Discovering Patterns of Urban Development in Skopje

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Abstract.
The goal of this research is to develop a tool that employs intelligent technologies to capture the patterns of urban change driven by a diverse set of context factors. Data mining provides opportunities and knowledge embedded in the urban structure, which complement and extend the data previously obtained with other approaches. A case study is in place to investigate the modeling and predictive capabilities of the tool. A number of simulations have revealed distinctive local patterns of urban change in the city of Skopje, shaped by local urban spatial and institutional structures. This study shows the possibilities of intelligent technologies in the interpretation of the historical evidence of urban development and better understanding of the urban phenomenon.

Keywords. Urban dynamics, urban transformation, knowledge-based approach, data mining.

Introduction

Cities, the biggest and most complex creations of mankind, may be best recognized by their complex organization and dynamics. Its complexity is enhanced by its constantly changing and evolving shape and structure. Hence, the urban phenomenon has become very difficult to delimitate and hard to comprehend. In the words of Sanford Kwinter: “We no longer know where to look to find the glorious ensembles and performances that we once called the city” (Kwinter, 2010). Therefore, we are in the quest for the new tools and knowledge that will enable us to learn from the past in order to comprehend the future of our cities.

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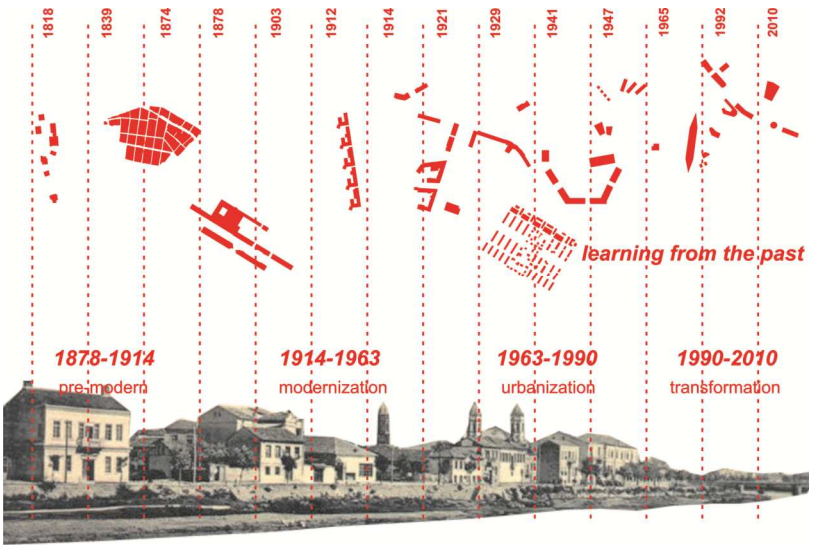
The idea of a city as an urban space that is sustained by human connections requires suitable models that recognize the sound interplay between physical and phenomenological aspects of the urban system. If the general structures of urban systems are complex, the processes and behaviors that can be observed are far from being entirely stochastic (Bretagnolle et al, 2005). The management of such a complex systems requires institutions and tools that will be able to cope with the challenge of managing such an amazing amount of data. Our knowledge of urban phenomenon might have been deepened on many levels, though its modeling and computational representation is still an open problem (Hillier, 2003). By acknowledging the existence of such a systematic approach toward the research of dynamic of the cities and meticulous exploration of knowledge and information that is embedded within the city structure and the rules of its transformation, regardless of the momentary usability of the same, we can clearly determine that the cities and city structure are an excellent systems for provision of data that could be organized and used in a more comprehensive systems for supporting planning policies, management and development of cities.
It is our believe that the problem today is not the availability of data but rather the production of comprehensive information out of urban structure and alternative resources with appropriate and useful level of detail, organized in systematic way and updated in manner that will serve the purpose. This situation urges for establishment of an approach to the research of the urban transformations that will be based on the data that is embedded within the city structure and that will result into the comprehensive knowledge coherent with the nature of the urban phenomenon and the process of change (Stanilov, Batty, 2011).
Experimentation with predictive urban models are expected to lead the way to a better understanding of the general processes and conditions at play in the urban world. Past analytical methods for studying urban dynamics were greatly limited, mainly because of the kind of data and research tools that were available. The interdisciplinary nature of the problem under consideration requires a diverse set of researchers (architects, computer scientists, sociologists) and efforts that exceed the expertise of any individual field. The new digital, pervasive and intelligent technologies have brought more information to consider, though the process of their utilization is far from straightforward. Thanks to the achievements in domains such as multimedia, knowledge management, machine learning and data mining technologies, computer support of urban planning received new resources and can move to new directions, e.g. creating intelligent simulation and modeling tools and systems.

1. Learning from the past

Skopje is one of the most dynamic examples of radical urban transformations that have shaped the identity not just of the cities in the Balkan area but had a greater impact to the emergence of the modern societies in the region. The city has been part of the six states in the last century and due to the changing geo-political conditions it has gained different identities clearly being the place where most of the history of the 20th century exercises its creation and destruction in this part of Europe. Skopje is a place of dynamic examples of massive urban changes, discontinuities and developments in the last hundred years where different urban patterns and development trends have occurred coexisting as a hybrid structure of the city. Hence, understanding the societal changes framed within the dominant ideology of the time visible through different city fragments, each being a part of the complex urban structure, are in the focus of our study.

The urban plans of Skopje in the last 100 years share the same believe in the power of the modernization, progress and technological development as the main driving forces in providing a better world. The end of Socialism, the “shattered dream” or the end of the utopia as a basis for the construction of cities, has also been followed with general disappointment of the power of politics as the force within the society that is capable in providing ideas and means of reaching the better world and urban identity. The concepts, theories and policies of urban development that have been behind the founding ideology of the urban identity of new greater and grandeur city have substantially changed the urban, social, political and ethical context of the city of Skopje.

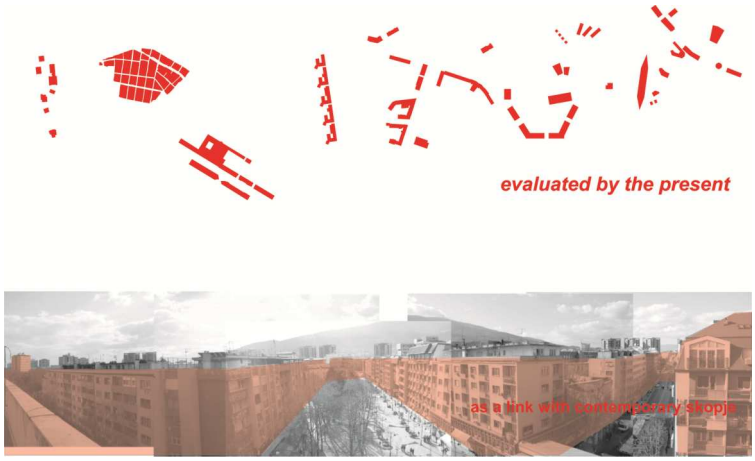
Fig. 1. Learning from the past development of the city



The history of urban planning in Skopje begins at the end of 19th century and caused the emergence of various urban patterns strongly influenced by the ideological background of the planning process promoting top-down implementation of novel concepts and ideas while disregarding the rules of natural growth in the city. Difference between urban plans and level of their realization in Skopje in the first half of 20th century, followed with rapid urbanization during the city reconstruction with assistance from UN after the 1963 earthquake has created the planned city existing between urban form and territory (Marina, Armando, 2013).
The urban plans of Skopje from 1929, 1948 and 1963 although very different in their conceptual imagery share the same believe in the power of the modernization, progress and technological development as the main driving forces in providing and building a better world. The inadequacy and failure of the design strategies imposed by the elite is radicalizing the urban agenda pointing out once again to the importance of the urban theory and practice in comprehending and solving the challenges of the contemporary world. Only through acknowledging the principles of the system and yet criticizing and always challenging its concrete manifestation we can reach the complexity of the city. In Skopje, the city between territory and form, it is evident that when the theory is faced with the reality, regardless if it is on the level of single building or an urban structure it is always a reaction and result of social, spatial and political agenda. Hence, the knowledge that we have attempted to acquire is the data that is simultaneously

dependant on the complexity of the urban reality, mixing social, cultural and spatial layers, and is embedded into the structure of the city acting as a spatial and material memory of the phenomenon (Figure 1).

Fig. 2. Evaluating the knowledge through present condition



The proposed model of urban transformations attempts to test a series of hypotheses on how the mechanisms of social and economic stratification have manifested in urban space and whether population dynamics has reconfigured the spatiality of the city landscape. Our efforts are directed towards correlating real-world emergent patterns of urban change to contextual knowledge and incorporating them into model's predicting capabilities (Figure 2). Suitability of an extensive set of machine learning algorithms for simulation and prediction of urban development has been involved into development of the cellular automata based model of urban development in Skopje (Figure 3). Or: Can we determine what city would look like in 21st century based on the data and its history of urban development in the 20th century by using digital simulation models?

Fig. 3. Simulating the future of the city

2. Modeling Urban Transformation

A variety of image formats (e.g., orthographic image, scanned geographic map, cadastre data, AutoCAD image export) could be used as a spatial evidence of the urban state at a certain moment in time. Geo-referencing is a necessary requirement for their utilization. The image is overlaid with a cell grid with an adjustable cell size (shown in Figure 2). Cell type has a special importance in our simulations as a property that the model is trying to predict on the basis of past historical records.

Our goal was to extract the rules of urban change, by modeling the states that different parts of the city have undergone; from undeveloped land to dispersed residential houses to condensed areas with high-rise residential and commercial buildings. Some of the areas under investigation remain relatively compact throughout recent history; no extensive development until last decades. The study presented in this paper primarily focused on settlement in Skopje for the period from the 1960s. Orthographic images, scanned geographic maps, cadastre data and AutoCAD image exports were used (Fig. 4).

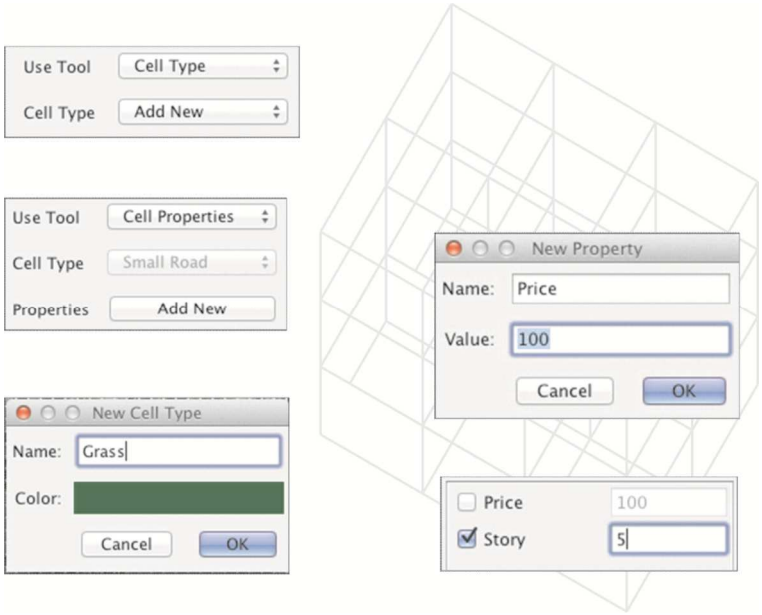
Fig. 4. Various urban data (1) Orthographic image (2) Historic geographic map (3) Cadastral record. (4) AutoCAD image export

The timeline in the bottom ribbon represents the time period the predictive modeling spans across. Editor options give a user capability to set and assign the cells' properties and their values, while the Simulator tool is used for running simulations. Color-coding is used for visual distinction between different cell types and the assignment of colors is determined by the user. The process of cell description is a cumbersome and time-consuming process that needs to be repetitively performed for all available images of different time periods (Figure 5). Employment of AutoCAD image parser facilities the process of cell description (only those subject to change).

Fig. 5. Application of cell grid on the image of the city structure

Each cell is assigned with a variety of properties that should be proposed by domain experts and researchers from various fields (shown in Figure 6). The set of selected categories hypothesized to have a prominent role in establishing appropriate urban knowledge could be broken down into three groups: (1) *urban factors*, (2) *socio-economic factors*, and (3) *population (individual and group) factors.*

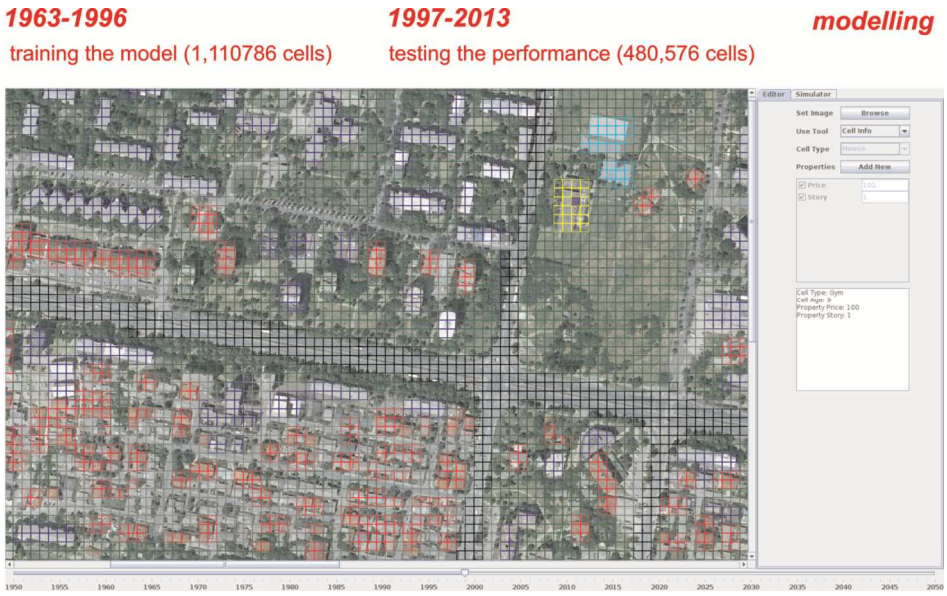
Fig. 6. Assigning cell properties as an editor tool



Trends and circumstances associated with economic development, historic events, legislative initiatives, excessive urbanization, and local government policies are important since they are likely to affect the pace and direction of urban change. Socio-economic aspects may sometimes constrain, at other times may create new incentives, goals and directions for the urban development. Population factors are included to support the representation of citizen-related data that have been shown to have an impact on the urban development (e.g., population size, age, income per family, preferences, proximity to work place).

The division of data into a training set, used to extract the patterns, and a test set, needed to evaluate the effectiveness of the predictions, could be adjusted for each run. A set of features included in the predictive modeling includes not only the cell type and its properties, but also the types of its eight neighboring cells.

Fig. 7. Training and testing of the model for simulation

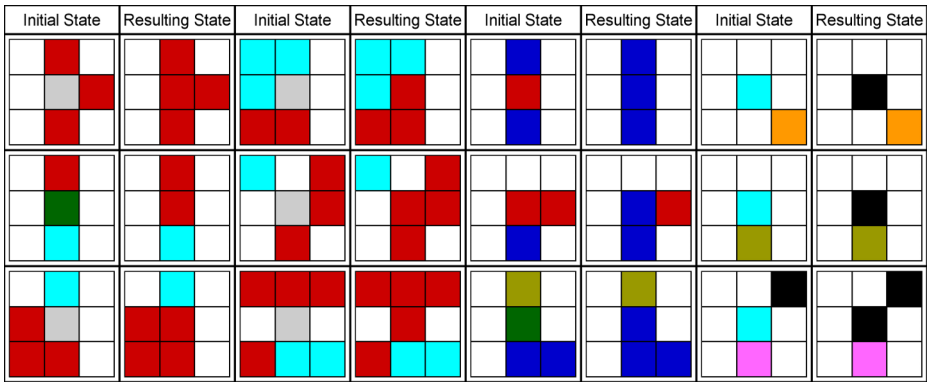


The performance results of the available algorithms are compared and the most suitable (independently or jointly used) set is selected. Summary results are presented in the bottom window, though the detailed results containing total number of instances, number of correctly and incorrectly classified instances, detailed accuracy metrics, confusion matrix and other statistics are available in the console output.

To validate our models, we run a set of experiments to investigate how accurate the selected algorithms are at predicting patterns of urban change. The dataset was divided into a training sample of 1,110,786 cell instances and testing set containing 480,576 cells. The period from 1960 to 1996 which was marked with rapid urbanization and urban development was used to train the model, while the time period 1997 - 2013 was used to test the performance (Figure 7).

A total of 204 rules were generated. For illustration we have selected to show the rules regarding two types of residence dwellings, cell types House and Apartment Building. The rule-based analysis has revealed several patterns of housing residence sprawl (shown in Figure 8). By urbanizing undeveloped land and taking over small parks, condensed and compact areas of houses emerged, reducing the space between a house and a peripheral street and diminishing the green zones. The emergent trends are in line with the rules derived with cellular automata model (Marina, 2010) although extended with new patterns, which could be clearly pinpoint to the exact time periods and related to socio-economic and population factors. While small isolated green zones were swallowed by housing development, and enlargement of existing commons (cell type Park) was detected as 4 rules (not shown).

Fig. 8. Transformation rules for cell type House (red) and Apartments building (blue)



The emergent rules of change within the system are clearly evolutive exhibiting the transformation that can be expected within the process of natural and planned growth of the city where single House cells are upgraded through aggregation into the Apartment building cells and Small streets cells are upgraded to Main street cells. Important trend that has been recognized within the process of change is the influence of certain group of city functions (like in case of Residential, Government offices or other Social infrastructure) to the development of the street network and housing aggregations. It is a mutual dependant interaction making House cells developed toward street network and Streets cells developing toward housing aggregations creating service based traffic infrastructure and housing urban structure closely related and connected with commercial, educational and leisure facilities in the city. Another evident tendency is the growth or industrial complexes through acquisition of Park (green) cells or a vacant land and the growth of Park cells toward the residential complexes as the result of planned development and industrialization of the city after 1965 and the establishment of

standards for industrial and green areas within the city structure. One of the main challenges is to observe and to compare the development of mutual dependences and interaction between different urban programs in the future development of the city and relative comprehension of the socio-political and economic processes that are shaping our city.

3. Conclusions

We have explored the use of model of urban transformations focusing on two main issues: the role of intelligent technologies in the process of discovery of emergent patterns of metropolitan change, and the predictive analysis as a way to make informative decision regarding urban planning. Our experience points at the tremendous potential and relevance of applying intelligent technologies and predictive modeling that may help in understanding the code of the city through the exploration of its memory embedded into the urban structure and representing urban phenomena in a comprehensive way. Still in the early phases of exploratory testing and model implementation, the proposed integrated data mining approach provide a promising start in building a foundation for urban modeling that aims at being both theoretically- and empirically-based.

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