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SIMULATION OF HUMAN MOVEMENT AND BEHAVIOUR IN CROWDED SPACES USING GAMING SOFTWARE

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ABSTRACT

This paper discusses the development of human movement and behaviour simulation in crowded spaces as part of the AUNT-SUE (**A**ccessibility and **U**ser **N**eeds in **T**ransport for **S**ustainable **U**rban **E**nvironments) research project. The research starts with applying a video observational method to understand human movement and behaviour in crowded spaces in the real world. Six hours of video were recorded at a multi-mode transportation system and almost 19,000 individual human movements and behaviours were analyzed. Six types of behaviour were derived from the three major movements of free, opposite and same direction. Six factors affecting human movement and behaviour were recognized from the video analysis. The DarkBASIC Professional gaming software was used to simulate the human movement and behaviour in the virtual world. The six factors affecting human movement and behaviour were considered as the parameters for the virtual humans. Case studies considering multi-mode transportation systems, bottleneck and non-bottleneck situations were applied to validate the prototype software system.

Keywords: AUNT-SUE, Video observation, Simulation, Gaming software

1 INTRODUCTION

Human movement and behaviour in the real world is an important input to develop human movement and behaviour simulation in the virtual world. In this research, a video observational method was developed to understand human movement and behaviour in real world. Six hours of video were recorded at a multi-mode transportation systems and almost 19,000 individual human movements and behaviours were analyzed. The steps taken in the video observational method are shown in Figure 1 and a detail discussion is provided in (Mohamaddan and Case, 2012)

Figure 1: The video observational method

The video observational method starts with the focus subject which is the individual human in crowded spaces with three focus movements of free, opposite and same direction. Six different types of behaviour were derived from the focus movements (Moving Through, Move-Stop-Move, Avoiding, Passing Through, Queuing and Competitive Behaviour). Based on the analysis conducted, six different factors (Personal Objective, Visual Perception, Speed of Movement, Personal Space, Crowd Density and Avoidance Angle or Distance) were recognized as affecting human movement and behaviour in crowded spaces. The steps taken for the video observations were enhanced and applied to develop the software design model for the virtual world simulation as shown in Figure 2.

Similar to a real world subject, the individual humans were selected as the focus entity in the software design. The factors affecting human movement and behaviour in the real world were designed as the parameters for each entity. The parameters refer to the command or source code for each entity in the virtual world before the program is executed. Different parameter values were set up for the entities based on information from the literature or assumptions made from observing different movement scenarios in the real world. Three types of movement (free, same and opposite direction) were selected for the entities in the virtual world. The movement of the entities in the virtual world was analyzed and compared with the movement in the real world in order to understand the advantages and limitations of the software. Selected case studies were conducted to evaluate the software.

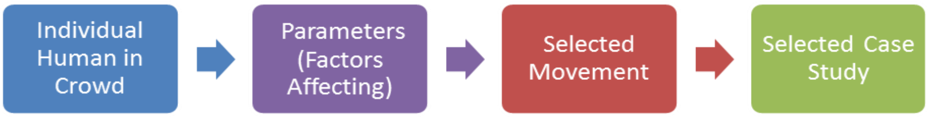

Figure 2: The software design model

This paper discuss the strategy developed to simulate the human movement and behaviour in the virtual world using the DarkBASIC Professional gaming software and is based on a video observational method. The discussion includes the design of parameters and entities in the virtual world. An overview of selected case studies, namely the multi-mode transportation system, bottleneck and non-bottleneck layout design is also presented.

2 DESIGN OF PARAMETERS

In this research, the parameters represent the factors affecting human movement and behaviour observed in the real world. This section discusses the command or source code applied for each parameter in the virtual world. Some modification had been made to represent the parameters in the virtual world due to the limitations of the software. The parameters play important roles in developing different types of simulation that employ different movement scenarios in the real world.

2.1 Personal Objective

Personal Objective refers to the goals that humans have during movement. In the virtual world the Personal Objective parameter was represented by the command *Position Object* and *AI Entity Go to Position*. The *Position Object* command refers to the initial position or starting point for each entity in the virtual world before performing any movement. The *AI Entity Go to Position* command refers to the selected location or end point for the entities (shown in Figure 3). The *Position Object* and *AI Entity Go to Position* command was applied to develop the selected movements (free, same and opposite direction). Figure 3 shows the example of Same Direction Movement of the entities in the virtual world where the Personal Objective parameter is represented by the red path.

2.2 Visual Perception

Visual Perception refers to the visual region that humans have during movement. In the virtual world the Virtual Perception parameter is represented by the view arc and the view range. The view arc is the angle at which the entities can see their surroundings. In the DarkBASIC the value of view arc ranges from 1 to 360 degrees and is represented by the *AI Set Entity View Arc* command. The view range is the distance where the entities can see from the current location and is represented by the *AI Set Entity View Range* command. The entities in the virtual world are able to see anything that appears within the view range and the view angle. Figure 3 shows the overview of the Visual Perception parameter that is represented by the coloured region in front of the entities.

2.3 Speed of Movement

Speed of Movement refers to the walking speed of humans during the movement. The Speed of Movement in the virtual world was represented by the *AI Set Entity Speed* command. This command sets the movement speed of the entity in DarkBASIC units per second (unit pixels). In DarkBASIC the units per second are dependent on the design of the entity. In this research, 5 pixels per second (DarkBASIC unit) was defined as equal to 1 cm per second in real world. An experiment was conducted previously (Cheong *et al*., 2011) to measure the size of DarkBASIC units in real world measurements based on the design of the entity.

2.4 Personal Space

Personal Space refers to the invisible surrounding or territory around humans. The Personal Space in virtual world was represented by the *AI Set Radius* command. The command sets the global radius that is used by all entities in the virtual world. The command controls how much space is allowed between the edge of any obstacle and the waypoints that define movement around the entities. Since the entities use the waypoints to navigate around the virtual world, the entities will attempt to maintain at least the radius distance from all obstacles. An overview of the Personal Space parameter is shown in Figure 3.

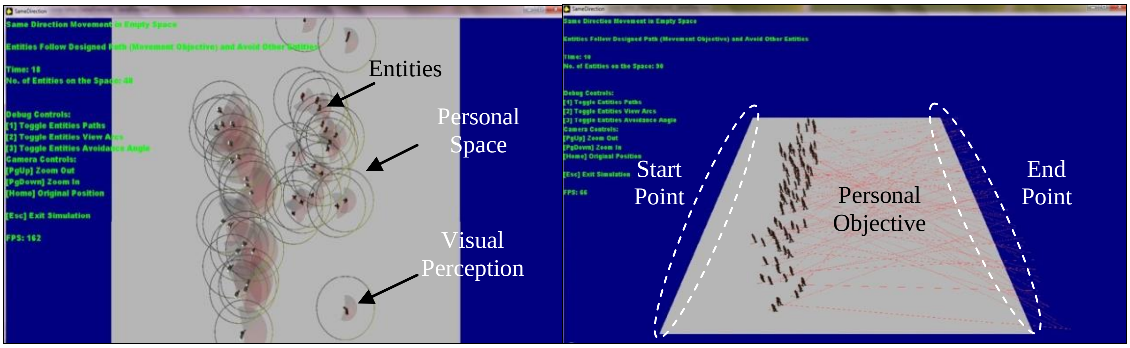

Figure 3: The personal objective, visual perception and personal space parameter

2.5 Crowd Density

Crowd Density is defined as the number of people per square meter for a standing and moving crowd. In the virtual world Crowd Density refers to the total number of entities per unit of floor area. The floor area for the simulation is designed accordingly due to the maximum number of 90 entities in order to ensure that a viable simulation can be conducted. The crowd density was designed with three scales namely low, medium and high crowds. Although the number of entities required for the simulation can be selected manually by the user, Table 1 below was applied as the guideline for the analysis.

Table 1: Type of crowd and the definition used for this research

Type of Crowd	Definition of the Crowd
Low Density	The movement of 30 entities within 600 unit pixels × 600 unit pixels (30 m × 30 m) area
Medium Density	The movement of 60 entities within 600 unit pixels × 600 unit pixels (30 m × 30 m) area
High Density	The movement of 90 entities within 600 unit pixels × 600 unit pixels (30 m × 30 m) area

2.6 Avoidance Angle or Distance

The Avoidance Angle or Distance refer to an action performed by humans to keep away from colliding with other objects or humans during the movement. In this research, the Avoidance Angle or Distance is totally based on the Dark AI effect from the movement as shown in Figure 4. The Avoidance Angle or Distance is represented by the green area in the picture. The Avoidance Angle or Distance is also affected by other parameters such as Visual Perception and Personal Space. When the floor area becomes more crowded (number of entities increased), the avoidance behaviour is observed to occur many times.

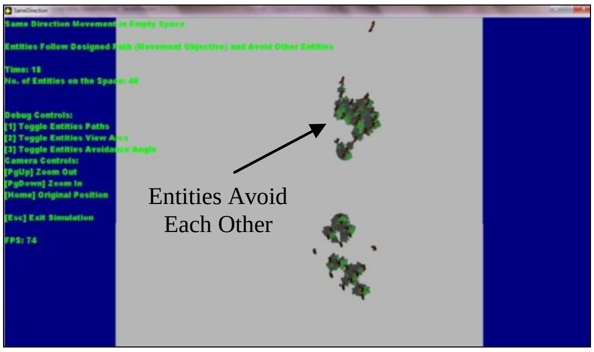

Figure 4: The avoidance angle or distance parameter

3 DESIGN OF ENTITIES

In the software design two subjects, the adult and the elderly person, were selected as the entities for virtual world simulation. Both entities was designed with the three dimensional appearance based on (Cheong *et al*., 2011) to provide more realism for the simulation. Figure 5 shows the example of an elderly entity in the virtual world.

Table 2: The adult and elderly entity source codes in virtual world

Adult Entity	Elderly Entity
AI Set Entity Speed I, 24	*AI Set Entity Speed I, 16*
AI Set Entity View Arc I, 160, 210	*AI Set Entity View Arc I, 140, 190*
AI Set Entity View Range I, 40	*AI Set Entity View Range I, 20*
Color Object I, RGB (0, 0, 255)	*Color Object I, RGB (255, 0, 0)*

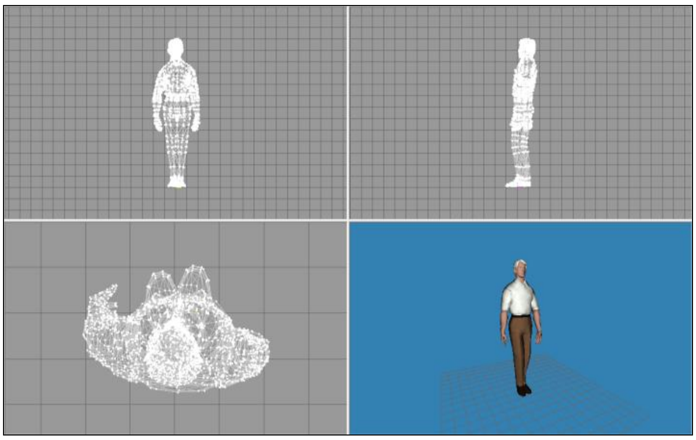

Figure 5: The elderly entity in 3D design

The source code for the adult and elderly entities in the virtual world is shown in Table 2. The values of the parameters were designed based on the literature (Sukhatme, 2001)(Teknomo, 2002) and assumptions made by the authors. The adult entity is set to be 24 unit pixels or 1.2 m/s speed of movement. The view arc is set to between 160 to 210 degrees with a view range of 40 unit pixels or 2 metres. The adult entity is identified by the blue colour. On the other hand, the elderly entity is set to have 16 unit pixels or 0.8 m/s speed of movement. The view arc is set to between 140 to 190 degrees with a view range of 20 unit pixels or 1 metre. Finally, the elderly entity is identified by the red colour.

4 THE CASE STUDIES IN THE VIRTUAL WORLD

The case study in the virtual world was focused on two types of design known as empty and building design. The empty design includes the simulation of movement by entities in free, same and opposite directions. The building design includes the simulation of a multi-mode transportation system, bottleneck and non-bottleneck designs. Each simulation was developed in a modular pattern where each simulation can be executed independently.

4.1 Empty Design

The empty design was used to simulate the movement of entities within the empty floor area as shown previously in Figure 3 (example of Same Direction Movement). The empty design simulation was conducted with two major objectives. Firstly, the empty design simulation is aimed to evaluate the parameters of the individual entities in the simulation. Different values of the parameters were selected to evaluate the parameters in order to understand how the parameters can affect the entities movement in the virtual world. The different parameter values can be used to represent different movement scenarios in the real world.

The second objective of the empty design simulation was to evaluate different sizes of crowd or crowd density. Although the number of entities can be selected manually in the range of 1 to 90 entities in the programming, the different size of crowd (low, medium and high density) is applied for the evaluation purposes. Table 2 shows the definition of low, medium and high density crowd. The results from the empty design are analyzed to understand human movement using gaming software and appropriate application were conducted to develop the software prototype.

4.2 Building Design

Building design simulation shows the movement of entities within three different types of building layout and is an example of an application developed from the understanding of entities movement in the empty design simulation. Three different types of building layout was selected namely the multi-mode transportation system, bottleneck and non-bottleneck layout design. The objective of the building design simulation was to determine suitable solutions for the design of crowded public spaces.

Figure 6: Multi-mode transportation system

The multi-mode transportation system was designed based on the Stesen Sentral Kuala Lumpur, the location for video observation analysis. Figure 6 shows the real world and virtual world layout design of the multi-mode transportation system that consists of different spaces or areas such as stalls, ticket machines, information centre, showcases and others. In the real world, the layout was designed to make the area more accessible and to be convenient for the users. However, the spaces might become obstacles for the users when the crowd density is increased. In this research, the layout of the transportation system is designed in the virtual world and applied to evaluate and predict the effect of different layout designs on the movement of entities in the crowd. Different layouts and obstacles were designed and the results compared.

Besides the design of multi-mode transportation systems, the building design simulation also focuses on the design of bottleneck and non-bottleneck layouts. The objective is to understand how the bottleneck and non-bottleneck layouts can affect the movement of entities in the crowd, especially during an evacuation process. Bottleneck design is defined as the phenomena where the design due to size of the door or pathway limits human movement. The bottleneck design can be found at many places in the building. Figure 7 shows an example of bottleneck and non-bottleneck layouts in the virtual world. The simulation shows the entities moving towards the end point which is the exit door that is marked with a red dot.

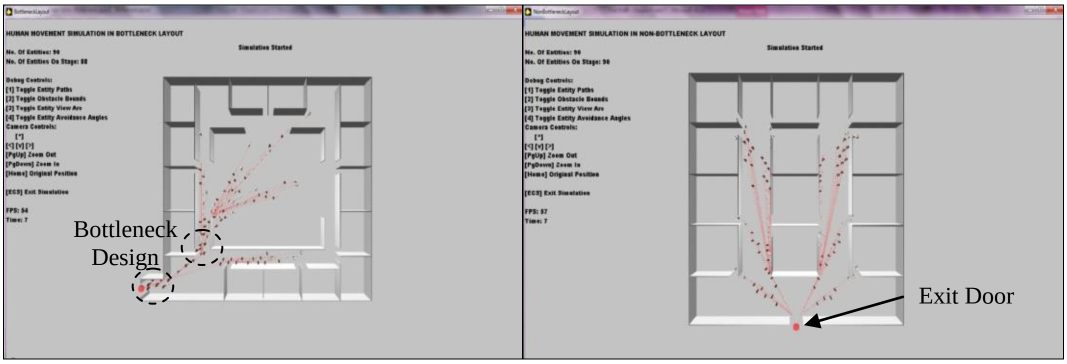

Figure 7: Bottleneck and non-bottleneck layout design

5 CONCLUSION

This paper has described the strategy developed to simulate human movement and behaviour in virtual world using the DarkBASIC Professional gaming software. The six factors affecting human movement and behaviour in the real world were applied as the parameters for each entity. Two subjects, an adult and an elderly person were selected as the entities for the virtual world simulation. The simulation was conducted firstly in an empty design in order to understand the advantages and limitations of the software. Applications using the building design included the multi-mode transportation system, bottleneck and non-bottleneck layouts were conducted to evaluate the software. For future work, analysis from the simulation will be carried out in order to further develop the software prototype.

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