Geosimulation of Urban Housing Market Conditions: A Preliminary Investigation

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1 ABSTRACT

A key objective of this contribution is to evaluate the suitability to geosimulate housing market conditions. Systems for geosimulation, such as multi agent systems (MAS) or cellular automata (CA) exhibit various lacks when it comes to usability, data handling, data availability, visualization of simulation results and, not least important, GIS-MAS/CA coupling. This contribution evaluates different systems for geosimulation to identify lacks and to define an appropriate system for the geosimulation of urban housing market conditions. Systems considered include UrbanSim, REGISTA (Reality Emulating Geographical Information System for Territorial Analysis), MAGI (Multi Agent Geosimulation Infrastructure), Agent analyst and OBEUS (Object Based Environment for Urban Simulation). Prior to the evaluation a generic conceptional process framework for a housing rent appraisal simulation as an organizational geosimulation framework for housing market analysis is set up. This framework contains process components such as visual interpretation and descriptive statistics of housing market data, generation of spatially interpolated surfaces and intersection with (socioeconomic) ancillary data. The preliminary study serves as groundwork for the creation of a prototype simulation in the test area of the German city of Potsdam.

2 INTRODUCTION

The focus of this paper is the design of a conceptional framework for a housing rent appraisal simulation. A further focus lies on the the evaluation of different modeling toolsets for the purpose of modeling conditions in housing rental markets. In recent years the term geosimulation was used as a fuzzy phrase under which a whole range of new spatial simulation approaches has been subsumed. Torrens and Benenson (Torrens & Benenson 2004), the developers of the Geographic Automata System concept, consider geosimulation as "urban geosimulation". Spatially-related automata are the basis for their concept of geosimulation. The difference to conventional urban simulations are the constitutional "elements"of geosimulation, e.g. human individuals and infrastructure entities. The interactions between complex and dynamic phenomena in urban systems are modeled.

Urban simulation models in a traditional sense represent urban units in different scales of aggregation (e.g. census tracts, administrative boundaries etc.); geosimulation models are based on spatially non modifiable objects e.g. homes or households. This view of geosimulation already adresses one of the problems of geosimulation approaches, the acquisition of spatial data at the highest possible scale. Most popular tools in geosimulation are automata, mostly cellular automata (CA), and agent-based modeling approaches as multiagent systems (MAS). In the first volumeof their book series "Geosimulation" Koch & Mandl (Koch & Mandl, 2011) give some recent applications of geosimulation in the field of urban development, land-use change, gentrification etc.

3 CONCEPTIONAL PROCESS FRAMEWORK FOR A HOUSING RENT APPRAISAL SIMULATION

In general, existing housing market models are real estate appraisal models and concentrate on modeling effects on the housing price but not on housing rent. In this presentation an adaption of existing models to simulate effects on housing market rents in "core cities" of urban areas, following the nomenclature of the German Federal Institute of Urban- Construction and Regional Science, is suggested (BBSR 2011). Common approaches of real estate appraisal models are hedonic approaches where the bundle of the overall housing price is broken down in different prices, often using ordinary least square estimation methods (OLS) (Liu, 2011). Further methods are the application of moving window regression analysis, GWR (Geographically weighted regression analysis) and moving window kriging (Montero et al., 2011).

The goal is to adapt a model to the aim of housing rental appraisal and to integrate the adaption into a geosimulation process framework. The hereby suggested conceptional simulation process framework (figure

1) consist of six modular components. The process starts with a data acquisition and preprocessing component following and extending a process chain for a GIS-based housing market analysis suggested by Schernthanner & Asche (Schernthanner & Asche, 2010). This analysis includes the visual data interpretation, descriptive statistics and the rent appraisal of the current market situation via methods coming from geostatistics (Kriging, GWR). Next comes submarket creation by means of polynomial declustering, followed by the core component, a multiagent based geosimulation of rental market conditions and a final forecasting/prognosis component based on the result of different simulation scenarios concludes the framework. While the process components from data acquisition to the rent appraisal of the current market situation have been evaluated (highlighted green in figure 1), prototype development for the simulation components is on the way. Core component is a multi agent simulation (MAS). The MAS component incorporates agents representing virtual tenants interacting in urban real estate submarkets. The agent's interactions allow conclusions to dynamics in rental trends based on their interactions. The process framework serves as simplified assumption of the complex dynamics in rental markets and their influence on the formation of apartment rents in core cities (see figure 2).

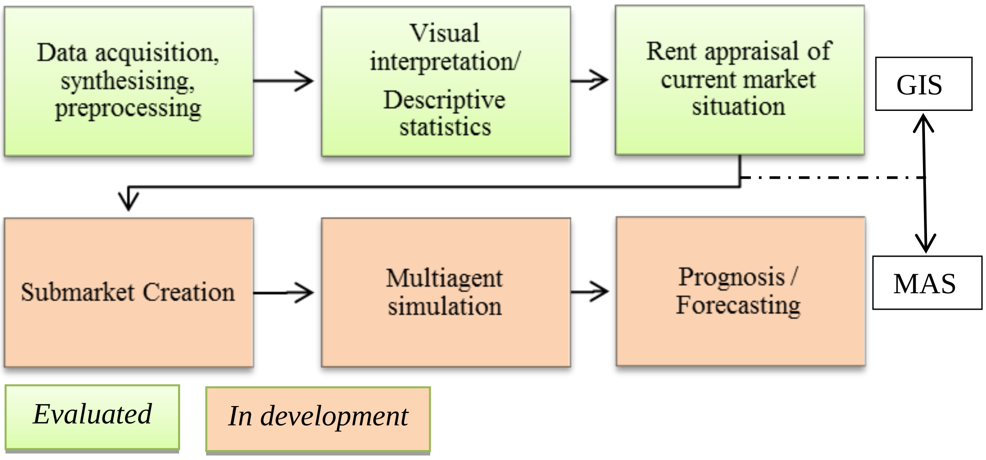

Fig. 1: Conceptional process framework for a housing rent appraisal simulation.

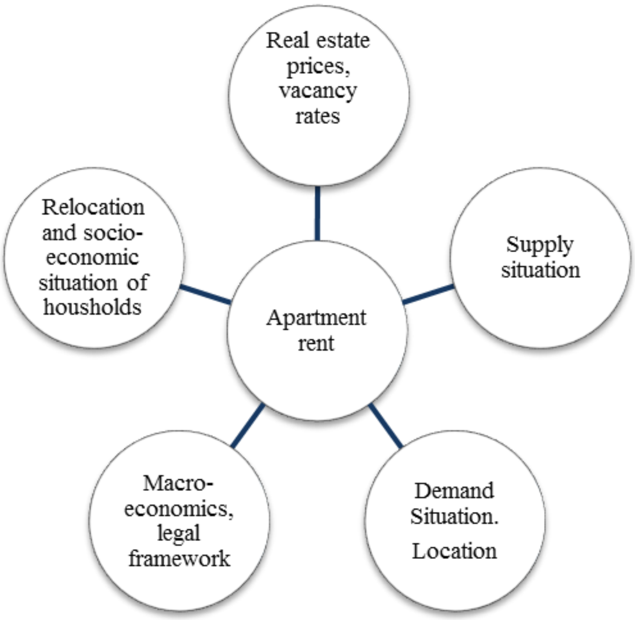

Fig. 2: Influence factors on the formation of apartment rents (own representation based on Waddell, 2011).

4 METHODOLOGY OF A TWO STEP EVALUATION PROCESS

Choosing an appropriate modeling system is a comprehensive task. The intended audience to use geosimulation modeling systems are expert groups made of specialists in the field of spatial planning, urban planning, GIS etc. Ideally a modeler possesses perfect knowledge about the geosimulation system to use, in practice the complexity of geosimulation systems show that this assumption does not fit to real world conditions. Therefore different researchers suggested different criteria to evaluate simulation systems previously to the actual geosimulation process (Smith et al., 2007). The evaluation of simulation systems is important groundwork for setting up a prototype simulation following the designed framework. The evaluation process consists of two steps. First a criteria-based search process is done searching for geosimulation software. Criteria have been taken from guidelines suggested by Smith et al. (Smith et al., 2007) and have been adopted and extended to suit to the suggested geosimulation framework. Second step is a simplified form of a cost benefit analysis as performed by e.g. Krüger (Krüger, 2006), Schernthanner & Tyrallova (Schernthanner & Tyrallová, 2010), based on the principles of cost-benefit analysis introduced by Zangemeister (Zangemeister, 1973). Criteria simulation software has to possess to fulfill a certain function were scored in a 5 point scale according to their relevance to achieve a certain target, by summing the overall scores a cost benefit is calculated for each geosimultion system. Scoring is a subjective process based on the performer's knowledge. Nevertheless general recommendations for the use of geosimulation software can be derived aligned to the goal of the simulation of housing markets. Nine criteria have been scored in the evaluation process, 45 points is the highest possible score, meaning that a simulation system is perfectly suitable for the suggested simulation framework.

4.1 Evaluated Criteria

The criteria have been divided in three general criteria simulation software systems had to possess; these criteria have been used for the search process. Geosimulation systems had to be of the CA and/or MAS type and had to have any kind of GIS coupling. Further divisions have been the criteria that have been evaluated by a cost benefit analysis:

- License: Open Source, Closed source, Shareware, Freeware or Unknown.
- Import Export functions.
- Help system: Documentation, "How-to", and Community.
- Degree of maintenance: is the system actual, out date.
- Programming: Scripting / Objectbased, necessary programming knowledge.
- User interface: GUI and/or command line.
- Results: Visualization.
- Complexity of data requirements: Minimum to maximum data requirements.
- Availability of real estate models (model templates).

Scores range from 0 points (criteria not suitable for) to 5 (perfectly suitable). In addition, the software system training time was examined based on experience found in literature and own tries resulting in training time assumptions.

4.2 Simulation software systems

The following software systems have been identified for further evaluation: UrbanSim, REGISTA (Reality Emulating Geographical Information System for Territorial Analysis), MAGI (Multi Agent Geosimulation Infrastructure), Agent analyst and OBEUS (Object Based Environment for Urban Simulation). Beside the evaluated systems several other systems exist, e.g. MASON or Netlogo. Castle et al. (Castle et. al., 2007) give a good overview over existing software for geosimulation.

UrbanSim/OPUS (Open platform for urban simulation) is a modular open source simulation software system for the analysis of urban development in the context of urban planning. Software development was initiated in the 1990s by Paul Waddell (Waddell, 2010) at the University of Berkley. Real estate demand and supply models exist but so far only indirect effects of infrastructure changes on the attractiveness of residential areas can be measured by the simulation software (Liu, 2011). REGISTA (Reality Emulating Geographical Information System for Territorial Analysis) is a CA-GIS concept presented by Blecic et al. (Blecic et al., 2009) . Blecic et al. developed a CA-modeling toolbox with tight GIS coupling to uDIG an open source desktop GIS. Blecic et al. (Blecic & Cecchini, 2008) also developed MAGI (Multi-Agent Geosimulation Infrastructure), an agent-based simulation software with tight GIS coupling. Agent Analyst is an extension of

ESRI ArcGIS developed by the U.S. Argonne National Laboratory's Center for Complex Adaptive Agent Systems Simulation in collaboration with ESRI (Environmental Research Institute). The software is a middleware coupling ArcGIS capabilities with Repast, an open source multi agent system, allowing users to run Repast models within ArcGIS . Repast itself is a free open source simulation toolkit, implementations of the Repast framework for housing applications already exist e.g. done by Jordan (Jordan, 2011). OBEUS (Object based environment for urban simulation) has a special status as it aims to implement the Geographic Automata System (GAS) paradigm described by Torrens and Benenson (Torrens & Benenson 2004) combining MAS with CA. OBEUS was developed as part of a unfinished PhD project by Vlad Kharbash (Benenson & Kharbash, 2005).

5 RESULTS AND CONCLUSION

A cursory examination might find that several promising modeling systems exist for the implementation of the suggested modeling framework. Lacks not recognized at the first glance could be identified in the evaluation process. Most projects seem to be in a permanent experimental status within an academic domain, few operational models exist. The learning curve for all the systems is steep and all the evaluated systems lack a satisfying visualization of simulation results. UrbanSim receives the highest score (33) but the training time that has to be calculated to set up a basic model and the enormous amounts of high scale geodata (e.g. socioeconomic data at household level) that has to be acquired to set up a basic model disqualifies UrbanSim for prototype development for one single person. Patterson and Bierlaire (Patterson & Bierlaire 2008) give an detailed description in the time that has to be spent to set up an UrbanSim model, they categorize the learning phases to understand UrbanSim into a familiarization phase during 0,5 person-months, an implementation phase lasting 1,5-2 person-months and an evaluation phase lasting 0,5-1 person-months, Nguyen-Luang (Nguyen-Luang, 2008) even claims that an interdisciplinary team of 4 people and a period of 4 years for a successful operational implementation of UrbanSim is necessary (Nguyen-Luang, 2008). REGISTA, although a promising approach, is not available; evaluation has been done only based on literature review, due to this fact the reached score of 23 can´t be compared with the other tested systems as the system can´t be accessed for prototype creation. MAGI (28) developed by the same research group as REGISTA (Blecic & Cecchini, 2008) unites MAS and GIS under one graphical user interface, biggest problem of MAGI is, that the software seems to be without maintenance since the first version published in 2007. Agent Analyst (18) also is without maintenance, Mathur (Mathur, 2007) even states: "I feel that the Agent Analyst was developed as an experimental product and has since then been without patronage or support". OBEUS has not been evaluated by scores, because the simulation system is not accessible.

In assumption that a big research team consisting of about 4 persons can set up a prototype, UrbanSim would be the software of choice for prototype creation. Repast (without Agent Analyst) and Magi are the authors' first choices for prototype development.

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