MultiAgent GeoSimulation of human behaviors in micro-scale geographic environments: The case of the shopping behavior in a mall

Walid (Oualid) Ali (1), Bernard Moulin (2,3)

Oualid.b.ali@hyms.ac.uk, Bernard.moulin@ift.ulaval.ca
Computer Science Department,
The SimVis Research group and the HIVE research group
The University of Hull, Hull, UK (1)

Computer Science Department (2)
Pouliot Building, Laval University, Ste-Foy, QC, Canada

Centre for Research in Geomatics (3)

Abstract

The past decade has seen a rising interest in, and strong development of, simulation applications of human behaviors, with special focus on pedestrian behavior in spatial environments. The recent generation of models employs a multi-agent system (MAS) based approach in order to represent the movements of humans in geographic environments. Our literature review revealed the existence of several research works which use MAS to simulate urban phenomena or pedestrian/crowd movements in large-scale geographic environments. These research works succeed to measure and model these phenomena and help to understand the way in which people move in geographic environment or urban setting. But, there are few MAS-based research studies attempting to simulate human 'knowledge-based' behaviors in micro-scale geographic environments (e.g., malls, shops, hotels, airports, etc.). The main aim of our research is to fill this gap, and to examine the applicability of MAS technique to simulate *human 'knowledge-based' behaviors* in *micro-scale geographic environments*. As a case study we developed a 2D-3D simulation prototype of human shopping behavior in a mall. The results of our research show that the multi-agent geo-simulation approach has a good potential to simulate human behaviors in micro-scale geographic environments. Hence, this technique can be used easily in order to simulate other kinds of behaviors in different micro-scale geographic environments.

Keywords

Multi-agent geosimulation, micro-scale environment, shopping behavior in shopping malls, Mall-MAGS prototype, MAGS platform

1. Introduction

During the past decade there has been a rising interest in, and strong development of, simulation applications of human behaviors, with special focus on pedestrian behavior in spatial environments. Simulating urban phenomena or pedestrian/crowd movements has attracted the attention of not only urban planners and government officials, but also of retailers, advertising agents, and people involved in urban management. The recent generation of models employs a multi-agent system (MAS) based approach in order to represent the movements of people in virtual geographic environments. In most cases, these virtual geographic environments are obtained from a Geographic Information Systems (GIS). Combining MAS and GIS for simulation purposes gives birth to a new simulation approach called MultiAgent GeoSimulation (MAGS) (Moulin et al, 2003). MAGS has a great potential when it comes to explaining the subtle interactions of heterogeneous actors in complex social systems, taking into account the geographic aspect of the simulation environment. The characteristics of the agents (autonomy, social ability, pro-activeness, advanced spatial behaviors such as perception, navigation, and memorization, etc.) and the spatial features of the simulation environment make MAGS an attractive approach to develop simulations of complex systems involving agents interacting with each other and with the geographic environment. In addition, the complexity of the simulation models and their visualization capabilities (cartographical visualization, 2D-3D displays) make them more realistic and, therefore, closer to users' mental models (Ali and Moulin, 2005). Thus, MAGS approaches potentially open numerous avenues for exploratory and applied simulation in different fields and especially in urban geography (Benenson and Torrens, 2004). Our literature review revealed the existence of several research works which applied the MAGS approach to simulate urban phenomena or pedestrian/crowd movements in geographic environments. These research works succeed to measure and model these phenomena and help to understand how people move in a geographic environment or urban setting. However, we found few MAGS-based research studies attempting to simulate what we call 'knowledge-based behaviors' (behaviors involving the apprehension of spatial features of the environment) in micro-scale geographic environments such as malls, shops, hotels, and airports. The nature of the geographic environment (micro-scale), the behaviors to be simulated (knowledge-based), and the characteristics of the interactions between the actors and the environment in the simulation (spatial interaction), make this kind of simulation a challenge in itself.

One of the main goals of our research was to examine the applicability of a MAGS approach to simulate human '*knowledge-based*' behaviors in micro-scale geographic environments. As a case study, we developed a 2D-3D simulation prototype which simulates the shopping behavior of a real population of shoppers inside a shopping mall.

In this paper, we start off with a presentation of the basic concepts of geosimulation and multiagent geosimulation techniques (Section 2). In Section 3, we present why developing multi-agent geo-simulations of human behaviors in a micro-scale environment is a challenge. Then, we present our MAGS simulation prototype of human shopping behavior in a mall and its usability. In Section 4, we present some related works and conclude the paper.

2. Geosimulation and multiagent geosimulation

Geosimulation is concerned with the design and the construction of high-resolution spatial models, using these models to explore ideas and hypotheses about how spatial systems operate, developing simulation software and tools to support object-based simulation, and applying simulation to solve real problems in geographic contexts (Benenson and Torrens 2004). Geosimulation differs from conventional urban simulation in its constituent 'elements'. Geosimulation models operate with human individuals and infrastructure entities, represented at spatially non modifiable scales such as households, homes, or vehicles. Many of these entities are animated (visually and dynamically), and such an animation drives the behaviors of inanimate objects in a simulation (Benenson and Torrens 2004). Geosimulation is a useful tool to integrate the spatial dimension in models of interactions of different types (economics, political, social, etc.).

(Mandl, 2000), (Koch 2001), and (Moulin et al. 2003) presented *MultiAgent GeoSimulation* as a coupling of two technologies: the Multi-Agent Based Simulation technology (MABS) and the Geographic Information systems (GIS).

Based on the MABS technology, the simulated entities are represented by software agents with autonomous behaviors. They can interact with other agents and with the spatial environment. They may be active, reactive, mobile, social or 'cognitive' (Koch 2001). Thanks to the agents' capabilities, we can use them to model and simulate complex entities or systems.

Using the GIS technology, the spatial features of geographic data can be introduced in the simulation. The GIS plays an important role in the development of geosimulation models. Multi-Agent Geo-Simulation (MAGS) is a powerful concept that can be used to simulate complex systems in geo-referenced environments.

According to our literature review, there exist few applications which use the MAGS technology in order to simulate human behaviors in geographic environments (Koch, 2001) (Dijkstra et al., 2001) (Moulin et al., 2003) (Torrens and Nara, 2007). These applications, focused on the simulation of urban phenomena or crowd movements in large-scale geographic environments. Until now, there were very few research works using MAGS-technology in order to simulate 'knowledge-based' human behaviors in micro-scale geographic environments. The only existing research works which simulate human behaviors in micro-scale environments (Raubal, 2001) (Frank et al., 2001) use only MAS, or GIS and do not benefit from the combination of these technologies.

3. Multiagent geosimulation of human behaviors in micro-scale geographic environments:

3.1. Challenges of using a MAGS approach to simulate human behavior in micro-scale geographic environments:

Simulating 'knowledge-based' human behaviors in micro-scale geographic environments is a challenge in itself because, especially for this kind of simulation, we need:

- Detailed structures of the simulation agents which represent humans in the virtual environment are required. When we deal with this kind of simulation, we focus more on individual agents and their behaviors. Most simulation applications of crowd behaviors or urban phenomena do not focus on individual features or behaviors of the agents because they are more interested in global or emergent behaviors.
- Agents with advanced knowledge-based and spatial capabilities such as perception, memorization, navigation, communication, decision-making, etc.
- A detailed model of the geographic environment. At a micro-scale level, we can not ignore the small entities which belong to the environment and thus, we should model them.
- Meaningful and credible data which feed the models of the agents and those of the geographic environment.

- Appropriate visualization for the virtual agents representing the humans as well as the virtual geographic environment. For example, the 3D virtual human agents should be represented by 3D human bodies moving like humans in reality.

As one can see, simulating ‘knowledge-based’ human behaviors in micro-scale geographic environments is very challenging because we need to focus on many details concerning: the simulation models, the behavior to be simulated (individuals), the data which is used to feed the simulation, etc. In our research work, we tried to take up this challenge and developed an application which uses the MAGS-technology in order to simulate ‘knowledge-based’ shopping behavior of human beings in a micro-scale geographic environment representing a shopping mall.

3.2. The application: The simulation of human shopping behavior in a mall

In order to show the applicability of a MAGS approach to simulate human ‘knowledge-based’ behaviors in a micro-scale geographic environment, we developed an application simulating customers’ shopping behavior in a mall. To develop such application, we need a geosimulation platform. According to our literature review, there exist a small number of multiagent geosimulation platforms that can be used to simulate systems in geographic environments using the agent paradigm. As an example, we can cite the platforms CORMAS (Common-pool Ressources and Multi-Agent Systems) (Bousquet et al. 1998) and MAGS (MultiAgent GeoSimulation) (Moulin et al. 2003). In our work we used the MAGS platform to develop our simulation prototype.

In order to feed the actors’ models (shoppers) in the simulation, we carried out a survey during October 2003 and collected 390 questionnaires filled by real shoppers in the *Square One* shopping mall, near Toronto. To feed the model of the micro-scale geographic environment (the mall), we used spatial data obtained from a GIS representing the Square One mall.

The simulation models are executed in the MAGS platform using the real data. Fig. 1, presents a 3D screenshot of a simulation that involved 390 Shopper software agents navigating in the virtual shopping mall.

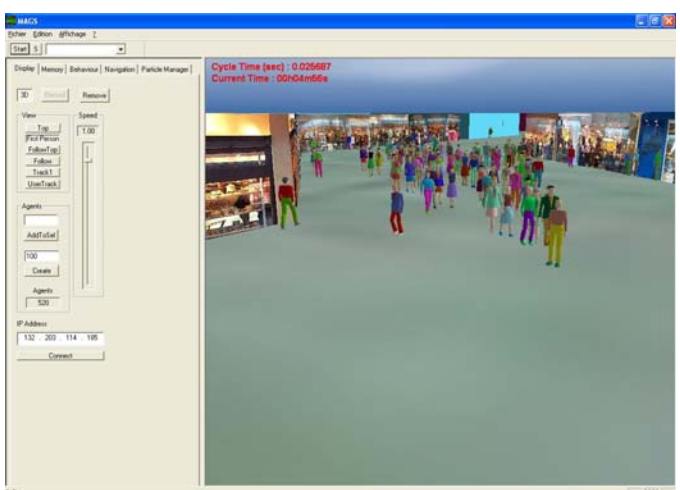

Figure 1. The 3D simulation in MAGS platform (Square One mall)

In the simulation prototype, the Shopper agent comes to the mall to visit a list of specific stores or kiosks that are chosen before the simulation on the basis of the agent's characteristics and according to the survey data (each shopper agent correspond to one of the surveyed persons). It enters by a particular door and starts its shopping trip. Based on its position in the mall, its knowledge of locations in the mall (memorization process), what it perceivs in the mall (perception process), it chooses the next store or kiosk to visit (decision making process). When a store or kiosk is chosen, the agent moves in its direction (navigation process). Sometimes, while it is moving to the chosen store or kiosk, the agent perceives another store or kiosk (perception process) that is in its shopping list and whose location it did not know *a priori*. In this case, the Shopper agent moves to this store or kiosk and memorizes it (memorization process) for its subsequent shopping trips. The shopper agent pursues its shopping trip until it visits all the stores or kiosks on its list or until it has no time left.

The Shopper agent can also come to the mall without any specific list of stores or kiosks to visit, for exploration purposes. In the exploration mode, the Shopper agent takes its preferred paths in the shopping mall.

During its shopping trip, the Shopper agent can feel the need to eat or to go to the restroom (simulated by a dynamic variable reaching a given threshold). Since these needs have a bigger priority than the need to shop, the agent temporarily suspends its shopping trip and goes to the locations where it can eat something or to restrooms.

4. Related works and conclusion

(Koch, 2001), (Moulin et al., 2003), and (Torrens and Nara, 2007) developed some applications that simulate pedestrian behavior in geographic environments using the agent technology. These works simulate human behavior in large-scale geographic environments. They do not focus on the individual features and behaviors of each agent but aim to study the emergent behavior of crowds in the simulation. Other research works like (Raubal, 2001), Frank et al., 2001), and (Dijkstra et al., 2001) simulated pedestrian behaviors in micro-scale geographic environments, but they do not benefit from the MAGS technology. In these applications, the environment is generally represented by cellular automata. In our study we proposed an application of MAGS technique to simulate 'knowledge-based' human behaviors in micro-scale geographic environment. In this study, we focus more on the agents individual features and on their behaviors related to the apprehension of space (perception and memorization). As a case study, we implemented an application which simulates customers' shopping behaviors in a mall. The results of our research show that the MAGS technique has a good potential to simulate 'knowledge-based' human behaviors in micro-scale geographic environments.Indeed, this technique can be easily adapted to simulate other kinds of behaviors in different micro-scale geographic environments.

5. Acknowledgments

The authors are thankful to Canada GEOIDE Network of centres of excellence in geomatics, to Canada Natural Sciences and Engineering Research Council and to Canada NSERC Industrial Research Chair in Geospatial Databases for Decision-Support for their financial support. Many thanks to the Square One management who allowed our team to carry out the survey and use data. The development of the MAGS platform has been funded by the Defence (RDDC Valcartier). Many thanks to the MAGS team and especially, W. Chaker, J. Hogan, J. Perron and F. Belafkir for their work on various aspects of the MAGS platform.

6. References

Ali W and Moulin B, 2005, 2D-3D MultiAgent GeoSimulation with Knowledge-Based Agents of Customers' Shopping Behavior in a Shopping Mall, in Proceedings of the COSIT'05 International Conference, A.G. Cohn and D.M. Mark (edts.), *Spatial Information Theory*, Springer Verlag Lecture Notes in Computer Science 3693, 445-458.

Bédard Y, Rivest S, and Marchand P, 2001, Toward better support for spatial decision making: Defining the characteristics of Spatial On-Line Processing (SOLAP). Geomatica, the Journal of the Canadian Institute of Geomatics, Vol. 55, No. 4,2001, 539-555.

Benenson, I and Torrens P M, 2004, *Geosimulation: Automata-Based Modeling of Urban Phenomena*, London: John Wiley & Sons.

Benenson I and Torrens P, 2003, Geographic Automata Systems: A New Paradigm for Integrating GIS and Geographic Simulation. In proceedings of GeoComputation conference. 24-30.

Bousquet F and Bakam, I, 1998, Cormas: Common-Pool Resources and Multi-Agent Systems. Lecture Notes in Artificial Intelligence 1416. 826-838.

Dijsktra J, Harry JP, and Bauke U, 2001, Virtual reality-based simulation of user behavior within the build environment to support the early stages of building design. In M. Schreckenberg and S.D. Sharma (ed.): Pedestrian and Evacuation Dynamics. Springer-Verlag, Berlin. 173-181.

Frank AU, Bittner S, Raubal M, 2001, Spatial and cognitive simulation with multi-agent systems, in D. Montello (edt.), *Spatial information Theory: Foundations for Geographic Information Science*, Springer Verlag, LNCS 2205,124-139.

Koch A, 2001, Linking Multi-Agent Systems and GIS- Modeling and simulating spatial interactions-. Department of Geography RWTH Aachen. *Angewandte Geographische Informationsverarbeitung XII*, Beiträge zum AGIT-Symposium Salzburg, Hrsg.: Strobl/Blaschke/Griesebner, Heidelberg, . 252-262, 2001.

Mandl P, 2000, Geo-Simulation- Experimentieren und Problemlösen mit GIS-Modellen. In Angewandte Geographische Informationsverarbeitung XII, Hrsg.:Strobl/Blaschke/Griesebner, Wichmann Heidelberg, 345-356.

Moulin B, Chaker W, Perron J, Pelletier P, Hogan J, 2003, MAGS Project: Multi-agent geosimulation and crowd simulation. In the proceedings of the COSIT'03 Conference, Ittingen (Switzerland), Kuhn, Worboys and Timpf (edts.), *Spatial Information Theory*, Springer Verlag LNCS 2825,. 151-168.

Perron J, and Moulin B, 2004, Un modèle de mémoire dans un système multi-agent de géo-simulation. *Revue d'Intelligence Artificielle*, vol 18 – n.5-6, 647-678. Hermes.

Raubal M, 2001, Agent-Based Simulation of human wayfinding. A perceptual model for unfamiliar building. PhD thesis. Vienna University of Technology. Faculty of Sciences and Informatics. 2001.

Torrens P, Nara A, 2007, Modeling gentrification dynamics: A hybrid approach. *Computers, Environment and Urban Systems* (in press).