Agent-Based Modeling of User Movements: A Case Study in a Museum Building

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ABSTRACT: This study aims to analyze relationships of users and spatial configurations using agent-based simulation systems under certain circumstances in a virtual environment with agents that represent users of a museum building. Multi-agent simulation methods are used to study patterns of user movements. Today, it is feasible to simulate the movement patterns of human societies at catastrophes like fire and earthquake within the buildings. Exposing the dynamics of user-space relationships will help both architectural students and professionals in practice, to observe and solve design problems in design process of museums.

1. INTRODUCTION

Computational design has more possibilities than before, because of the developments in information, communication and knowledge technologies (ICKT). Artificial intelligence is a discipline that conducts studies on computer models which can think, perceive, move and use knowledge to solve problems like humans. Distributed artificial intelligence, meaning multi-agent systems, is an agent society which can use distributed information sources and works collaboratively to reach a solution, for the purpose of solving more complex problems. Every agent in this society is software that is autonomous, that perceives environment and reacts to its surroundings, and exploits different techniques of artificial intelligence. It is inevitable for the multi agent systems, which is a field of artificial intelligence and used for transferring human movements to the virtual environment, to be in the architectural design area in which human factor plays an important role.

In architectural design, pedestrian movement has a role of both directing and restricting designs. Both in city scale and building scale, agent simulations are being used for testing user behaviors and movements in various disaster circumstances, and testing the building itself for its resistance to cover the necessities in these situations. Ability of testing the interactions between users and building before construction is especially important for solving problems in early design phases.

In recent years, some computer models about traffic flows have been developed, but simulations of user flows in public spaces and buildings are also important for architecture. There are some important related studies such as UCL Depthmap [URL-1] and EVAS [URL-2], Repast [URL-3], PEDSIM [URL-4], curating an art exhibition with social force model studies (Saunders and Gero, 2004), *ecomorphic* art gallery model (Turner, 2002), an agent-based model for London shopping streets (Penn and Turner, 2003).

This paper proposes an agent based user movements model. The proposed model is applied on a selected museum building and the user movements in the building are observed. In the paper, first the definition of an agent and characteristics of agents are explained. The model is defined in details; the structure and its computer implementation is described. The outputs of the model are evaluated and discussed. Some suggestions are given for further research.

2. AGENTS AND THEIR CHARACTERISTICS

There are various definitions in different studies used for explaining the word “agent” (Brazier and Wijngaards, 2001; Janca and Gilbert, 1998; Jennings and Wooldridge, 1998; Nwana, 1996). Briefly, agents are computer systems situated in an environment which can act autonomously to achieve their goals. Every agent has an environment that consists of other agents and the physical world. Agents can experience the environment by their sensors and play an act with their effectors like living organisms.

According to Wooldridge and Jennings, agents are software based computer systems, which have the following important characteristics (Wooldridge and Jennings, 1995):

Autonomy: Agents operate without the direct intervention of humans or others, and have some kind of control over their actions and internal state (Castelfranchi, 1995);

Social ability: Agents interact with other agents and humans via some kind of agent-communication language (Genesereth and Ketchpel, 1994);

Reactivity: Agents perceive their environment, (which may be the physical world, a user via a graphical user interface, a collection of other agents, the Internet, or combination of all), and respond in a timely fashion to changes that occur in it;

Pro-activeness: Agents do not simply act in response to their environment; they are able to exhibit goal-directed behavior by taking the initiative.

Mobility: It is the ability of an agent to move around an electronic network (White, 1994);

Veracity: It is the assumption that an agent will not knowingly communicate false information (Galliers, 1988);

Benevolence: It is the assumption that agents do not have conflicting goals, and that every agent will therefore always try to do what is asked of it (Rosenschein and Genesereth, 1985);

Rationality: It is the assumption that an agent will act in order to achieve its goals, and will not act in such a way as to prevent its goals being achieved (Galliers, 1988).

According to these characteristics, the agents in this study are mobile, veracious, benevolent and rational.

3. THE AGENT-BASED MODEL

How the users perceive the objects in the museums depend on the space organization and the design of the building. The number of the users is increased or decreased related to the space organization and the quality of the exhibition style of the museum objects. The increase of the number of users might cause problems such as not spending enough time at each object or lack of comfort conditions. Therefore, only well organized museum buildings prevent the negative effect of increment in the number of the users. This model provides the simulations of the user movements belonging different user profiles.
The proposed agent-based simulation model is explained in details. Target groups of this study are architects and special design groups for interior designs of museum buildings. These specialized groups design the interior relationships and the positions of the objects in the museum.

The utilization area of the agent-based model is the conceptual phase of design, before the application phase but no later than completing the entire design decisions. Using the model on this gap will help the designers to see the problems and change the design according to the results from the model in the early design phase.

Istanbul Archeology Museum is selected as case study (Figure 1). Istanbul Archeology Museum consists of two buildings: The old building and the annex. In this research, the proposed model is applied to the first floor plan of the museum. First of all, some observations such as the most preferred itineraries of users, how and where they spend their time inside the museum are made about the building. Then, data gathered from these analyses are transferred to the computer model (Figure 2).

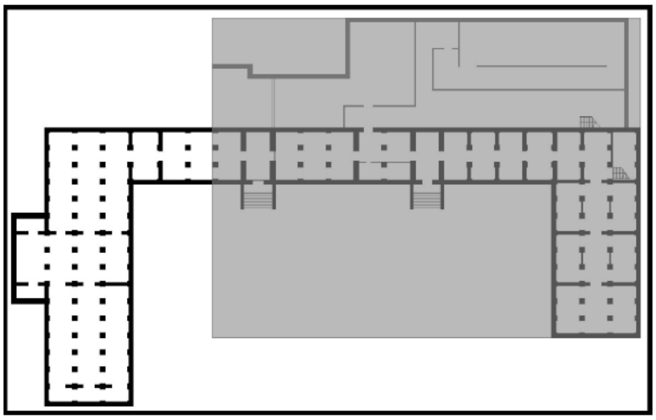

Figure 1. The first floor plan of Istanbul Archeology Museum.

4. STRUCTURE OF THE MODEL

The model has three main modules (Figure 3):

- Database Module;
- Agent Module;
- Main Program Module.

4.1. Database Module

This module consists of all the data by which user percepts the application and model functions. In database, there are files of plan matrix, matrix of fullness and the coordinates of the objects, also representation of the museum plan. Database module is used by both main program module and agent module.

The museum objects are defined in different scales. This is because some objects might be visited by a lot of users. In addition to this, different colors are used for the simulation of the museum objects. The difference represents the visiting priority and the importance of the objects. The order of priority from the most important to the less important is represented by colors and textures.

There is a variety in the area of vision of the objects. The area of vision could be either a rectangular area in front of the objects or the surrounding area around the objects. In the simulation model, if the agent enters the area of vision of any objects, it is assumed that the object is seen by the agent.

4.2. Main Program Module

Main program module has a role for creating of the agents in different types and different numbers and also the visualization of model. Agents can be created in different types by converting the defined parameters in the agent module. Main program module ensures the drawing of the museum plan and visualizing the agents as long as the model executes (Figure 4).

4.3. Agent Module

This is the module which ensures the defining of agents representing users and the movements of these agents. Agent module includes the parameters of movement, zone choosing, goal finding and the probabilities of paths in the museum.

Generally, agents are defined by four terms: Performance, Environment, Actuator and Sensor (PEAS). Performance represents the abilities of the agents such as way finding, self learning and finding the optimum solution. In the model, the agents complete a predefined route. Environment includes the environmental knowledge. The matrix file provides the information of the coordinate of the museum objects, the obstacles, the entrance and exits. Actuator includes the movement ability knowledge. The sensor includes the movement rules of the agents' movement. During the movement the agents are sensitive to the obstacles which are defined in the matrix file. When these four terms are explicitly defined, both agents and simulation model become more advanced.

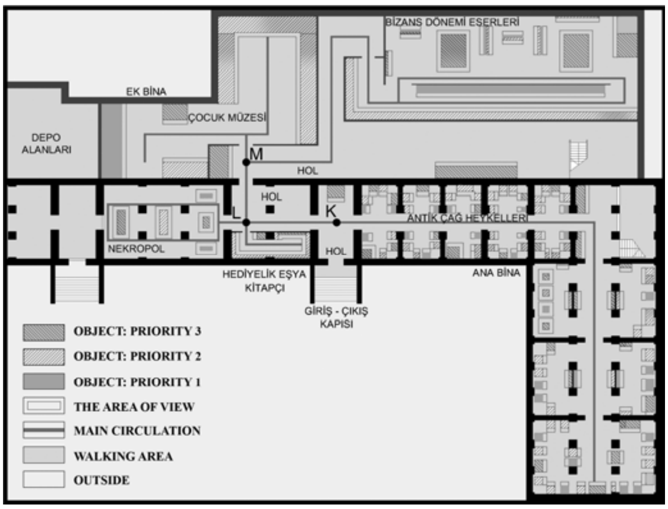

Figure 2. Representation of the museum plan.

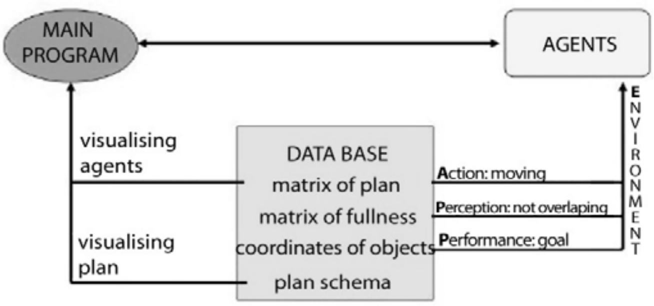

Figure 3. Structure of the model.

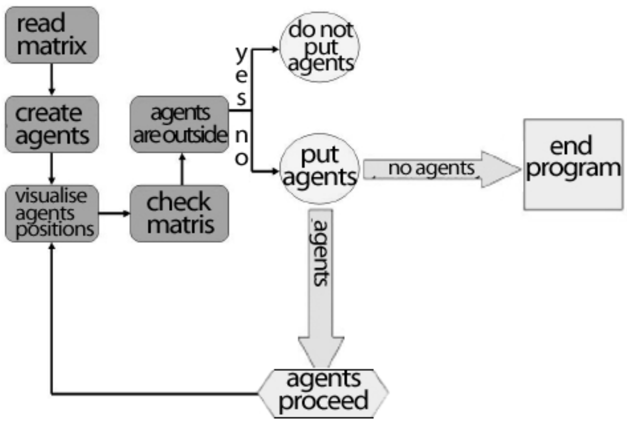

Figure 4. Flowchart of the main program module.

Developing agents

In this study, three resources are used for behavioral modeling of users. The first resource is environment and behavior studies gained by literature research. The second resource is the factors that affect behavior patterns and itineraries of users. These data are obtained from the case study on the museum building and related academic studies about similar subjects. The third resource is studies about AI. As a result of these studies, rules and limitations for agents are developed and an agent-based model is generated (Figure 5).

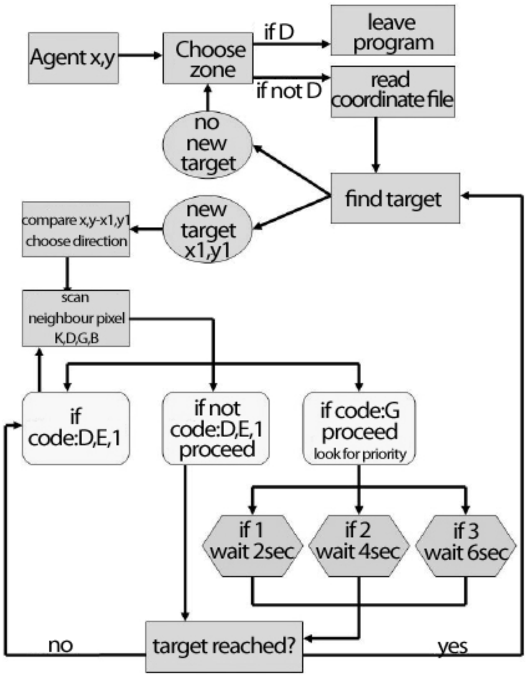

Figure 5. Flowchart of the agent module.

The start point of agents' itineraries is the entrance door of the museum building and the end point is the exit door. After an agent enters the building, it starts to walk towards its target (Figure 6). If it encounters an obstacle, it walks through sideway of the obstacle. When it reaches the target point, it starts touring around the object until it fills up the time. Then it walks to the next target. After finishing all of the targets, the agent leaves the system (Figure 7, 8, 9).

Perception of agents

Perception of agents is inspired from Yan and Kalay's study and has four parts; Knowing, finding, seeing and counting (Yan and Kalay, 2006).

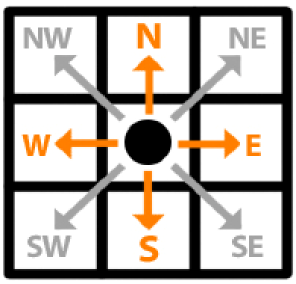

Figure 6. Movements of agents.

Knowing

Agents enter the museum, knowing the entrances and exits of the building and also locations of all division. Furthermore, they can perceive the environment so they can avoid collision by detouring.

Finding

User prefers to find the museum division which is related with the objects in it. They use shortcuts to reach one division to another one.

Seeing

People try to avoid collisions and obstacles. Also, they maintain a safe distance from objects and other people. These data are adapted to the agents based on Hall's study (Hall, 1966). On every step each agent controls its safe distance if there is a problem the agent makes necessary adjustments.

Counting

Counting defines the duration of a certain activity. Every agent (with or without a visiting list) has a preset touring time. Agents control their touring time and occupancy rate of divisions.

The constraints of the model

The matrix of the plan, which is prepared according to the plan of the Istanbul Archeology Museum, is limited by 600 x 800 units (pixel).

The real location and the coefficient of the priority of the museum objects are used without any change in the simulation model.

It is assumed that each agent visits the museum objects only one time.

The agents are assumed to use the shortest path during they change their area.

Each agent is assumed to move in the same speed.

The agents enter the museum in the same time period.

If an agent enters the area of the vision of an object, it is assumed that the agent saw the object.

The agents wait according to the priority ratio of the objects in the area of vision of the objects.

There is a same amount of the agent from different types.

Each agent moves individually in the museum.

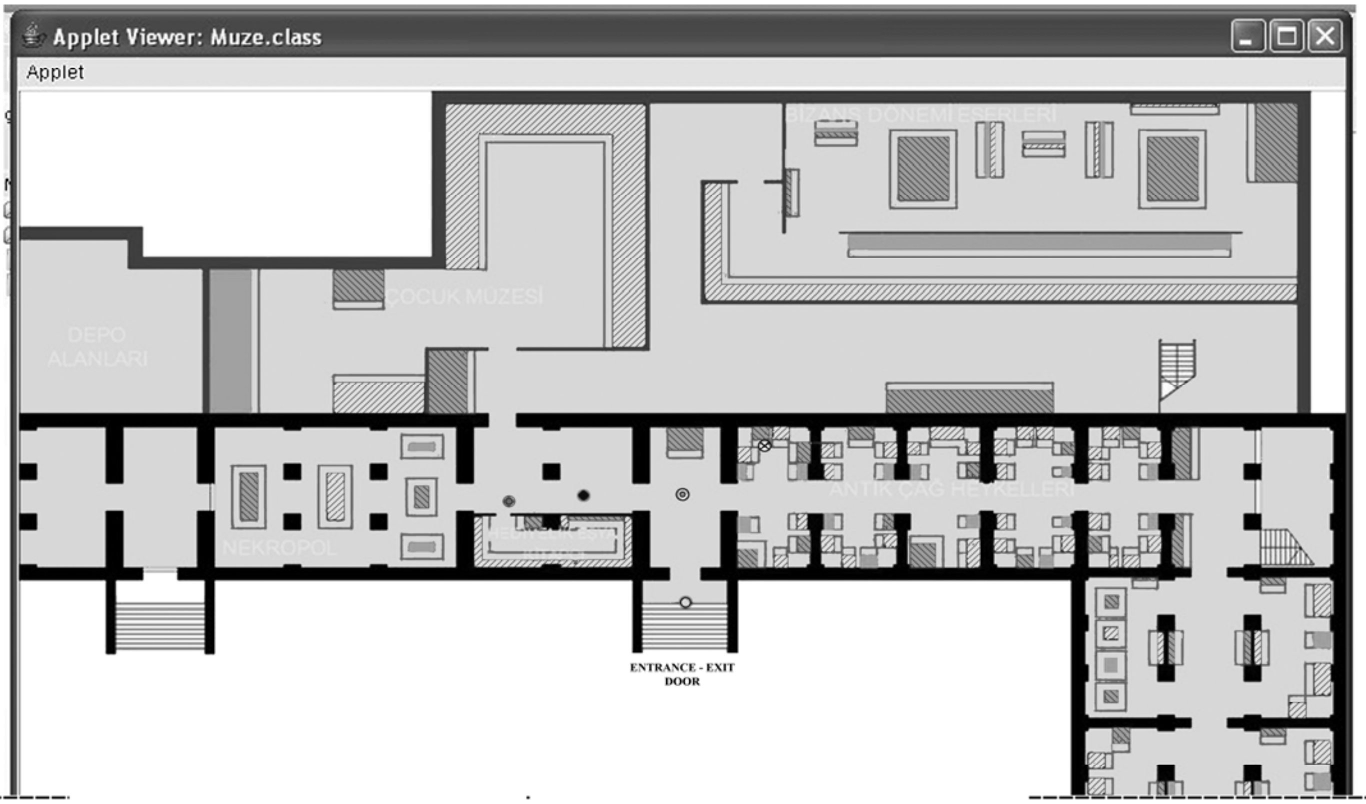

Figure 7. Agents entering the museum.

When the simulation model is executed, firstly the agents begin to appear in the front door of the museum and enter to the building by predefined speed and delay time. The speed of agents and the movement period are defined in the main module of the program code. The delay time is defined by one parameter therefore it is unique for all agents. Moreover the total number or agents, the types of agents, the order of the entrance are defined in the main module. The agents use the predefined paths according to their types and after they complete the route they will be deleted.

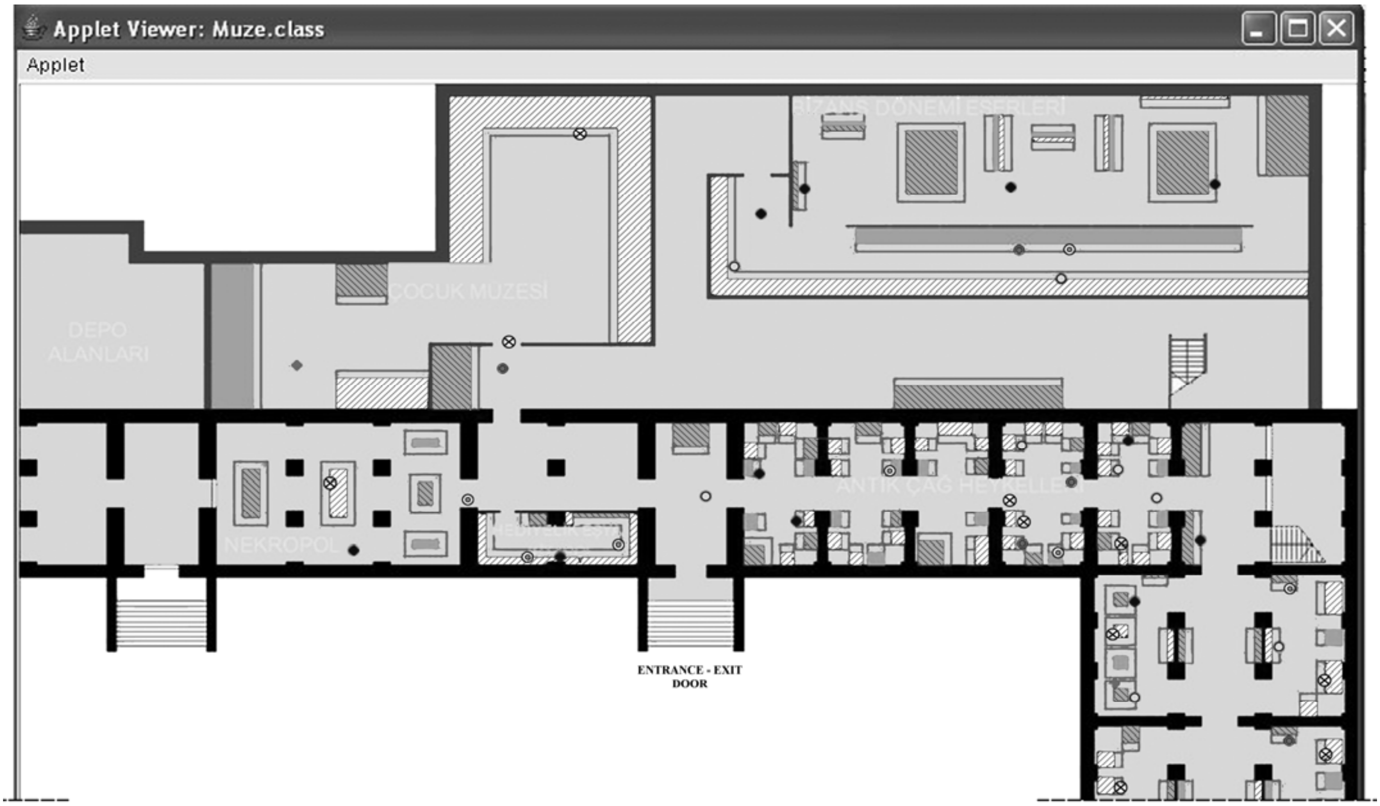

Figure 8. Agents in circulation.

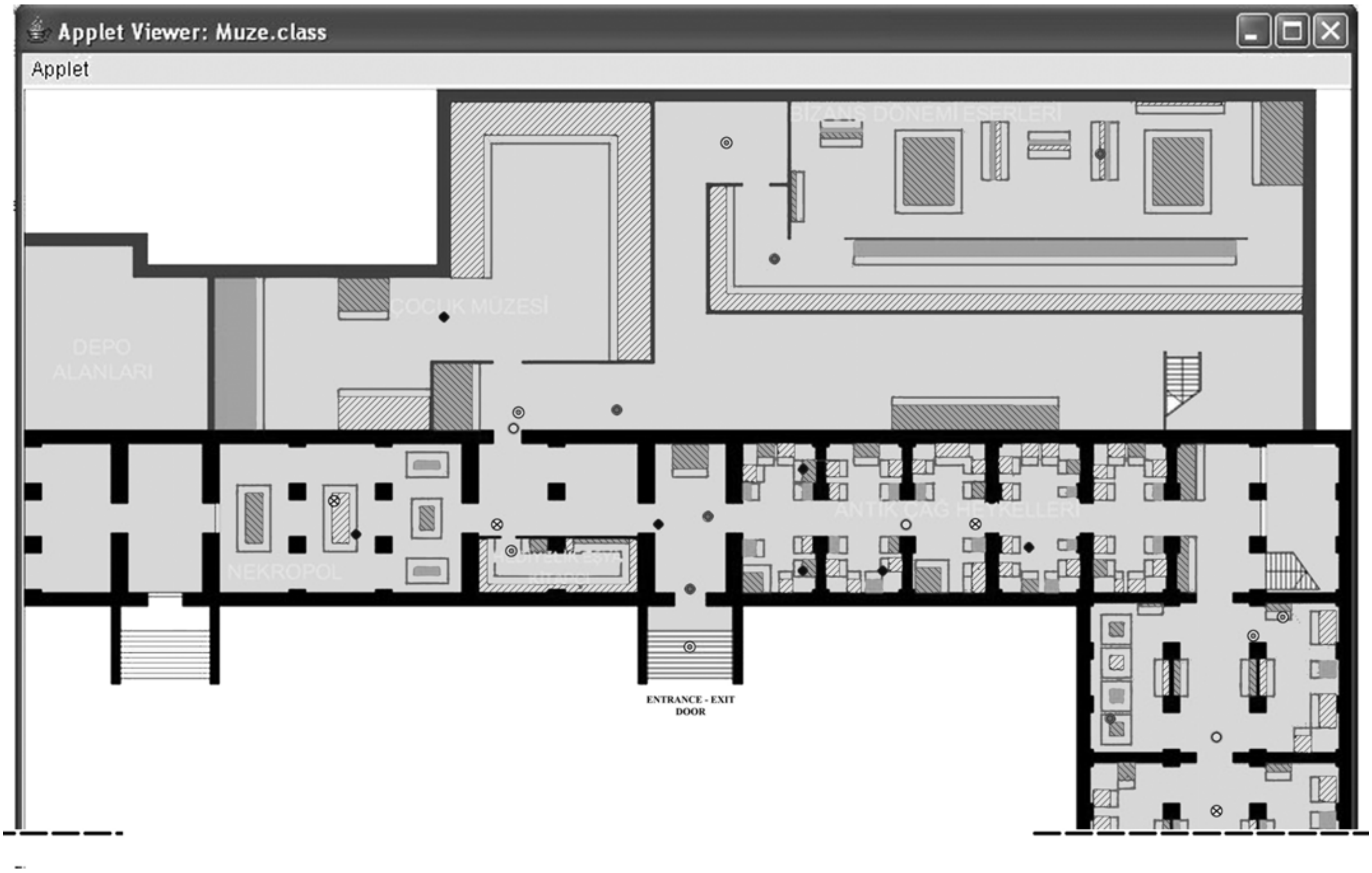

Figure 9. Agents leaving the museum.

5. CONCLUSION AND FUTURE WORK

The current version of the model implies the main goal; a designer will be able to see the user flow in a museum building to examine the areas with high/low user rate.

The sensitivity of the outcomes of the simulation model depends on the predefined parameters and initial assumptions. In this model we used different types agents with different behaviors. Each agent has different preference and its own path. In the further studies, self learning property and swarm behavior can be added to the agents. Moreover, the proposed for user movement simulation model for the Istanbul Archeology Museum is assumed to be a base model for the further extensive and apprehensive studies within the performance simulation in the earlier phases of design process.

In conclusion, high and low user density areas of museum buildings can be observed by this simulation model. In this way, poor locations (low user areas), rich locations (high user areas), problem areas which limit users' movements and do not cover high user rates can be determined and modifications can be made before the construction phase. Today, because most of the museum buildings are built without these kinds of preliminary studies, users encounter different problems on disaster situations and even on regular days. Some of the divisions of the museum cannot reach an optimum user rate because of their poor location or some parts of the buildings cannot respond to high user rate. This model will help designers to design more efficient interior organizations.

In the future, the model will have these features:

Using the system with multiple floor plans;

Analyzing different days and hours (user-time rate);

Architect friendly interface (to make real time changes on implementation);

Analyzing with space syntax methods of the re sults.

Such a study can be implemented for all public spaces, especially for traffic buildings like airports, train stations, public transport, cultural centers (cinemas, theatres, shopping malls). In this study, exposing the dynamics of user-space relationship will help both students in architectural design education and professionals in practice, to observe and solve the design problems before the construction of the museum buildings. Also, this research can help designers to think about the users of buildings and to incorporate users' needs in the design phase.

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