Abstract: During the time society, economy and urban areas manifesting a rapid development which makes cities hard to control. Therefore, many problems in environment and society have appeared in urban districts; thus the study of the past and present stages gives the possibility to detect patterns of urban growth. The aim of this article is to create a model which will allow us to simulate different stages of urban growth in Iasi and Cluj-Napoca city. In order to use this approach we applied a genetic algorithm to detect patterns of urban growth for different areas of interest (AOI). Satellite images offer the possibility to cover a large area and those images will use as an input for our model. Cellular Automata (CA) model is applied to determine the states of grid cells (pixels) before selection on any AOI are performed. After this stage the results will be calibrated based on the urban foot prints from our time line. In this way, urban growth can be predicted based on past and present information and can be used as a support for decision in the planning process or as indicator in business models.

Keywords: urban growth, patterns, genetic algorithm, satellite images, CA

1. INTRODUCTION

The history of urban expansion indicates that the urban areas are one of the most dynamic places on the Earth’s surface. The process in change of land use is the result of urbanization and at the same time it is one of the causes of urban environmental problems, reflecting the direct and indirect relations between natural environment and human activities (Alpopi, 2009). Studying the land use change and the implication of anthropic actions is essential not only for detecting the global environmental change, but also for framing suitable strategy for land planning on a local scale (Ianos & Talanga, 1994). Urban growth is commonly used to describe physical expanding of urban areas and used as an indicator of industrialization and usually has a negative impact on the environmental health of a region (Suditu, et al., 2010).
In a larger frame we can assume that every city is an open system, which establish a transfer of energy between itself and his subsystems. In this way the central region (city) can expand chaotic, and absorb points (small counties) with a small magnitude into the main system (Boutot, 1997). CA model can integrate this complex behavior into a linear sequence of two states, which further is mapped over a lattice with finite states: on or off (H. & M., 2010).

Many scientists have been used in their studies techniques like GIS and remote sensing, for measuring urban areas and estimating urban population (Bryan, 1982). The allometric growth model allows correlating population data to a specific urban area. This approach has the ability to revert the workflow process, taking the output (urban areas from remote sensing) and transforming into input (Sutton, 2003). As a part of CA (Cellular Automata) model it has a dynamical system in which space and time are behave discrete.

In this study we choose two cities, Cluj-Napoca (CJ) and Iasi (IS) which are distinct from each other in many ways. The main difference are highlighted by their spatial position, historical course, economy, education and external influence from other countries (Groza, Turcanasu, & Rusu, 2005). These factors determine clusters and trends for urban sprawl and can be integrated into CA model for simulation.

2. CASE STUDY AND DATA USED

In this paper, we take two cities (Cluj-Napoca and Iasi) as a sample site for CA model to estimate the expansion of urban space, based on a specific period of time (1983 – 2010). In order to cover a large area we used topographical maps and satellite images (Landsat and SPOT) provided by U.S. Geological Survey and Spot Images.

We introduce CA model as a new tool which can be used in urban planning for measuring the possible growth. CA was developed by Ulam and von Neumann in 1940’s as a model to study and understand the behavior of complex systems. Because every city is a complex system which interacts in space with dispersed (urban satellites) and local factors, it is possible to be integrated into CA flow.

CA model can be define as a dynamical discrete system in space and time that operate on a uniform grid-based space through implementing a set of local rules. CA process every cell in grid (lattice) iteratively and determine the future cell state using a neighborhood function which establishing a set of transition rules (Ulam & von Neumann, 1966). Thus, any CA systems are composed of four components: cells (Boolean values are assigned),
transition rules (set the importance accordingly to the seeds), states (classes), neighborhood (circle, square matrix).

a) The study area

This study is focused on two cities from Romania: CJ and IS, located at 23°36' E - 46°46'N (CJ) and 27°35' E - 47°09' (IS), which is illustrated in Figure 1. Both cities CJ and IS have a different growth pattern, because of their culture history reflected on past, present and future development. One of the main reasons for the selection of these cities was the spatial distribution of their infrastructure, which tends to link only the major cities (Suceava, Bucharest, Oradea, and Timisoara) and isolated other regions.

![Fig. 1 – Location of the study areas](image)

b) Data

CA models consists of a regular grid of cells, each one of which can be in one finite a number of $k$ possible states, update synchronously in discrete time steps according to a local, identical interaction rule. Thus, in this study we used satellite images and topographical images (Fig. 2) because these types of data are structured as a 2D array, with a finite number of states.

Satellite images offer a good spatial resolution of 1 meter SPOT and respectively 30 meters Landsat TM, with 8 bit radiometric resolution. Both images have a good reflectance for urban space (Fig. 2) and it allows extracting different features (built-in areas, vegetation, water body, crops). These features were selected based on their role in urban system (Batty & Xie, 1994).
3. METHODOLOGY AND RESULTS

Image processing for CA involves a chain of procedures that includes co-registration, classification (supervised in our case), geometric transformation and correction of the data and digital enhancement, which implies a better interpretation. Applying different filters for digital enhancement does not affect the image matrices or the output result. Thus, for these processes we used the Envi and ArcGIS software which have allowed analyzing and extracting the information we need. Land used was classified into 4 classes based on spectral response, such as water bodies, vegetation areas, built-up land and crop land.

a) Image processing and data analysis

The RS data presented in this study implies a number of errors which appear because the satellite sensors have been recorded the data close to the true value. In the first phase we applied a co-registration process to solve the geometric problems and assure each pixel in all the satellite image corresponds to each other. Geometric correction was applied to SPOT images using 1:5000 scale topographic maps. The result was a rectified image which served as the source to rectify the Landsat images by the use of image-to-image registration method and resample using a cubic convolution algorithm (Jiazheng & Stephan, 2008). For the registration process The Root Squared Error (RMSE) was 0.64 pixels, after verification calculation.

b) Classification based on Supervised Methods

In this stage was chosen for the classification the Maximum Likelihood (ML) method which assumes that the statistics for each class in each band are normally distributed and calculates the probability that a given pixel belongs to a specific class. The ML was processed in Envi software. Because the ML is a supervised classification method, it was
necessary to include a set of training samples (TS). The TS were digitized on-screen based on terrain knowledge acquired during fieldwork and scattered all over the study areas. Each class which represented the TS was checked so all classes could be separated in at least one combination of bands.

The analyst searches and identifies in the satellite imagery uniform representative samples of the different surface cover types of interest based on a supervised classification (Peng, Xu, Xue, & Yang, 2010). This is based on the statistics of training areas representing different ground objects selected subjectively by the analyst on their own knowledge. The computer used the numerical information (spectral respond) to recognize spectral similar areas for each class based on the numerical information from all of the spectral bands. After the computer had determined the signature for each class, each pixel in all of the images is compared to these signatures and labeled as the based class. The data will be extracted from the satellite images and combined the clustered output to produce a map of change, in the interest region. Once we have the results in a cluster form, a segmentation algorithm will be applied that exploits the direct correlation between neighboring pixels and then extractsthe features into polygon forms.

c) Cellular Automata Model Process

Cellular Automata model takes into consideration the invariance of space and time and permit to expand forecasting results for long periods of time (between 30 to 50 years). Thus, a dynamic model consists of five key components:

1) A grid or raster space (2D array);
2) A set of states which characterize the grid cells;
3) A definition of the neighborhood of a cell
4) A set of transition rules that determine the state transition of each cell as a function of the states of neighboring cells;
5) A sequence of discrete time steps, with all cells updated simultaneously.

In order to run CA model for urban growth, we developed an algorithm in Python language which can take as an input parameter a grid data (raster) and an external file which contains a set of rules. Transition rules are the core for CA model because it implies the state of all cells with an individual approach.

By comparing the simulation resultswith the real ones, the coefficient of accuracy has values between 6.25 (water class) to 100% (i.e. build-in). The graphic below illustrates (Fig.3) those values and present the fitness of simulation, which in our case is express in percent, and it is greater than 70%. Predicted results are displayed in Fig. 4 and 5.
Both results present a percent of errors which tend to cluster in the isolated areas. In Fig. 5 we illustrate a few examples of those errors indicated by a red circle. This type of distortion arises from transition rules and the type of seeds (Rui, Jiulin, Fusheng, & Min, 2010).
4. CONCLUSIONS AND DISCUSSIONS

We can conclude that the obtained results from CA model, for Cluj-Napoca and Iasi city provide a good approximation of the reality, which accentuates two important aspects, economy development (arable land transformed into built-up area) and natural growth of population (Fig. 4 and Fig. 5). Both of them tend to accelerate after the year 1989, when Romanian government downfall and the development of every city depend on political reforms (Ianos, 2000). The universities in CJ and IS city had been consolidated during the time and become a pole of attraction for young people (Groza, Turcanasu, & Rusu, 2005).

The main urban area enlarged continuously in both of the cities, over the years, with a different trend of expansion which appears in peri-urban areas. Historical part of CJ and IS city is stable, in reality and also in simulated version of city growth (Fig. 5). All of these results imposed the urban growth for both cities to be chaotic. For instance, the IS city absorbed Vale Lupului (NV), Tomesti (SE) and Bucium (SE) counties without a proper planning and now their inhabitants do not have access to all utilities (clean water, gas, electricity).

As we had mentioned in the previous paragraph, the model it will need further improvements because the prediction for some classes had been distorted (Peng, Xu, Xue, & Yang, 2010). A good way to reduce the occurring of errors it will be by providing new type of seeds (demographic, economic, policy factor, environmental and climate factors) and using high resolution images (satellite or radar). This behavior occurs because CA model take into consideration incertitude in the input data, in order to verify in which condition is
and it will be all of the seeds (buildings, crops, others). The CA model can be used by authorities as a support in decision making and also by scientist in different models.

REFERENCES


