A multi-agent system to simulate the decision process of stakeholders involved in a land residential project in the Calgary region

Michael Kieser and Danielle J. Marceau

Department of Geomatics Engineering, University of Calgary, mejkiese@ucalgary.ca, dmarceau@ucalgary.ca

Abstract

The objective of this project is to build a multi-agent system to simulate the decision making process of stakeholders in a residential land development project and the influence of such decisions on land-use resources. The environment over which decisions are made is the Town of Strathmore, Alberta, where competition for land-use resources is increasing as a result of its proximity to the City of Calgary. The stakeholders simulated as agents are the citizens, the town planner and the developer. Interviews were conducted with representatives of each group to gather information about their goals, decision making process and influence. Simulations were performed over 30 years with a one year interval to mimic different land development scenarios. The model generates a series of land-use maps showing the changes in the environment based on the goals and decisions of agents. This model represents a valuable tool to better understand the complex interactions among several stakeholders involved in a land redesignation process and forecast the cumulative impact of their decisions on the environment.

Background and Relevance

In Alberta, prior to the development of a parcel of land, the land-use designation must be legally changed to allow for the proposed development. Several stakeholders are involved in this process including but not limited to the land owners, the land developers, the citizens, the municipal planners, the utility companies, and the environmental organizations. These stakeholders make decisions by weighing the social need, environmental impact, economic advantages/disadvantages and political support/opposition of a proposed land development. The municipal planner also attempts to fit a proposed land development into future plans that have been developed for the community. Each stakeholder has different opinions on the land development and different goals that he attempts to meet. There is a structure of formal and informal communication between the stakeholders, and the outcome of this complex system is a decision which changes the land-use designation of the parcel. Municipal planners use various tools including historical data and past experiences, statistical analyses of census data, and community economic models to make decision. However, these decisions are still quite often made in the face of uncertainty. Planners do not have the ability to forecast the cumulative effect of many individual decisions made by stakeholders on the environment over which they make their decisions. They need a tool that can model how final environmental patterns and trends emerge from the cumulative effect of complex behaviors and interactions of several individual stakeholders who might have conflicting views. This project has been undertaken to fulfill these requirements through the development of a multi-agent system.

Methods and Data

A multi-agent system (MAS) simulates a community of agents making decisions and taking actions on an environment. These agents are autonomous, they control their own decisions and actions, they are social, they communicate to negotiate and cooperate with one another; they are able to perceive changes in the environment and react to them; they have goals and are able to take initiative to achieve them (Marceau, 2008). MAS are built from a bottom up approach, explicitly reproducing the actions of individual agents in attempts to understand how the properties of the system emerge from individuals perceiving and acting upon their environment. They are increasingly used for wildlife and natural resource management (Anwar et al., 2007; Feuillette et al., 2003), and land-use planning (Ligtenberg et al., 2001; Monticino et al., 2007). In this project, the environment, the Town of Strathmore, is represented by a series of raster-based maps at 4 m spatial resolution including the land-use designation, the cadastral base, and the land use. The stakeholders include the town planner (also representing the town council), the land developer and the citizens. Structured interviews with representatives of each agent type were performed and the information was compiled to determine their goals, how they make decisions, the factors that influence their decisions, and how they communicate with each other. A decision module was built to simulate the intricate process of negociation and decision of these interacting agents. The model was programmed in Java and simulates agent-environment interactions that occur when agents "see" the environment over which they make decisions, and agent-agent interactions that are defined as logical rules and communication between agents. The model involves three components: 1) a simulation module of the agent goals, interactions and decision making that creates the development scenarios, 2) a module that changes the land use based on development scenarios and neighbouring existing land use, and 3) the combination of the two modules that takes the agents' decisions in a development scenario and applies them to the environment. Simulations were run for a period of 30 years, which lies within the future plans of the Town, with a one year incremental step.

Results

The model allows the user to modify the parameter values of each agent type: the planner, the citizen, and the land developer. This is done through the use of a pairwise comparison matrix where the intensity of importance of one goal over another is recorded. The user can also modify the land-use bylaws and environmental regulations, the real estate market value and construction costs, and the population and housing properties. The Run-time Variables panel shows the values of the variables as the model runs such as the population statistics and the proposed development, the opinion and change of behavior of each agent, and the variables affecting their decisions. Several different development scenarios were performed using the model to visualize the impact on the development of Strathmore, including: increasing and decreasing residential density, allowing, forbidding, or compensating any impact on wetlands present in the proposed development area, and decreasing the average household size. The model generates a series of raster-based land-use maps showing the change of the environment based on the goals and decisions made by the agents.

Conclusions

The results generated by the model are being validated using two approaches: conceptual validation that consists in verifying if the underlying assumptions are appropriate for the purpose of the modeling exercise, and operational validation that will determine the extent to which the model produces outcomes that match the real system under investigation. Meetings with the stakeholders will be organized during the fall 2008 where they will be shown the results and asked if they accurately portray the intentions of the actual decisions made on the land development project. The stakeholders will be invited to suggest additional development scenarios to forecast the possible future town growth based on the carry-over of agent goals. This will allow further testing of the robustness and usefulness of the model in a range of conditions. This model could potentially lead the stakeholders to achieve a beneficial outcome in the best interest of everyone when facing the challenge of new urban development.

References

Anwar, M., C. Jeanneret, L. Parrott, and D.J. Marceau, 2007. Conceptualization and implementation of a multi-agent model to simulate whale-watching activities in the St. Lawrence estuary in Quebec, Canada, Environmental Modelling and Software, 22: 1775-1787.

Feuillette, S., F. Bousquet and P. Le Goulven, 2003. Sinuse: A multi-agent model to negotiate water demand management on a free access water table, Environmental Modelling and Software, 18: 413-427.

Ligtenberg, A., A. Bregt & R. van Lammeren, 2001. Multi-actor-based land use modelling: spatial planning using agents, Landscape and Urban Planning, 56(1-2): 21-33.

Marceau, D.J., 2008. What can be learned from multi-agent systems? In: Monitoring, Simulation and Management of Visitor Landscapes, R. Gimblett, ed., University of Arizona Press, pp. 411-424.

Monticino, M., M. Acevedo, B. Callicott, T. Cogdill and C. Lindquist, 2007. Coupled human and natural systems: A multi-agent-based approach, Environmental Modelling and Software, 22(5): 656-663.