

Visualization and classification of urban change patterns on the basis of state-space transitions

Alex Hagen-Zanker

Urban Planning Group, Eindhoven University of Technology, PO Box 513, Eindhoven,
The Netherlands
a.h.hagen.zanker@tue.nl

1. Introduction

Descriptive models of urban patterns are, by large, based on static situations i.e. single moments in time. They may present us with surprising regularities in space and time, such as the rank size distribution of city populations (Ioannides & Overman, 2003), the cluster size distributions of urban areas (Benguigui et al, 2006) and fractal relations in urban form (Batty & Longley 1996). Furthermore there are many metrics of spatial clustering and diffusion (e.g. Verburg et al. 2004). Patterns are recognized, but due to the static nature the relation with processes is unclear and understanding of causal relations remains low.

Explanatory models of urban areas, by contrast are typically based on the dynamic interactions between actors and their relative geographic position. Such relations can include for instance network effects and benefits of scale or negative externalities that lead to buffers, segregation and diffusion. Modern computing makes it possible to simulate virtual cities which are composed of many small elements and relatively simple interaction rules, for instance by Cellular Automata (White & Engelen 1993) or Agent Based Modelling (Parker et al. 2003). Although the results of these explanatory models are promising and they find applications in urban planning practice, they often lack empirical support. Lambin et al. (2001) even identify a number of myths (popular but false assumptions).

This paper explores a descriptive model of urban change that may offer empirical support for the kind of hypotheses that underlie the dynamic exploratory models. The model is based on transitions in state-space. As a proof of concept it is applied to classify urban change in the Netherlands.

2. Methods

On the basis of different attributes a location on the map is linked to a location in state-space. Over the course of time the characteristics of a location change and therefore the location in state-space changes. The transitions in state-space characterize the spatial dynamics of a region.

In a categorical raster map every location (cell) is primarily defined by its category. However, the geographic relation between locations implies further attributes that need to be derived. In this application we characterize the state-space of a location by two attributes; the fraction of urban area within a radius of 2 km and 7.5 km. Both attributes are categorized in 5 bins, yielding in total 25 categories to characterize urban form. The categorization is made on the basis of 500m resolution land use maps of 1989 and 1996.

Next the transitions that take place are tabulated for 40 separate (NUTS3) regions. Thus the changes in each region are summarized by a 25*25 transition matrix. This matrix is normalized and contains proportions of transitions for each class of urban form in the initial map. The difference between transition tables is calculated on a (matrix) cell-by-cell basis, according to equation 1.

$$d(A,B) = \frac{\sum_{i,j} (|A_{i,j} - B_{i,j}| * w_{i,A,B})}{\sum_i w_{i,A,B}} \quad \text{Equation 1}$$

Where $d(A,B)$ is the difference in urban change between regions A and B. $A_{i,j}$ is the proportion of cells originally in class i in region A that changed state to class j . The weight $w_{i,A,B}$ is included to account for regions that initially do not contain any cell in class i . If region A or B does not contain class i initially, then the weight is 0, otherwise it is 1.

Finally, a nearest-neighbour algorithm finds clusters according to the regional similarity in urban change patterns.

3. Results

The classification of urban change creates a pattern that correlates to urban form in the Netherlands, for instance as measured by the distribution of population per municipality (Figure 1). It is perhaps not surprising that regions with large municipalities display different dynamic behaviour than regions with small municipalities. Nevertheless, it must be kept in mind that the analysis is strictly based on the transitions in spatial structure that took place and not on the spatial structure itself.

A sensitivity analysis indicates that the results are robust for small changes in the parameters (i.e. the radii of 2 and 7.5 km and the categorization in 5 bins). The results are also robust for different region definitions, except if regions get too small (15*15 km).

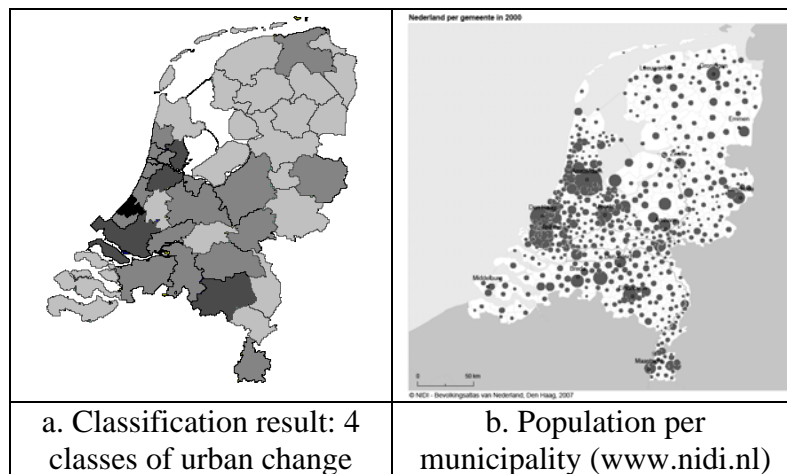


Figure 1. The classification of urban change correlates with the spatial distribution of population in the Netherlands.

4. Conclusion and further work

The results are an indication that the state-space approach is robust and provide confidence in further research towards the description and classification of patterns of urban change.

The combinatorial approach puts practical limits on the number axes in state-space that can be included. Ongoing work focuses on changes in population, residential area, urban area and the urban envelope.

The classification in this paper is unsupervised. Future work will include supervised classifications, aiming at the recognition of processes such as abandonment, densification, sprawl and infill.

An elaboration of the method in terms of Markov Chains may open windows for further analysis. It will be a challenge, however, to account for the fact that transitions at neighbouring locations are not independent of each other.

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6. References

- Batty M and Longley PA. 1996, *Fractal cities*. London and San Diego: Academic press.
- Benguigui L, Blumenfeld-Lieberthal E and Czamanski D., 2006. The dynamics of the Tel Aviv morphology. *Environment and Planning B: Planning and Design*, 33(2):269-284.
- Couclelis H, 1997, From cellular automata to urban models: New principles for model development and implementation. *Environment and Planning B-Planning & Design*, 24(2):165-174.
- Ioannides YM and Overman HG, 2003, Zipf's law for cities: an empirical examination. *Regional Science and Urban Economics*, 33(2):127-137.
- Lambin EF, Turner BL, Geist HJ, Agbola SB, Angelsen A, Bruce JW, Coomes OT, Dirzo R, Fischer G, Folke C, George PS, Homewood K, Imbernon J, Leemans R, Li X, Moran EF, Mortimore M, Ramakrishnan PS, Richards JF, Skanes H, Steffen W, Stone GD, Svedin U, Veldkamp TA, Vogel C and Xu J, 2001, The causes of land-use and land-cover change: moving beyond the myths. *Global Environmental Change*, 11(4):261-269.
- Parker DC, Manson SM, Janssen MA, Hoffmann MJ and 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):314-337.
- Turner MG, 1989, Landscape Ecology: The effect of pattern on process. *Annual Review of Ecology and Systematics*, 20(1):171-197.
- Verburg PH, de Nijs TCM, Ritsema van Eck J, Visser H and de Jong K, 2004, A method to analyse neighbourhood characteristics of land use patterns. *Computers, Environment and Urban Systems*, 28(6):667-690.
- White R and Engelen G, 1993, Cellular-Automata and fractal urban form - a cellular modeling approach to the evolution of urban land-use patterns. *Environment and Planning A*, 25(8):1175-1199.