Steering Behavior Model of Visitor NPCs in Virtual Exhibition

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Abstract. We propose *steering behavior* model to simulate virtual characters (NPC) which walk around in virtual exhibition environment and see exhibits one by one just like humans do. Steering behavior model of such environment has its significance in that it would raise the reality level of virtually recreated exhibition space such as museums or city area with points of attraction. However, currently available steering behavior models and techniques are improper to generate such behavior patterns. Our model is autonomous and individual–centric; virtual characters autonomously determine what exhibit they are going to see, in what order, at which view point, and how long, based on their personal preferences. We also describe the implementation of our model and provide the graphical results of simulations.

1 Introduction

We propose *steering behavior* model to simulate that visitor *Non–Player Characters (NPCs)* walk around autonomously in a virtual exhibition hall and see exhibits one by one just like humans do. NPC is a computer controlled virtual character which is mainly used in online games to raise the entertainment level as well as the reality of the virtual space. Steering behavior means the ability of NPCs to navigate around their world in a life-like and improvisational manner.

The research about the steering behavior modeling of NPCs in virtual environment draws more and more interest recently because of its wide applications [7]. Autonomously behaving NPCs are able to improve the reality experiences of virtual space; imagine two virtual cities, one is crowded with human–like behaving NPCs, while the other is empty. Another important application of NPCs is to study the social behavior during building emergency evacuations [8].

Steering behavior model of visitor NPCs has its significance in that it would raise the reality level of virtually recreated exhibition space such as virtual museums, art galleries, and busy city area with a number of points of attraction. As the number of such spaces increases, its necessity also rises. However, currently available steering behavior models and techniques are improper to generate such visitor behavior patterns because they are mainly focusing on the modeling of flocking of a large number of people, most of them are mindlessly wandering city

Z. Pan et al. (Eds.): ICAT 2006, LNCS 4282, pp. 113–121, 2006.

area without purpose following a group leader, just like the notorious zombie characters. The most prominent deficiency of such models to simulate visitors is the lack of the capability to reflect individual properties.

We address this issue by proposing steering behavior model to simulate visitor NPCs in virtual exhibition. Our work presented in this paper makes the following contributions

- We propose individual–centric and autonomous steering behavior model, which is discussed in Section 2; NPCs with their own personal properties determine what exhibit they are going to see, in what order, at which view point, and how long, autonomously, based on their personal preferences.
- Our model is not computing intensive. It allows to increase the realism and, at the same time, satisfy the real time simulation constraints.
- We describe how to implement the proposed model in Section 3 and 4, thus able to provide insight how to incorporate the steering model into the systems.

2 Steering Behavior Model of Visitor NPCs

We propose steering behavior model of NPCs to simulate that visitor NPCs in a virtual exhibition hall appreciate exhibits one by one in order of the popularity of the exhibits and individual NPC's preference. The following assumptions are made about the visitor behaviors in exhibitions, e.g. museums and art galleries, to propose the NPC behavior model.

- Visitors have knowledge in advance about what exhibits are and where they are located.
- Visitors have their own preference which differs depending on exhibits.
- Visitors like viewing such exhibits first which they have preference to and which are closely located to them among many items.
- Visitors have tendency to appreciate exhibits at the location which is optimal for viewing in terms of angle and distance.
- Good locations for viewing exhibits are determined by both angle and distance from exhibits.
- Parameters determining how long visitors are going to stay for each exhibit are the visitors' preference to it, its own popularity, the fatigue level of visitors at the moment, and the optimality of visitors' view point.

We establish, based upon the aforementioned assumptions, three steering behavior models of visitor NPCs; the first model is to decide in which order visitors view exhibits, the second one is to determine at which view points visitors locate themselves, and the third one is how long visitors stop for viewing exhibits.

2.1 Visit Order Model

This model determines which one of exhibits a visitor NPC views first by judging from the visitor's preference to it, the exhibit's own popularity, and the distance from the visitor to the exhibit. Each visitor tags every exhibit with *order* value and views the exhibits in descending order of the order values. The order value O_{ve} assigned to an exhibit e by a visitor v is calculated as

$$O_{ve} = P_v * PP_e * (1/D_{ve}{}^2) \quad (1)$$

where P_v is the preference of visitor v to exhibit e, PP_e is the popularity of exhibit e, and D_{ve} is the distance from v to e. This order value is linearly proportional to visitor's preference and exhibit's own popularity, while exponentially inverse proportional to distance. Intuitively, the distance has a more critical influence to the order than personal preference and popularity of exhibits. The implication of this model can be understood if we retrospect to our own experiences in exhibitions; we never rush to the most interesting exhibit at the beginning, instead we move toward it gradually viewing other tempting exhibits close to us first.

2.2 View Point Selection Model

Selecting the view point of exhibits is affected by both the angle and the distance between exhibits and visitors. People like, for example, seeing exhibits from the front rather than either the reverse or the side, and from a decent distance at which a good look at exhibits can be obtained. However, since there are only a few locations which satisfy both angle and distance constraints, it is common that visitors find second best locations when the surroundings of exhibits are crowded with other visitors.

The view point selection model assigns every exhibit the angle limits by two vectors, the minimum distance, and the maximum distance, and finds a list of

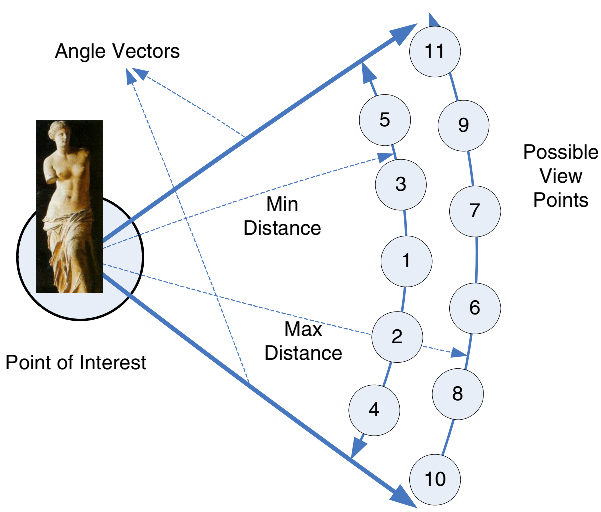


Fig. 1. View point selection model finds a list of possible view points

possible view locations of the exhibit. Figure 1 shows the procedure to calculate the candidate view locations. An exhibit is located at *point of interest*, the possible view points are represented as circles inside which numbers mean the optimality of the view locations; the lower number a location has, the more optimal view point it is. The best location is at the front and at the middle of two angle vectors, the second best locations are around the best location while maintaining the same distance from the point of interest, then next best locations are found at little bit far distance. The possible view points are located only between two angle vectors, and the nearer the location is to the point of interest, the more optimal it is. The algorithm to find the view points will be discussed in Section 3.

2.3 Appreciation Time Model

Parameters that determine the time during which visitors appreciate an exhibit are the popularity of the exhibit, visitors' preference, how optimal visitors' view point is, and the fatigue visitors feel. The appreciation time A_{ve} that a visitor v stay to see exhibit e is as

$$A_{ve} = P_v * PP_e * L_v * 1/logF_v \tag{2}$$

where P_v is the preference of visitor v to exhibit e, PP_e is the popularity of exhibit e, L_v is the optimum degree of the view point of visitor v, and the F_v is the fatigue level that visitor v feels at the moment. The more optimal the view point of visitor v is, the higher value L_v has. The implication of this model is that visitors tend to stay longer as long as exhibits are popular, interesting to them, they are less tired, and at the better view points. We let the fatigue degree have little influence on the results by using its logarithmical value, because we believe, based on a heuristic ground, that people can somehow forget how they are tired when they are dealing with interesting subject.

We proposed in this section three steering behavior models. The mathematical equations used in the models are composed based on heuristics and our experiences, thus how good they are can be judged by how natural the movement of visitor NPCs is. We discuss the implementation of these models in Section 3, and present the results simulating the virtual exhibition space crowded with visitor NPCs in Section 4.

3 Implementation of Visitor NPCs

This section discusses the implementation of the proposed models in Section 2 and describes necessary algorithms in detail. We use the object oriented approach to realize the models. Implemented classes represent visitor, exhibit, and (exhibition) space as shown in Figure 2. We implement visitor by two classes; `visitor` class contains individual information such as preference, fatigue level, etc, and `steering` class is responsible for controlling visitor movement, e.g. seek, turn, avoid collision. Detailed description of basic steering behaviors can be found in

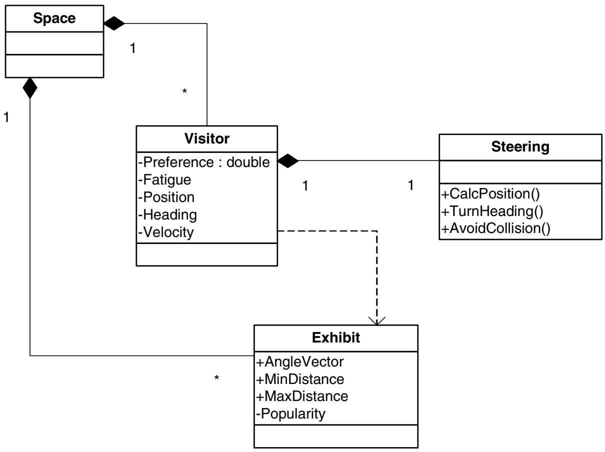


Fig. 2. UML class diagram of classes implementing the proposed models

[1]. We use exhibit class to store information about the geometric location of exhibits, popularity, and a list of view points. Space class provides visitor and exhibit with geometric space in which they reside and move around. This class also sets up walls limiting the exhibition area.

Steering class, in particular, implements a finite state machine which represents that visitor NPCs wander through exhibition hall and appreciate exhibits. The finite state machine consists of five states as shown in Figure 3. A visitor NPC is in `STATE_SELECT_EXHIBIT` at the beginning and selects an exhibit to see first according to the visit order model of Section 2. If no exhibit is left to visit, it changes its state to `STATE_EXIT` and ends its life cycle by exiting from the exhibition area. Otherwise, it changes to `STATE_MOVE_TO_EXHIBIT`. The visitor NPC, in this state moves toward a selected exhibit and avoids collision with obstacles and other visitors on the way. Once it reaches at a specified distance from the exhibit, its state is changed into `STATE_SETTLE_DOWN` and it tries to find a best view point to position itself to view the exhibit. If the best view point is already occupied by other visitors, it selects secondary best view point available based on the order how locations are optimal, moves toward it, and its state becomes `STATE_APPRECIATE` once it reaches the view point. It first decides in this state the how long it will stay at this exhibit by using the model Eq. 2 and stops until the appreciation time expires at which it goes into `STATE_SELECT_EXHIBIT` state to visit next interesting exhibit.

4 Simulation of Virtual NPCs

This section presents the graphical results of the simulation that applies the implementation of the proposed models to the steering behavior of virtual visitors wandering in an exhibition hall. Since the simulation focuses on the verification

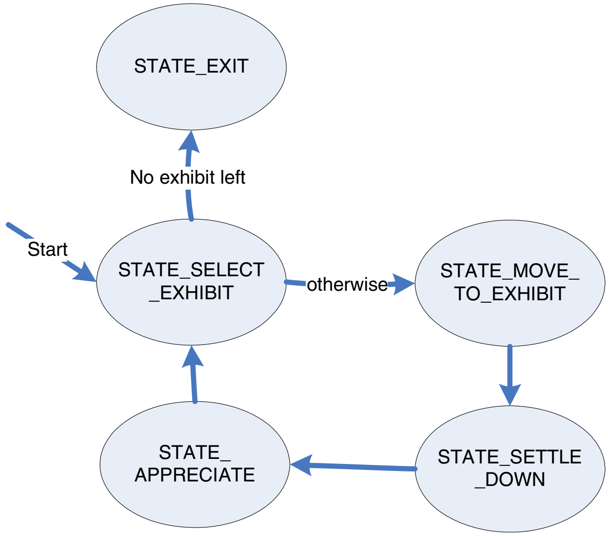


Fig. 3. Finite state machine controls visitor behavior

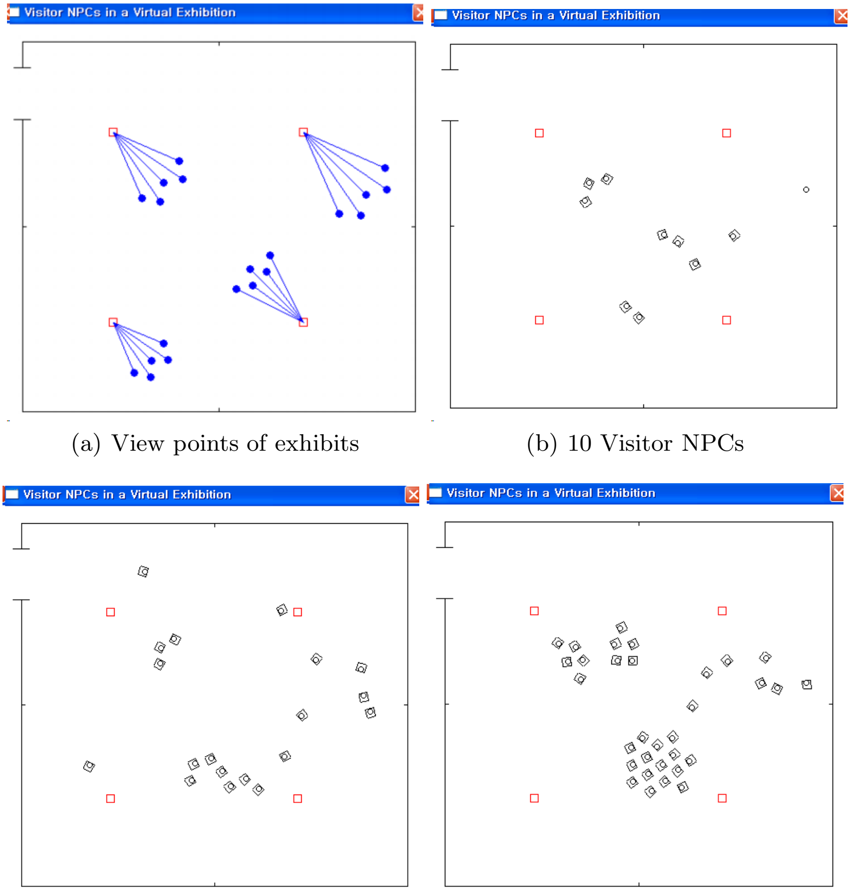
of the model implementation and aims at checking how similarly visitors walk around just as human visitors do, we configure the simulation environment with 2D graphic contents with very tersely simplified characters. Once we prove, however, that the models are effective to reproducing visitors' behavior, they can be easily employed with little modification to the systems equipped with more elaborate graphic capabilities.

The exhibition hall modeled in the simulation is the one that can be easily seen in museums or art galleries, and it is rendered in 2D graphics as shown in Figure 4. There are four exhibits rendered as squares, and each exhibit has its own popularity and parameters for possible view points as shown in Table 1. Figure 4(a) shows possible view points as filled circles that the exhibits can have. The exhibit at the top right corner has the longest view distance, while the one at the bottom left corner has the shortest.

Table 1. Properties of exhibits

Location	Popularity	View Angle	Optimal View Distance
Top/Left	30	60	90
Bottom/Left	10	60	70
Top/Right	50	60	110
Bottom/Right	60	60	80

Figure 4(b)(c)(d) show visitor NPCs as squares containing a circle, which is slightly biased to a side, representing the heading to which a visitor faces at



(a) View points of exhibits (b) 10 Visitor NPCs

(c) 20 Visitor NPCs (d) 30 Visitor NPCs

Fig. 4. Simulation of virtual visitors in exhibition

the moment. The visitors walk around the exhibition hall and stops for a while to see the exhibits as directed by the proposed models. We execute simulations several times each with different number of visitors: 10 in Figure 4(b), 20 in (c), and 30 in (d). As more visitors participate in the simulations, the exhibit at the top right corner, possessing the highest popularity, has the largest number of visitors around it, while the one at the bottom left corner, having the lowest popularity, has the least number of visitors.

5 Related Work

Since Reynolds [1] laid down a foundation for the steering behavior modeling, there have been a lot of research efforts in this field. Among them, our work builds upon the motivation endowed by the following bodies of research. Ashida [2] intended to improve individual features of NPCs, for example, its work added subconscious actions such as walking stopped when feel sad so that there may be a greater diversity of behaviors. In our work, we allow visitors to have their own preference about exhibits, thus able to reproduce the individual behavior pattern more realistically. Feurtey [3] collected a large number of crowd features, e.g. the relation between the flow of pedestrians, the density of the area and the speed, or the influence of the weather on the behavior. These data can help to find what is significant in the way a crowd behaves so as to be able to incorporate this into a model. Our model also try to integrate common features of visitors in exhibition by retrospecting to our own personal experiences, but research about this issue should be pursued more in our future work. Space syntax techniques [4] have a long tradition in urban studies. In the context of cities, space syntax aims at describing some areas in the sense of integration and segregation. A location is more integrated if all the other places can be reached from it after going through a small number of intermediate places. With such parameters, the movement pattern in a city can be understood and predicted: for example, the more a region has extensive visibility from the surrounding area, the busier it will be. Some space syntax analysis results even show correlations between predicted segregated areas and areas of high incidence of burglary. This space syntax technique motivated us to assign popularity to exhibits, thus able to realize that visitors gather around popular exhibits.

6 Conclusions

We proposed the steering behavior model of virtual visitors in exhibitions filled with many exhibits and showed through a simulation that the proposed model is able to reproduce the visitor behavior pattern. The model considers the popularity of exhibits, visitors' personal preferences, and other factors to decide in what order visitor NPCs view exhibits, at what location and how long they appreciate the exhibits. We performed the simulation in 2D simplified graphical environment; however, our models can be adopted in 3D environment with little modification. In our future work, we plan to extend the models to add the visitor group support since visitors rarely come to exhibitions alone.

Acknowledgement. This work was supported by the Brain Korea 21 Project in 2006, by grant No. RTI05-03-01 from the Regional Technology Innovation Program of the Ministry of Commerce, Industry and Energy and by grant of the Korea Science and Engineering Foundation through Multimedia Research Center at University of Incheon.

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