

## Urban Geometry as a Factor for Urban Growth

Mantelas A. Lefteris

Regional Analysis Division, Institute of Applied and Computational  
Mathematics, Foundation for Research and Technology,  
Vasilika Voutwn, GR 71110, Heraclion Crete, Greece  
[mantelas@iacm.forth.gr](mailto:mantelas@iacm.forth.gr)

### INTRODUCTION

In this paper we introduce the hypothesis that urban geometry is a factor capable of describing some aspects of the urbanization process and we examine the validity of this hypothesis through two different perspectives. We use the term Urban Geometry to refer to the geometrical attributes of the urban shape through the perspective of Euclid's geometry and its axiomatic structure that embodies the principle of continuity within difference, which is manifested in relationships of congruency or similitude (analogies, proportions) (Carl 2000). First, we tested the performance of non-expert people that made urban growth estimations based entirely on urban shape. After that, we explored the possible gain of geometrical information through the concept of directionality within anisotropic urban cellular automata (CA).

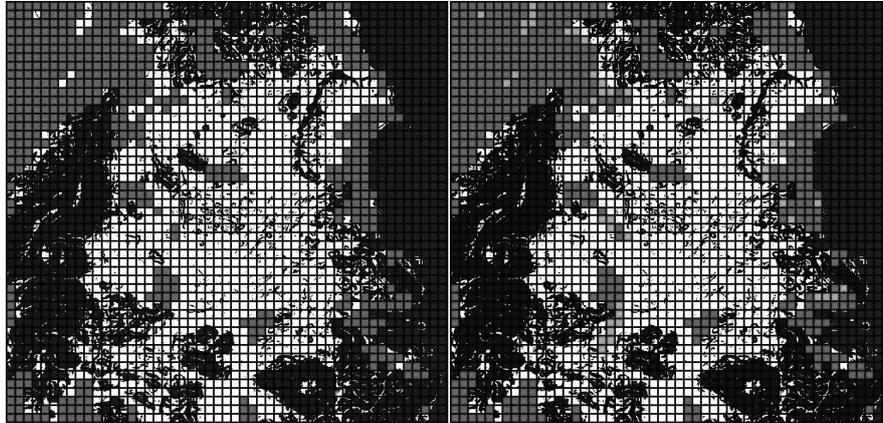
### CCGI FOR LARGE-SCALE URBAN GEOMETRY

The first part of our analysis focuses on the empirical utilization of large-scale geometrical attributes of urban shape. Apparently, large-scale processes have an equal if not greater role to play than local circumstances (Green 2002). We conducted a web experiment and collected information concerning future urban cover estimations based on the shape of the current urban cover alone. Linking human understanding with a formal system like GIS involves communication, as well as, interaction and presentation (Kratochwil and, Benedikt, 2005); hence, to put our experiment in motion we had to come up with a way to provide all necessary information in a simple, comprehensible and attractive form. To do so, we thought of the urban order as built upon distinctions and distances under the concept 'city as image' (Carl, 2000) and we created simplified raster-based maps of the east Attica region. The maps were referring to the year 2000 and 2004 and included three categories of cells – urban cells, vacant cells and fixed non-urban cells. The cell size was determined to be 500x500m for both the maps; as a result the number of cells that were urbanized during the period 2000-2004 was limited to 40. Figure 1 shows the correspondent mappings for 2000 and 2004.

We developed a website ([www.tem.uoc.gr/~eamantel/urbanexperiment.html](http://www.tem.uoc.gr/~eamantel/urbanexperiment.html)) including all necessary information and created a new discussion in the Moto.Gr<sup>1</sup> internet forum. Twenty four anonymous volunteers participated in this experiment within the first two weeks. The participants were given an image of the 2000 and they were asked to mark the 40 cells they thought more probable to get urbanized based on the image alone ignoring any possible knowledge about urbanization or the specific area. To evaluate the responses, we used the number of correctly allocated cells as an indicator. 4 responses allocated correctly more than 15 cells while the average value is 7.25 cells or 18%. Table 1 shows the correspondent descriptive statistics.

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<sup>1</sup> Moto.Gr ([www.moto.gr](http://www.moto.gr)) is a forum dedicated to motorcycle issues. Nevertheless, a great variety of general topics is discussed in it while the great number of active members ensured an adequate response.



**Figure 1:** The simplified maps for 2000 (left) and 2004 (right), dark grey cells are urban, black cells are fixed non-urban and white cells are vacant.

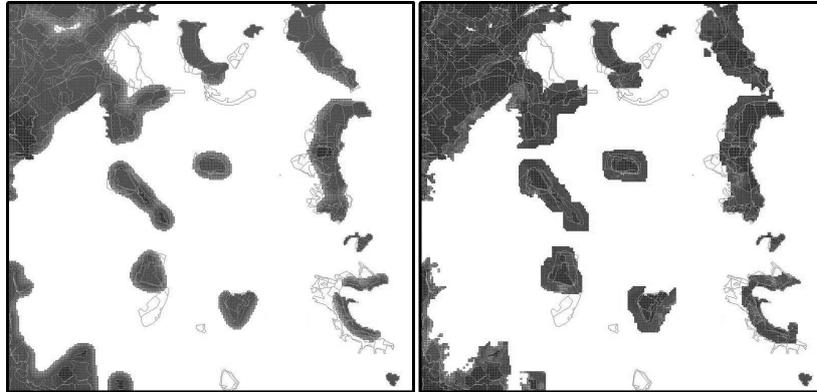
Index	Mean	Median	Std. Dev.	Min	Max
<b>A</b>	<b>7.25</b>	<b>5.00</b>	<b>5.64</b>	<b>0.00</b>	<b>19.00</b>
<b>A%</b>	<b>0.18</b>	<b>0.13</b>	<b>0.14</b>	<b>0.00</b>	<b>0.48</b>

**Table 1:** Descriptive Statistics for the evaluation indexes.

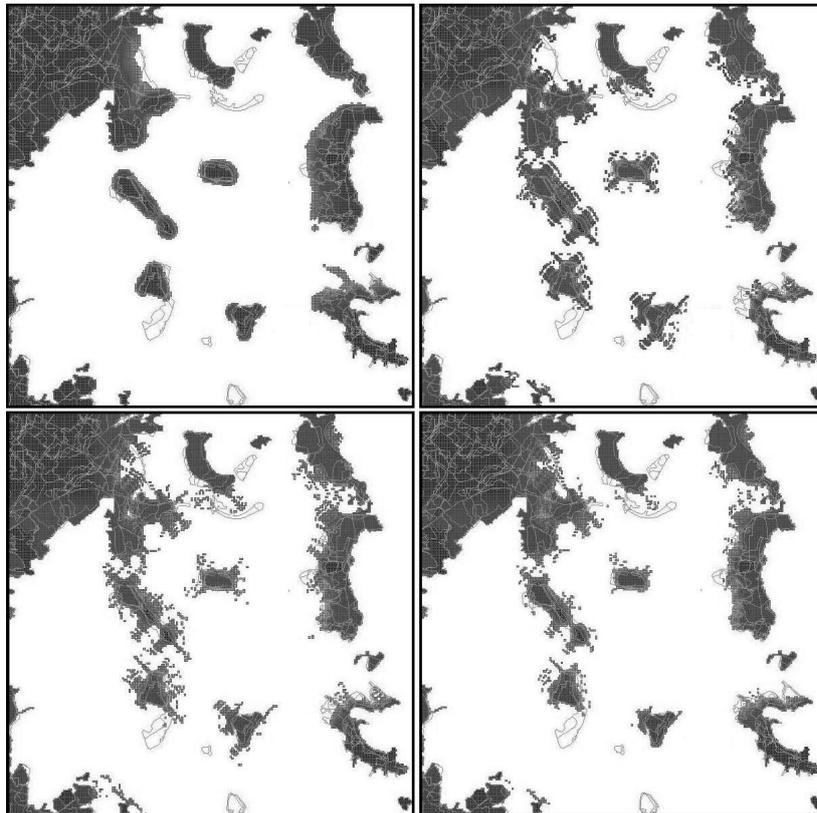
At first sight, 7.25 cells or 18% does not seem much. In order to appreciate the relative importance of this value though, we compared it with the portion of urban growth's variance referring to the same area during the same period that can be explained through the variance of road network data. The R-criterion values for the distance from and density of main road network are 13% and 26% correspondently, while for the case of secondary network the correspondent values are 15% and 54%. Although the indicator used can not be directly compared to the statistical R-criterion, the general conclusion is still valid. Large-scale geometry of the urban shape can provide information about the future urban growth, information whose significance is comparable to that of the main road network.

## DIRECTIONALITY WITHIN FUZZY CELLULAR AUTOMATA

In this section we attempt to provide a systemic proof of concept for our hypothesis through the concept of directionality within fuzzy CA. For this purpose we use as basis a simplified version of the fuzzy CA based urban growth model that we have developed (Mantelas et al. 2007, 2008) with some additional features. We equipped the model with a second set of directional rules that are triggered by conditions defined upon 8 directions (the north-south and west-east axes and the 45 degrees intervals), while the initial isotropic rules were defined upon Moore neighborhoods. The hypothesis's criteria for both sets of rules are the same; the difference is the area on which they are aggregated. For example an isotropic rule take into account the 8 surrounding cells while a directional anisotropic rule takes into account the first 8 cells across any direction. For our study we could use either one of the sets or any given weighted combination of them. The first stage test was to run both sets of rules for the area of Mesogia in Attica without using any additional data. The outcomes (figure 2) revealed that while isotropic CA tend to return smooth and homogenous results (as expected), anisotropic directional CA return more sharp estimations. Directional CA also spread further in open space and demonstrate a different spatial distribution of urban intensity.



**Figure 2:** Estimations of the actual urban growth for the case of isotropic CA (left) and anisotropic (right) without utilizing suitability. The grey outline shows the actual urban cover.



**Figure 3:** Estimations of the actual urban growth for the case of isotropic CA (top-left), anisotropic (top-right) and different combinations (bottom). The grey outline shows the actual urban cover.

Following, we ran both sets and a number of weighted combinations while we took into account the suitability for urbanization thematic layer which is calculated based on LU, road network and slope data. The results (figure 3) were consistent to the previous one; directional rules presented a scattered pattern of growth that resembles the noise around electrical signal; a pattern that isotropic urban CA are not capable of producing. In terms of numerical error, isotropic CA are more efficient for the whole area of study but directional CA might behave better locally. Specifically directional CA fit better to the actual urban growth in areas where small urban clusters grow faster than the average rate of the whole area. Finally, combinations appear to inherit both advantages and disadvantages of the primary sets of rules according to the weights used.

## CONCLUSIONS AND FUTURE WORK

In this paper, we presented two proofs of concept for the hypothesis that urban shape contains geometrical information that can be used for the purposes of urban modeling. The experiment we conducted does not consist a mathematical proof of our case while the produced estimations are not sufficiently accurate to be compared with estimations provided by urban models. On the other hand, it appears that non-expert people may be familiar with urban growth and provide locally realistic outcomes based on urban geometry alone, which supports that urban geometry can provide information about urban growth. Following, we examined the behavior of directional CA alone and in combination with isotropic CA. We didn't manage to improve the overall accuracy of the results but we provided evidence that directionality can locally improve the behavior of urban CA and present an entirely different pattern of self-organization. Specifically, the "electrical noise" pattern brings forward the question whether anisotropic directional CA fit better in spatially more detailed data. We intend to examine this and further focus on configuring the utilization of directionality within the scope of CA based urban modeling.

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