing cities for the near future.

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