Agent-Based System for Modeling User Behavior in Shopping Malls

MallSim

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Abstract. *Agent-based systems are being used as decision support systems for solving architectural design problems. Usually in design phase, user behavior is ignored by the designers. Therefore, after the construction, the users face difficulties in emergency situations and in daily usage. As a result, buildings become insufficient to respond to users' needs and design goals of the building itself. Before construction, ability of testing the interactions between the building and its users is particularly important to solve the problems in early phases of the design. Hence, to design a building that functions better in certain situations and time loss decreases in the design process. For these reasons, the aim of this study is to develop a model to simulate users in shopping malls.*
Keywords: *User behavior; decision support systems; agent-based systems; simulation; shopping malls.*

Introduction

According to most of the people, computers cannot really be creative; it is the computer programmer's creativity. Many people think computers' creativity is related to its programmer's creativity, because the computer is not conscious, it has no desires or values, so it cannot judge or appreciate (Boden, 2004). This approach can be true in one way, but the important thing is questioning where creativity is, instead of what it is. People interpret the information gathered from their environment. If this information is valuable to the community, it will be added to the culture. Actually, nor information neither the culture can cause creativity by itself. The interaction between these elements can cause creativity (Saunders and Gero, 2001). Computers can help people with their failures and their successes to make them think more clearly about the problems. This situation leads us to artificial creativity and artificial intelligence, which are the important aspects of today's design world. Today, to design virtual worlds and virtual people in

these worlds, and to create simulations is an emergent and a vital approach for architecture.

Simulation is a method used since a very long time to express and evaluate ideas. Perspective drawings, 3D physical models and 3D computer models are used for generating the simulation of designs from the conceptual phase to the construction phase. The advent of powerful computer graphics software has provided new technologies for producing the visual representations of designs. In these days, more realistic and effective visual simulations can be generated. Today's simulation systems are generally about user behaviors such as pedestrian flows or evacuation simulations. These simulations are developed to test human behaviors in general circumstances or in disasters inside the buildings. They are used for evacuation management and panic situation analysis, also for the behavior of pedestrians in usual conditions. Technological improvements of today let designers to use complex models for analyzing their designs. Studies about artificial intelligence provide new opportunities for many areas. In architectural and urban design, the agent-based simulations are being used to analyze user behaviors in various disaster circumstances, and to test the building itself for its resistance to cover the necessities in these situations. Some agents can determine certain goals and achieve them. Shopping is one of the examples of these situations. Some agent models are generated from fluid dynamics, particle systems or self-organization theories (Yan and Kalay, 2006). These models examine the interactions between the pedestrians and the environment, and their basic rule is to walk without collision by using the shortest path.

In this paper, the foundations of a conceptual model and the first version of a computer simulation would be explained. This study is based on studying real human users' behavior and achieving their movement patterns to generate a simulation. First of all, perception and its correlation with architecture will be discussed, and then the agent-based model will be thoroughly explained.

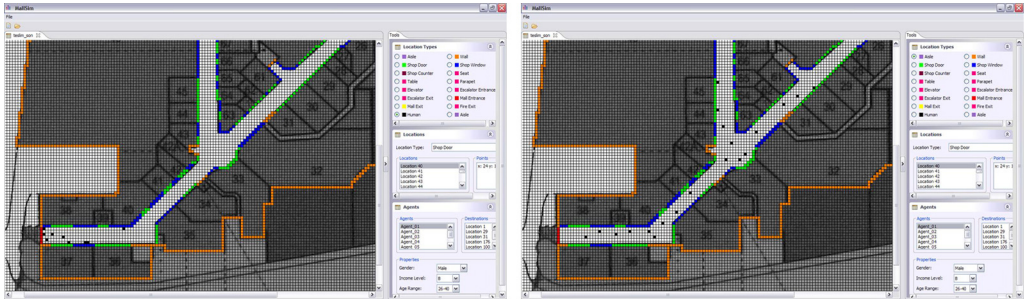
The perception and architecture

Computer mediated architectural design has more possibilities than before, because of the developments in information, communication and knowledge technologies. Architecture has close connections between the concepts of physical and virtual spaces. A virtual space has different elements from a physical space but both physical and virtual spaces have their own perception concept. Throughout the architectural history, many researchers have different studies about components of perception in design, especially in architecture. However, to form the concept of perception - particularly spatial perception - the definition of perception will be described, and then the elements of physical and virtual spaces will be analyzed.

Perception is the process of obtaining information from and about one's surroundings (Lang, 1987). Lang stated that perception occurred from reception of sensory experience and mental processes. The sensory experience is based on our senses; on the other hand, mental process is based on knowledge. The sensory experience is a process we interpreted with the information and the data gathered from surroundings; whereas, the mental process is the process that is obtained with our senses after the sensory experience. The mental process conceptualized the information from our surroundings. It is the process that we created in our minds. The sensory experience is occurred when an individual is being in a place at the very first time or been in this place for a short period of time. The sensory experience contains elements such as physiological data and the stimuli relating to spatial components. However, the mental process is based on the individual's memory about the place. At this point, prior experiences about this place become significant. At first the sensory perception occurs, and then the mental perception occurs depending on the duration of being in this place.

In his book 'The Image of the City', Lynch describes the physical and perceptible elements of

Figure 1
MallSim – screenshots



a city image as paths, edges, districts, nodes and landmarks (Lynch, 1960). These elements also can be considered as the elements of perception. The ability of remembering and learning at agents is based on the concept of human perception. Agents can store the information about the places where they have been before and the itineraries in their constructive memories; with their sensors they can perceive the environment. Agents with human visual angle (~170°) become closer to real human users. A wall or a crowd can be an obstacle for the agents; these obstacles will narrow the visual field and agents will become more realistic. In this study, the concept of perception at agents is based on Yan and Kalay's study (2006) and explained in detail in the previous study (Cenani and Cagdas, 2007).

The agent-based model

The computer model developed for this research, MallSim, is an agent-based system to simulate user movements in shopping malls (figure 1). The implementation has benefited from the information of object-oriented modeling and Unified Modeling Language (UML). People define their environments by objects. Therefore, it is wise to think alike when developing a computer model. Some of the objects from a system can have similar properties and these objects should be classified according to their common properties. In this study, classes of objects with similar behavior and information, and the relationships between these classes are formed. The relationships between the classes are designed as associations. These classes are considered as conceptual diagrams, not as implementation diagrams (figure 2). Association relationships between the main classes are studied but inheritance relationships are not within the scope of this study. A use case model is developed to define the actors and the use cases. While developing the model, at first, rules and restrictions about agents are defined. Rules are based on various criteria such as gender, income level or age range of users, etc. Then actors are determined, classes and relationships between the classes are built, and finally use cases of actors are arranged. The operations of agents are recorded on a database. Information about the grid cells, the location types and the properties of agents are being kept in this database.

Actors of the system are;

- Users with shopping lists,
- Random users without shopping lists,
- MallSim users.

Target groups of this study are architects and special design groups for interior designs of shopping malls. The aim is to use the model for the conceptual phase of the design, before the application phase; in other words before completing the entire design decisions. Using the model on this gap will help the designers to see the problems and to modify the design according to the results.

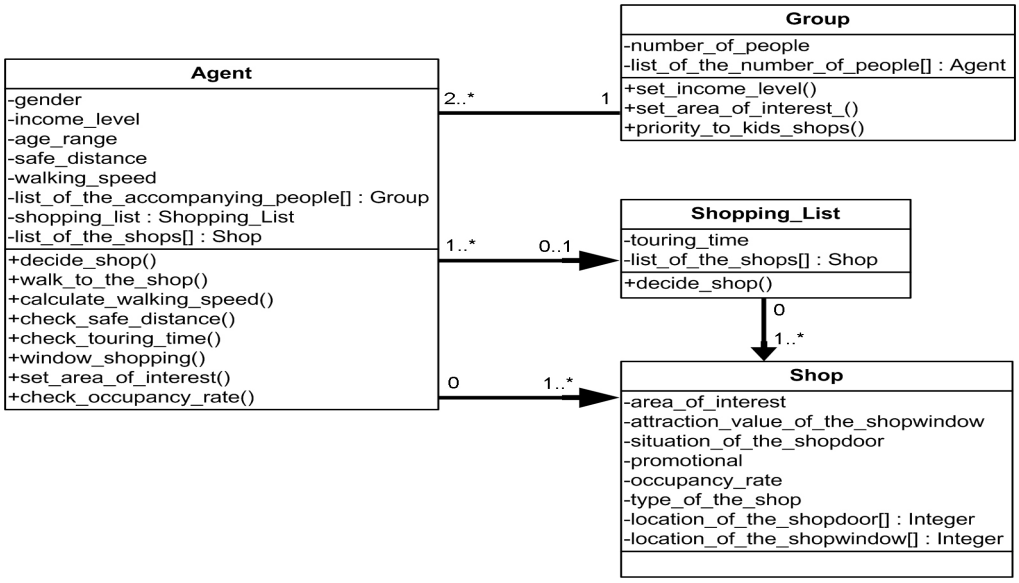


Figure 2
Relationship diagram of the classes

Today, because most of the shopping malls are built without such preliminary studies, users encounter different problems everyday. Some of the shops cannot reach an optimum user rate because of their poor location or some parts of the malls cannot respond to high user rate. This model will help designers to design more efficient interior organizations and it can be implemented for all public spaces, particularly for traffic buildings like airports, train stations, public transport or cultural centers (cinemas, theatres, museums). In this study, exposing the dynamics of spatial relationships of a building with its users can help architectural design students and architects, to observe and to solve the design problems before the construction of shopping malls. This research can help designers to think about the users of the buildings and include users' needs in the design phase.

The rules

The rules determined for the agents:

- An agent represents a user in the shopping mall.
- Agents considered as constant customers of the shopping mall, therefore they know the locations of each shop.
- Plan of the shopping mall is divided into cells. Each cell can be available or occupied. Agents can walk around in available cells. Occupied cells are assigned by program users as specialized utilization areas (location types).
- Agents can be female, male or child.
- Some of the agents have shopping lists that are designated by computer program users.
- Agents with itineraries walk around according to their area of interest (gender, income level and age range) and shopping lists.
- Each agent covers a cell and they can walk towards five directions as north, west, east, north-

east and north-west.

- Number of agents determined by computer program users.
- Customers are divided into six groups based on prices of the products, customers' income levels and the distribution of the expense (customer grouping system studies). According to this grouping method; these classes are A, B, C1, C2, D and E. Top income group and the shops aimed for this group are defined as A-class, and the lowest income group and the shops aimed for this group are defined as E-class.
- Age ranges of the users are divided into six groups. These are '0-6', '7-15', '16-24', '25-40', '41-60', '61 and over'.
- Age range also determines the speed of the agents. Accordingly, the groups of '7-15' and '16-24' are fast, the group of '25-40' is standard, the groups of '41-60' and '61 and over' are slow walkers.
- Agents maintain safe distance from objects (walls, doors, shop windows, etc) and other people to avoid collision (Cenani and Cagdas, 2007).
- If a shop is overcrowded (occupancy of 90% and more), the agent heads towards to the next target.

The agents and their behavior

The social character of the agents and their behavior are supported by observations of real human users in shopping malls, personal experiences and interviews. The observations are both occurred in Istanbul, Turkey and Rotterdam, The Netherlands. Finally, Alexandrium Shopping Mall from Rotterdam is used as a case study for the preliminary computer program (Cenani and Cagdas, 2007). Simple behavioral rules for agents are implemented, for instance walking towards a direction or obstacle avoidance. According to this simulation, the origin and the destination point (where users enter and exit the system) must be defined. These are the doors, elevators, stairs, escalators and the boundaries of the modeled area. The behavior of each agent can be modeled as a series of specific choice; such as the choice of the destination, the choice of the itinerary, the choice of a direction, or the choice of where to put the next step (Bierlaire et al, 2003). There are some critical decisions should be made when creating a simulation such as destination choice, route choice, speed and collision avoidance, and crowd effects. Some users may not have a destination (random agents). In shopping areas, the destination may change rapidly depending on the environment or on the attractors. The main rule is to choose a destination based on the activities agent wants to perform. The most important operation for an agent is choosing the appropriate shop in its visual field. Appropriateness criteria are gender, income level, age range, promotional information and being at close range. One of the studies regarding route choice is Penn and Turner's study. They implemented a computer model includes several agents, and each agent takes a decision about its destination and chooses the route every three steps. This decision process based on their visual field and the direction is chosen randomly inside their visual field (Penn and Turner, 2002). When the environment is crowded and contains obstacles, the direction and the speed of the users can be significantly affected. According to Blue and Adler's study (2002) walking speeds observed in the real world can be listed as follows:

- Fast walkers: maximum speed of 4 cells per time step (about 1,8 m. per time step),
- Standard walkers: maximum of 3 cells per time step (1,3 m. per time step),
- Slow walkers: maximum of 2 cells per time step (0,85 m. per time step).

In their experiments, they use a population composed of 5% of fast, 90% of standard and 5% of slow walkers. As mentioned before, in this study, age range also determines the speed of the agents.

When an agent starts to walk inside the shopping mall according to its visual field, it should maintain a safe distance from the obstacles. Agents with vision behave like real human users, because a crowd can block the way, cause agent to change the itinerary or

determine a new target. If the agent can pass by the crowd, it can continue to walk to its target destination. Sometimes people want to avoid crowd places or attracted to the crowds. These desires indicate human behaviors. Usually customers without shopping lists and female customers do window-shopping. For this reason, in the simulation female agents and random agents do window-shopping. Deciding a shop depends on agent's area of interest, which is related to gender, income level and age range.

Attractors are places with specific meaning for users, like shop windows or special areas (exhibitions, musical events, sales, promotional activities, etc). Attraction value of a shop is decided as a number between 1 and 5. If other decision factors are provided, agents would choose the shops with higher attraction values. Shops with promotional activities or sales have priorities than regular shops. Another significant factor deciding a shop is the shop door. The doors can be whether open or closed, but some shops do not have doors (shops with shutters). If a door is closed, less people prefer to come inside. The most preferred shops are the ones without doors. Additionally, according to the customer grouping system studies, the closed door shops are generally chosen by A-class income levels. When there are no doors, then all income groups can choose that kind of shops, but generally classes except A-class prefer these shops. In this simulation, there are also groups of agents that act together (friends, relatives or coworkers). A 'group' can consist of at least two agents. Individuals in a group should be in the same income level. If there is a child in this group, the child and his needs become a priority.

Experience and learning

Experiments of Sosa and Gero indicate that populations with imitative behavior are able to adapt more rapidly to changes, but further experiments show that high levels of imitative behavior may block group adaptation (Sosa and Gero, 2002). If individuals of a population have the similar skill to learn and imitate, the action of an individual is formed by four components that interact with each other. These four components are: the internal state of an individual, the state of adjacent neighbours, the environment state, and the interaction channels. Hence, two individuals with similar skills can perform different behaviors. In terms of the ability of learning at agents, learning improves their future behaviors. Learning occurs as a result of the interaction with the world and observing the decision processes. There are various studies that Zeng and Sycara carried out, about agents with learning abilities and positive and negative impacts of this situation on the agent itself, neighbour agents and the social system (Zeng and Sycara, 1998; 1997).

If an individual visits the same place several times, past experiences may help to remember the locations and important details; in this manner his next visit will become less time-consuming. Constant customers of a shopping mall will learn the locations of the shops in time and will not stop by at unscheduled shops in order to complete their existing shopping lists. By remembering past experiences, the behavioral differences between new customers and constant customers can be examined. For the time being, the constructive memory system and the learning ability are vital features in designs of agent-based systems. The prior knowledge of the agent, the memory of past experiences from the interaction between other agents and the world support the constructive memory system and long-term learning ability to improve today's agent systems. In designing a behavioral simulation of agents, learning from experience as real human users is a crucial component of a successful model.

Conclusion

In general, the agent-based systems are being used as decision or design support systems to solve the design problems and the simulations developed with agents are used for evacuation management and panic condition analysis. The agent-based model developed in this research aims to analyze the

relationships of users and spatial configurations using agent-based simulation systems in a virtual environment with agents that represent users of a shopping mall. The impacts of variables like socio-economical structure, gender, age range and the number of the users on movement patterns are studied. In the simulation, the itineraries of the agents can be observed. In order to achieve the goals of this study, the social character of the agents and their behavior are supported by observations of real human users in shopping malls, personal experiences and interviews. This research can be used for all kinds of public spaces such as airports, train stations, cinemas, theatres or museums. In this paper, the foundations of a conceptual model and the first version of a computer simulation are explained. In the near future, with the help of more detailed behavioral simulation and the data gathered from the improved model, we will get more realistic results.

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