Presentation of the doctoral research project to obtain the doctoral degree by the Technical University of Catalonia

Multi-scale integrated cellular modeling for the study of urban change phenomena

School of Architecture of Barcelona
January 31st, 2008

Doctoral Candidate  Nuno Norte Pinto
Thesis Director  Prof. Josep Roca Cladera, UPC
Thesis Director  Prof. António Pais Antunes, University of Coimbra

Introduction

Introduction

- PhD as part of a long-term research project on the use of high resolution modeling techniques for urban simulation
- The key issue in the research is the use of Cellular Automata (CA) in urban simulation, a mathematical technique developed during the 1940s by von Neumann and by Ulam for devising mathematical rules in biological systems
- CA was introduced in urban geography by Tobler during the 1970s
  - Simple technique based on a set of 5 components: cells, neighborhood, cell states, transition rules and time
  - Powerful technique for simulating complex urban phenomena
  - Intensive research in urban studies during the past 15 years
Long-term Research

- **First stage** – to understand both the urban change problem in small urban areas and the use of microsimulation techniques
  - MSc in Planning at the University of Porto
  - First approach to the CA technique – SmallUrb CA
  - Innovative approach focusing on small urban areas and considering irregular cells

- **Second stage** – to make a deep reflection on the main characteristics of a multi-scale spatial simulation model
  - MSc in Urban Management and Valuation at UPC
  - Reflection on several theoretical issues on microsimulation
  - Development of a conceptual framework on multi-scale CA modeling

- **Third stage** – the development of a multi-scale CA approach under the PhD program at UPC

Introduction

### Cellular Automata Models

<table>
<thead>
<tr>
<th>CA Component</th>
<th>Traditional approach</th>
<th>Innovative approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell and Cell Lattices</td>
<td><img src="cell_and_lattices.png" alt="Image" /></td>
<td><img src="innovative_cell_and_lattices.png" alt="Image" /></td>
</tr>
<tr>
<td>Neighborhood</td>
<td><img src="neighborhood.png" alt="Image" /></td>
<td><img src="innovative_neighborhod.png" alt="Image" /></td>
</tr>
<tr>
<td>Cell States</td>
<td><img src="cell_states.png" alt="Image" /></td>
<td><img src="innovative_cell_states.png" alt="Image" /></td>
</tr>
<tr>
<td>Transition Rules</td>
<td>( T : (S_t, I_t) \rightarrow S_{t+1} )</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td><img src="time.png" alt="Image" /></td>
<td></td>
</tr>
</tbody>
</table>
Scientific Backgrounds

Previous Work on CA

Set of 20 theoretical test problems

Real world case study

Software Development

PhD Research Program

Research Goals

- To create a new CA-based approach for simulating urban change phenomena with a multi-scale perspective
- To deepen the research on the main characteristics of CA
- To develop new modeling tools for assisting decision-making processes in planning
- To incorporate policy testing tools in urban simulation models to meet common planning practice needs of producing feasible prospective analysis
- To apply the methodologies developed under this research to two real world case studies
PhD Research Program

Research Methodology

1. To gather the state-of-the-art on urban simulation and CA based on the expertise gained during the previous research stages

2. To develop a set of modular simulation tools based on CA considering
   - Multi-scale approach
   - Irregular cells
   - Variable neighborhoods
   - Accessibility assessment
   - Policy testing
   - Learning CA

3. To integrate these simulation tools into a user-friendly planning procedure

4. To test the methodologies developed under this research to two real world case studies in Spain and Portugal

5. To produce a PhD thesis based on a group of scientific papers to be published on indexed journals covering the entire research scope

PhD Research Program

Research Methodology Flowchart

- Integrated Modular Multi-Scale Model Development
  - Macro-scale Cellular Model
  - Micro-scale Cellular Model
  - Accessibility Model
  - Land Use Suitability Indicators
  - Calibration Procedures
  - Policy Testing Procedures
  - Expertise on Modeling and on Cellular Automata

- MSUs in Planning (University of Porto)
- MSUs in Urban Management and Valuation (UPC)
- A Cellullar Automata model for urban areas of variable dimension
- Calibration procedures for urban-based models: comparison of optimization approaches
- Measuring cellular model performance
- A multi-model, multi-scale, multi-function cellular-based modeling

- Case Study applications
  - Spanish Mediterranean Coast
  - Portuguese Northwestern Coast
  - Development of new methodologies towards a multi-scale cellular-based generalization model

Spanish Mediterranean Coast
Portuguese Northwestern Coast
PhD Research Program

Additional Information

- PhD research granted with a doctoral scholarship from the Portuguese Foundation for Science and Technology, FCT-Portugal
- Coupled research with research projects on urban change/growth in Spain (Spanish Mediterranean Coastal Area) and Portugal (Portuguese Northwestern Coastal Area)
- The research work will be carried on in close contact with CA and modeling experts and research groups
  - Memorial U., Newfoundland, Canada
  - UCL, Louvain-la-Neuve, Belgium
  - CASA, UCL, London
  - The S4 European Research Group
  - COST action TU602
  - MIT-Portugal Program

PhD Research Program

Research Chronogram

<table>
<thead>
<tr>
<th>Research Subject</th>
<th>1st Quarter 2007</th>
<th>1st Quarter 2008</th>
<th>1st Quarter 2009</th>
<th>1st Quarter 2010</th>
<th>1st Quarter 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>A literature survey on modeling and urban studies and on cellular automata and urban studies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A cellular automata model for urban areas of variable dimension</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calibration procedures for cellular-based models: comparison of optimization approaches</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measuring cellular models' performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A multi-modal accessibility model for cellular based modeling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Definition of new methodologies towards a multi-scale cellular-based geosimulation model</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case studies applications</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
References