Dissertation Proposal Literature Review

Sample

Modelling Tools and Simulation of Urban Development

The city is one of the most complex creations of man. They are "living" creations that develop and change according to many internal and external influences. The city's building plays a major role in its development and success as a creation that should make life easier for people in it. That is why architects are trying to plan and guide the development of the city. But this proved to be not easy at all. Proper city development is of great importance to its inhabitants as it has a direct impact on their health and quality of life. But with its complex organization and dynamics, the city is a challenge to understand and predict its development (Portugali, 1999). The development and survival of the city through time and space is guided by a number of parameters such as degree of development, socio-economic status, demographic data for the population and type of land, and especially their interdependence. The complexity of this process and its dynamics makes the definition of a mathematical model, and therefore the possibility of its planning extremely difficult. From here comes the need for tools that will help architects understand the city and discover its development pattern. Several attempts have been made to understand the city's development process and the forces involved in it (Alkheder & Shan, 2005; Alkheder & Shan, 2006; Dawn et al., 2003). Most of them include creating a city model and using a simulation model for urban development. In the early 1990s, urban modeling was again becoming a reality, partly because of the development of new approaches to understanding urban dynamics (Stanilov & Batty, 2011).

There are more approaches to modeling and simulating urban development. Multi-agent systems are suitable for representation of each entity, that is, a process that drives the development of the city as a separate agent, while the interaction between agents realizes the connection and interdependence of the drivers of urban development. Therefore, multi-agent systems represent a natural metaphor for modeling and simulating urban environments, which allows to reveal the hidden rules of the development process (Keil & Goldin, 2006; Gasser, 2001). Cellular automata are also often used approaches to modeling and simulating urban development, due to the local action of cells, guided by transition rules, which causes global effects, analogous to local urban processes with global effects. Michael Batty, one of the most active and respected researchers in the field of urban modeling, uses many cellular modeling machines in the city and software tools for simulation and detection of transition phenomena. A group of researchers use cell automata with genetic algorithms to set the parameters of transition rules (Alkheder et al., 2007; Shan et al., 2008).

The aim of this master's thesis is to develop a tool for modeling the city using data in different format (geodetic bases, satellite imagery and scanned maps) and simulating its development using algorithms of machine learning. Data such as satellite imagery, geographic maps, and cadastral records can be entered manually via the built-in editor of cellular automatics. The tool enables testing and comparing the success and suitability of different algorithms for detecting the transition rules of cell units as a basis and support for urban development planning and testing of alternative scenarios and development plans. The first chapter presents the motives for preparation and the goals of this master thesis. So far, the approaches to solving the problem being discussed are briefly explained. The benefits gained from the preparation of the master thesis are listed. The second chapter presents in detail the problem of urban modeling, its complexity and approaches to solving it. The two most commonly used approaches to urban modeling are considered, using cellular automatics and

using multi-agent systems. The third chapter presents a tool that enables modeling and simulation of urban development. The approach that has been used is elaborated and a detailed description of the tool and its functionalities is given. The way in which the tool can be used to simulate possible urban development is described, which would help in urban planning. In the fourth chapter, two case studies are elaborated. Each case study begins with a chapter describing the area being investigated, followed by a chapter explaining the modeling process and ending with a chapter where discussion and interpretation of the discovered rules and results are offered. This chapter also describes the performance evaluation measures used to compare the algorithms used. The fifth chapter gives a conclusion on the benefits and disadvantages of this research. The guidelines for future research and ideas for improving the tool with new functionalities are listed.

Urban modeling is the process of identifying the appropriate theory and describing it in a mathematical or formal model, then developing appropriate computer programs and confronting the data model in order to be adapted, validated and verified before its use in simulations. Urban modeling is a result of the need for understanding the forces that govern the development of the city. The first attempt to model the city is described in von Thünen's book Der Isolierte Staat (von Thünen, 1826). Von Thünen presents the city model with mathematical formulas that captures the interaction between three factors: the distance of farmers from the market in the city, the purchase price that farmers receive for their products and the rent they have to pay for the country. Assuming that the city is located in an isolated state, without rivers, mountains and roads, with continuously good farming conditions, this mathematical model generates a city represented as concentric circles on a single-use land use. The von Thünen model is significant because of the analytical approach to the problem of urban modeling and serves as an inspiration to many other later models. The greatest rise in the use of urban models is in the early 1960s and continues until the end of the decade. This rise is a result of the increased use of the car as a means of transport that allows residents of the city much greater mobility. Increased mobility has a significant impact on the development of the city, leading to the use of transport models.

With the advent of computers with sufficient computational power in the early 1970s, the first attempts to build computer-based urban models appear. Large computational power makes it possible to build complex mathematical models. Urban models that model land use, transport network development, population and other urban-economic activities have been built and implemented using techniques of linear analysis and mathematical programming (Kilbridge et al., 1970). The new era of urban modeling began in the late 1980s, when the research in the field of complex systems contributed to the perception and interpretation of the rules of development and modeling of the city as a complex evolutionary system. Additionally, the emergence of geographic information systems (GIS) facilitates the process of urban modeling by providing the necessary data such as: land use, population number in a given area, close to the city center, distance from the street network and many others, which geographic information systems can contain them.

The process of modeling a complex open system over which many internal and external forces are active is always complicated and partially successful. The modeling process is further aggravated when there are insufficient data on the forces which lead the life and activities of the system. For determining and modeling the forces that lead the development of the city, data are needed that reflect their influence. The existence of a knowledge base that

will be applicable in the urban modeling process and will enable getting a full view of the city is of great importance for the creation of more effective urban models. When creating the knowledge base and explaining the perceived patterns of development, no primacy should be given to social, or technological aspects. By deciding which categories of data to be included in the knowledge base should be influenced by theoretical and empirical papers from different disciplines. The decision of a particular category of data to be used in a research should be made on the basis of whether there are previous studies that emphasized the importance and relevance of the data category for the purposes of that research. The knowledge base should be diverse enough to correspond to the complexity and interdependence of urban dynamics of a different nature. Due to the large number and diversity of forces, the data are usually in different areas and hardly accessible. Searching the data is further complicated, since many of them are not in digital format. The knowledge base should enable integration and linking of various data formats such as geographic maps, photographs, cadastral records and other unstructured data, as well as census and social survey data. This requires data access, provided by experts in various fields (e.g. architects, local government, social experts) using a variety of analytical methods. Some of the expected problems are: semantic heterogeneity, different terminology, inconsistency and redundant data. The knowledge base would allow for common and complementary use of data and thus would represent much more than just a set of data.

References

- Alkheder, S., & Shan, J. (2005). Urban growth simulation using remote sensing imagery and neural networks. Third international symposium of remote sensing and data fusion over urban areas, p. 14 - 16.
- Alkheder, S., & Shan, J. (2006). Change detection - Cellular automata method for urban growth modeling. Proceedings of International Society of Photogrammetry and Remote Sensing Mid-term Symposium , 7, p. 5.
- Alkheder, S., Wang, J., & Shan, J. (2007). Cellular Automata Urban Growth Model Calibration with Genetic Algorithms. Urban Remote Sensing Joint Event, p. 1 - 5.
- Dawn, P., Manson, S., Janssen, M., Hoffmann, M., & Deadman, P. (2003). Multi-agent systems for the simulation of land-use and land-cover change: a review. Annals of the Association of American Geographers 93 (2), p. 314 - 337.
- Gasser, L. (2001). Organizations in multi-agent systems. Pre-Proceeding of the 10th European Workshop on Modeling Autonomous Agents in a Multi-Agent World.
- Keil, D., & Goldin, D. (2006). Indirect interaction in environments for multi-agent systems. Environments for Multi-Agent Systems (2), p. 68 - 87.
- Kilbridge , D., O'Block , P., & Teplitz , V. (1970). Urban Analysis . Boston: Harvard University.
- Portugali, J. (1999). Self-Organization and the City. Berlin: Springer Verlag.
- Shan, J., Alkheder, S., & Wang, J. (2008). Genetic Algorithms for the calibration of cellular automata urban growth modeling. Photogrammetric Engineering & Remote Sensing (10), p. 1267 - 1277.
- Stanilov, K., & Batty, M. (2011). Exploring the Historical Determinants of Urban Growth Patterns through Cellular Automat. Transactions in GIS (3), p. 253 - 271.
- Thünen, J. H. (1826). Der Isolierte Staat .