Techniques for visualization uncertainty in analysing the suburbanization processes

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Abstract. The paper deals with visualizing uncertainty in spatial analyses and data associated with the analysis of the City of Olomouc development based on GIS processing. The urban pressure on the city surroundings is characterized by different types of land cover changes and transformations of land use: urban dispersion, suburbanization, industrial change of agricultural use, land use conflicts, etc. From this perspective the suburbanization process was chosen as the case study of city development. The geographic and the spatial analysis, as the evolution of town territories, are done using city plans of Olomouc. Identifying, delineating and mapping landscapes on a temporal scale provide an opportunity to monitor the changes, which is important for natural resource management and sustainable planning activities. In the form of synthesis, the maps also show stability and instability of spatial functional structure. The maps can be used as a significant source of information about developments of Olomouc during the 20th century. The results can be used as an important source for a number of geographical or urban studies, both for experts and the general public. The main result of this work ahead the visualization of the suburbanization processes is visualizing uncertainty associated with suburbanization changes in Olomouc in the last few decades. This uncertainty is connected with analysis of all kinds of data and cannot be ignored. Visualization of uncertainty enables the map's readers to understand the variability of the natural environment more comprehensively. Being able to perceive uncertainty can help improve general awareness of the uncertainty factor in geographic data and the environment due to the fact that maps are more appropriate for presentations than text or spoken word. However, the visualization of uncertainty regarding spatial data faces another significant problem in terms of presentation the results in understandable way for readers.

1 Introduction

Period of creation of urbanization is considered already establishment of cities itself; in a narrow sense the beginning of urbanization is set to the period of industrial revolution, where cities develop turbulently and people concentrate in cities. Observation of urbanization stages, that is city development, is one of the main topics of social geography [1].
In the course of the last decades, efforts have been made to come up with a theory that could describe the development of municipalities within the scope of the population system. Therefore, it is extremely useful to recognize the phases of the urbanization process in due time and respond with appropriate means of municipal planning. With the help of geographical information technologies it is possible not only to recognize, but also to determine, quantify, analyse or model particular phases of the urbanization process. [2] While analysing various natural and socio-economic systems, it is highly desirable to create their simplified models – so-called conceptual models which, considering the given level of abstraction, enable to model and predict the behaviour of these systems. Every model is, to a certain extent, a generalized reality [3]. Therefore, the results provided by a model can never be on a level of actual real results. Uncertainty, indeterminacy, indefiniteness, vagueness, ambiguity are components of every piece of information that is related to the real world If we, in any way, include real and experimental data into processes, models and creation of new information, we must realize that the original vagueness and uncertainty of the data is still present [4]. From this viewpoint, it is necessary to deal with the uncertainty and indeterminacy, and processes leading to results in order to have this viewpoint under control. A way how to control these processes during an estimation of the rate of suburbanization based on uncertainty visualization is described in this paper.

2 Data sources

During the 20th century, four ground plans (GP) of the City of Olomouc in total were created. The first document concerning the regulation of areas in Olomouc is a ground plan called Grand Olomouc from 1930. Another document is from 1955 and bears the name "General city plan of Olomouc". The third ground plan from 1985 is named Olomouc - ground plan and finally, the still valid ground plan from 1999 is named Olomouc - functional regulation, limits of ground use [5].

As mentioned, the pivotal data were the ground plans of Olomouc in the 20th century (Fig. 1). However, it was very difficult to get all these ground plans, because as time went, governments and regimes changed, not all the plans were located at the Municipality of Olomouc. With the exception of the GP from 1999, the plans were made on several sheets of paper and it was necessary to convert them into digital form so they could be used in the GIS (geographical information system) [6]. Old ground plans had to be scanned on a large-dimension scanner and converted into the S-JTSK coordinate system (System of unitary trigonometric cadaster grid) using georeferencing. Affine transformation using control points was chosen

Transformation into the S-JTSK system was seamless for ground plans from 1955 and 1985, as their base was a cadastre map, so it was easy to find all the control points. What is more, they both were created in the S-JTSK system (from the cadastre map), so the transformation in fact involved only placing both drawings into the coordinate system. For the oldest ground plan the situation was more complicated because it was based solely on a topographical map, which only contained a small number of significant and stable objects that would be suitable for control points. This plan was also not created in the S-JTSK system, so it had to be transformed [5]. After successful georeferencing of all the plans, their digitalization, i.e. their conversion to vector format, was necessary. Digitalization was the time-consuming stage of the research owing to high amount of data and their non-simple interpretation, which was burdened by inaccurate implementation of ground plans. In order to interpret this ground plan correctly, a further base had to be used, especially contemporary topographical maps.

Technical treatment of different sheets reflects the time of their creation. Old ground plans, i.e. GP from 1930, 1955 and 1985 were created manually, without using computers and there were some limitations. Contemporary GP makers had to use such geographical means of expression that could be plotted by hand, ranging from line thickness up to complexity of hatching. That is why the same amount of information as we know today could not be contained in these ground plans. Another technical limitation, which has not been worked around even with the use computers, is the size of the sheet. Ground plans bear significant amount of information, so we tend to choose the largest possible scale, which in turn leads to a very large area of the sheet. Old GPs solved this limitation by using several sheets of paper that were either loose (GP from 1955 and 1985), or they were glued to hard covers (GP from 1930). A digital database of ground plans was used as a base for all analyses, which were further processed in the GIS environment. Analyses consisted primarily from overlay analysis, which served for the assessment of stable functional areas (Fig.1), determination of intensity of changes and localization of urban and suburban processes.

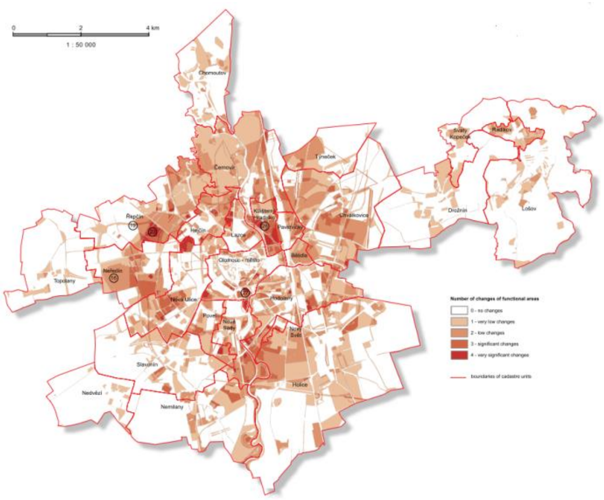

Fig. 1. Changes of functional areas in Olomouc during the period 1930-2009 according to city plans from 1930, 1955, 1985, 1999 and 2009

3 Methodology of uncertainty visualization

The main aim of visualizing the uncertainty in the ground plans was to find, measure and predict the accuracy of the acquired functional areas at every location in the modelled area. To achieve this, we subdivide the whole model space into a regular raster with equal cell sizes and calculate the Shannon's Index [7]. There are alternative methods for calculating this index and we use the Land Facet Corridor Designer tool [8]. Based on calculated entropy for each pixel we wanted to find and distinguish each of the raster cells based on measuring of uncertainty fulfilling the following criteria and schema:

1. The value should be 0 when no uncertainty exists, i.e. there is only one possible outcome (i.e. functional area of pixel is builder area).
2. The value should be maximal when all n possible outcomes are equally likely. In this cell there is very small chance to find the exactly desired functional area.
3. If more outcomes are equally likely, the measure should have a higher value ("monotonicity") [7]

The concept of entropy was them applied to each of the ground plan. Different setting of neighbourhood radius size for each ground plan according the positional accuracy error and judgment was chosen (Fig.4). The tool uses a circular neighbourhood approach [8]. Then sum of all entropies was calculated based on several calculations of entropies in each of ground plan. This step was done with using raster calculator in esri ArcGIS 10.1. Acquired raster was reclassified into 5 classes using 5 equal intervals. Final reclassified raster of entropies (Fig. 3) were then overlaid by vector grid with spatial dimensions 20x20m. Information about entropy of each square was acquired using tool Spatial join. This layer with vector GRID was finally visualized using the same theme as the map of Changes of functional areas in Olomouc city during the period 1930-2009 with using shade effect for each of entropy class make in Adobe Illustrator CS6. The places with (Fig. 2) higher entropy lies on the top and thanks to shade effect seems to be higher and reader can perceive this as a problematic part of the final map. Several different methods of visualisations were also proposed base on techniques already used [9, 10] (Fig. 3 and 4).

4 Results

Fig. 2. Shaded approach to uncertainty visualisation

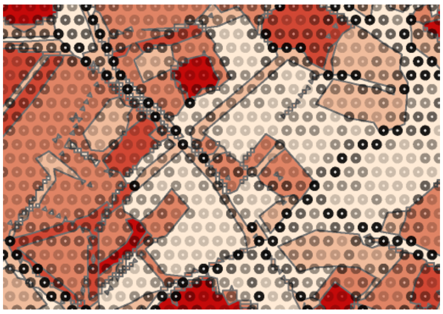

Fig. 3. Technique using circles transparency

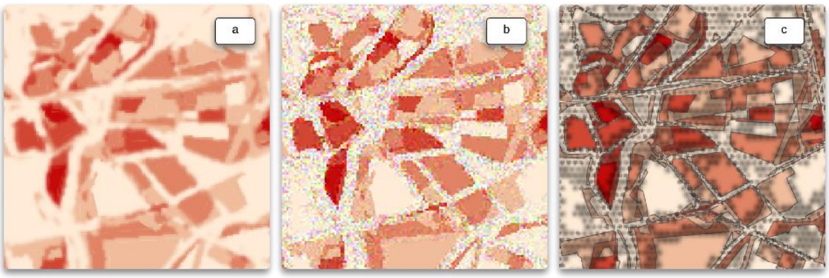

Fig. 4. Different approaches to uncertainty visualisation a) blurring, b) noise, c) dot fuzziness

5 Conclusion

Objective of this work was to investigate urbanization processes in Olomouc. Only the first two phases of the urbanization process - urbanization and suburbanization - were present in the area of Olomouc. The study attempted to quantify both processes and determine the prevailing phenomenon. Using this analysis, particular localities of residential and commercial suburbanization and/or urbanization were determined in the form of charts and map outputs. From the viewpoint of the uncertainty visualizations, it is possible to derive some important facts. In our study we try to capture the uncertainty connected with positional as well as attribute error. Nevertheless uncertainty is created in all parts of the process of cartographic communication and from the point of view of possible elimination, this is an element that cannot be removed. According to the occurrence of uncertainty, we can talk about the uncertainty during the presentation of spatial data due to differing quality of data due to gathering, transformation and other factors. There is still many questions concerning the effectiveness of proposed visualizations. Due to this there is need for user testing with using eye-tracking.

6 References

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