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Emergency Evacuation Simulation Development Using Game Programming

W. L. Cheong, S. T. Syed Shazali, A. M. N. Abg Kamaruddin, S. Mohamaddan and K. Case

***Abstract*— This paper discuss about the development of emergency evacuation simulation using DarkBasic Professional. This simulation was developed to simulate the evacuation performance in the buildings. The building design is designed using 3D World Studio for compatible with DarkBasic Professional. The human entities in the simulation are created with artificial intelligence using Dark AI. There are four option in the simulation that can display to the user which are display entities walking path, obstacles bounds, view arcs, and avoidance angles. The human entities are able to find the shortest path to the destination point with the Dark AI. Although the shortest path is blocked by the obstacles, the human entities are able to find alternative path to the destination unless no other path. This simulation will compute the total evacuation time after all the human entities have evacuated.**

***Keywords*:** evacuation simulation, building design, artificial intelligence, obstacles bounds, avoidance angles

I. Introduction

Human walking behaviour modelling is an important topic in different area of studies. Architects are interested to find out the optimal criteria for space design by understanding how individuals move around buildings. Transport engineers need to integrate the transportation facilities with particular emphasis on safety issues for pedestrians. The evacuation scenario during emergency is specially emphasis to prevent injury or fatality. Human behaviour modelling consider the human as a device with a great number of internal mental states, each with its own particular control behaviour and interstate transition probabilities [1]. Awareness of environmental problems has increase and the need for physical fitness encourage the demand to analysis and enhance the design of pedestrian facilities and building [2].

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Human walking behaviour is different between types of people due to different factors. Factors that affect the walking speeds of pedestrians are the personal characteristics of pedestrians (age, gender, size, health, etc.), characteristics of the trip (walking purpose, route familiarity, luggage, trip length), properties of the infrastructure (type, grade, attractiveness of environment, shelter), and environmental characteristics (ambient, and weather conditions) [3]. The simulation development will emphasize on adult.

Numerous simulations on human walking behaviour have been done based on the data of the pedestrian characteristics. A model of crowd behaviour present by [4] to simulate the motion of a generic population in a specific environment with the application of a graphic called sociogram that visualizes population during the simulation and a simple visit to a museum were based on approach of the relationship between the autonomous virtual humans of a crowd and the emergent behaviour originated from it. Reference [5] have used crowd modelling in collaborative virtual environments which create a sense of group presence to provide a more realistic virtual world. The mechanisms should be simulated in order to implement truly virtual humans or actors from a structure linking perception, emotion, behaviour, and action has identified by [6]. Then emphasize the central concept of autonomy and introduce the concept of Levels of Autonomy and propose a new abstraction for specification of behaviours in complex virtual environment simulations involving human agents, groups of agents, and interactive objects capable in different levels of autonomy.

Three microscopic simulation projects to compares one way and two way pedestrian traffic to gain more understanding about the pedestrian characteristics, distinguish the behaviour of the system if the number of elderly pedestrian increase and proposes a policy of lane like segregation towards pedestrian crossing and inspects the performance of the crossing was developed by [2]. Simulation of the scaling behaviour of crowd flow outside a hall by using the lattice–gas model of pedestrian flow was developed by [7]. The simulation has shown the distinct dynamical patterns of crowd flow: arching, flattening, pitting, and making a hole and the dynamical phase transition from the choking flow to the decaying flow at a critical time.

Reference [8] has use a way to combining crowd behaviour simulating techniques with human behaviour simulating techniques where the combined human crowd behaviour model bridges the gap between crowd models that simulates very large groups with human models that simulates one individual. The model simulates medium sized groups of a few hundred members where the human reasoning affects the behaviour of the individuals and the whole crowd. The velocity fields were used by [9] to design the macroscopic crowd behaviour interactively in a 2D behaviour editor, and synthesized the corresponding real time 3D crowd animation. Reference [10] has presents a computational model AutoEscape, which can simulate the evacuation process of the people in the building designed with an extensible multi-level structure. This model with GIS-based environmental analysis can automatically generate the geometric representation and formulate the cognition of agents. The GIS-based technology used to simulate the crowd behaviours with autonomously acting individuals.

In this research, a simulation that simulates the evacuation of human from a building is developed. The simulation is developed by using DarkBasic Professional with additional extension of Dark AI. The human entities are defined as having artificial intelligence from Dark AI language which can find path, avoid collision and reach the destination automatically in most of the situation. The building design will be designed in the 3D World Studio. Human adult entities can be generated in the building and evacuate from the building to the destination point. Total evacuation time will be review when all the human entities have reach destination point.

II. Evacuation Simulation

The simulation of the human evacuate from a building will be developed by using DarkBasic Professional. DarkBasic Professional is the advanced games development package built on the BASIC language which used Microsoft DirectX9 technology. Additional extension used in the DarkBasic Professional is the Dark AI. It was A.I. (artificial intelligence) commands that would help with path finding, and adding intelligent behaviour in the simulation [11]. The simulation environment is designed based on the building design drawn in 3D World Studio.

A. Simulation Rules

A test in the simulation to find the suitable Dark AI speed and scale of dimension in simulation with real world dimension have been done using a simple walking simulation with one AI as shown in figure 1. The distances of walking path of the AI are 800 pixels. The data are collected as in table 1. A graph of time versus Dark AI speed has been plotted and as shown in figure 2 from the data in the table 1. From the simulation testing, scales of 5cm equals to 1 pixel have been used in the simulation. The scale acquired can be use to design building, 3D human and objects.

According to [12], the field of view of human is between 160° to 208°. Therefore the view arcs for the entities in the simulation are set between 160° to 208°. According to [13], the intimate space is the closest circle of space surrounding a person in personal space which is 46cm. The human entities in the simulation must not penetrate intimate space to avoid collision. Therefore the radius of AI is set to 9 unit pixels which represent their personal space with radius of 45cm. All the entities are moving individually to the destination.

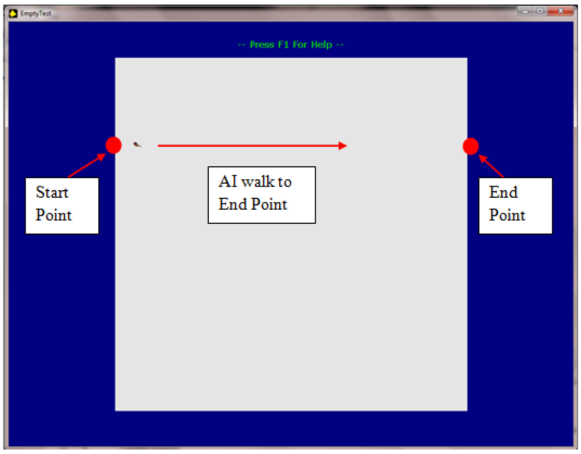

Figure 1. Simple walking simulation test.

Table 1. Time of travel 800 pixels with Dark AI speed.

Dark AI Speed(unit/s)	Travel Time(s)
2	399
4	199
6	132
8	99
10	79
12	66
14	56
16	49
18	44
20	39
22	36
24	33
26	30
28	28
30	26

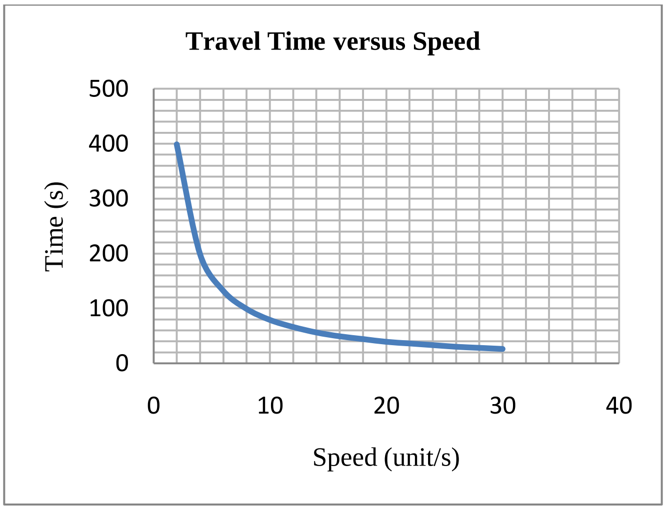

Figure 2. Time versus Dark AI speed.

B. Building Design

The human entities in the simulation will walk in the building designed layout to the destination point. The design of the building layout will be designed in 3D World Studio.

The building design is designed as one floor building with one exit or few exits. The building design is save as DirectX format to readable by DarkBasic Professional. Figure 3 shows an example of building design in 3D World Studio.

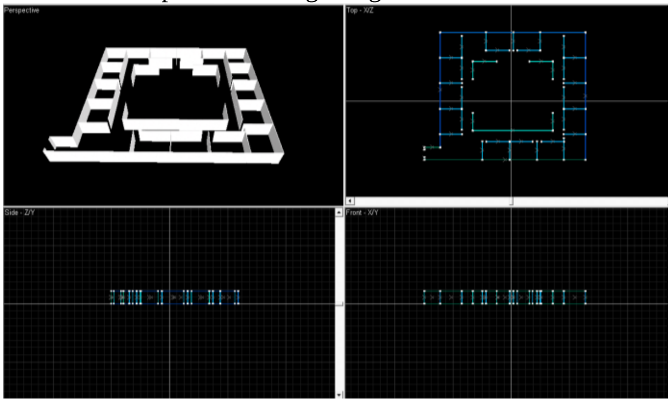

Figure 3. Example of building design.

C. *Simulation Flow Chart*

Figure 4 shows the simulation flow chart for the emergency evacuation simulation. First the simulation will load the building design. Then the user can put human AI entities or obstacles in the building. Next, user required to set the destination point. The AI entities will walk to the destination point when the simulation starts. Total evacuation time will be compute after all human entities evacuate and reach destination point.

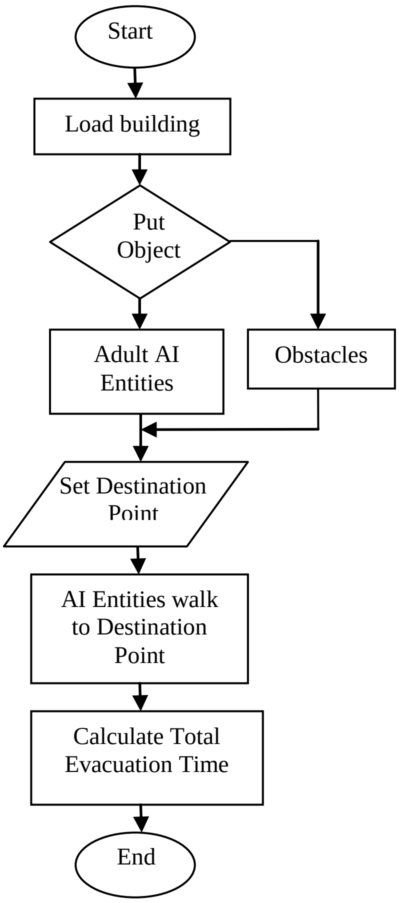

Figure 4. Flow chart of emergency evacuation simulation.

D. *Simulation Design*

The 3D human entities that used in the simulation were designed to animated and save as DirectX format so DarkBasic Professional could run the animated 3D human. Figure 5 shows the 3D adult human entities. In the simulation, user can put obstacles to block the human entities. The obstacles are box, warning cone, plant, table and chair. Figure 6 shows the 3D obstacles.

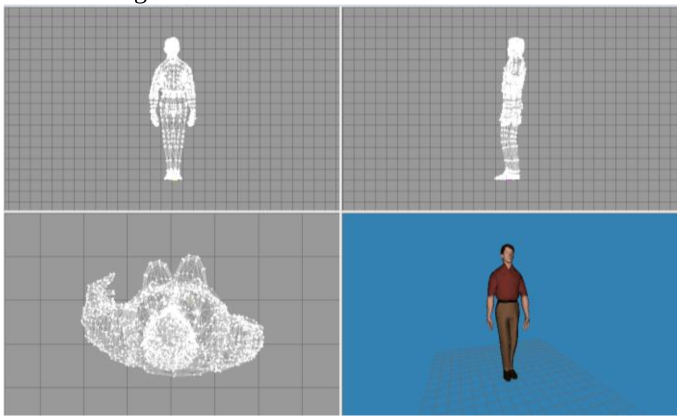

Figure 5. 3D adult human entities.

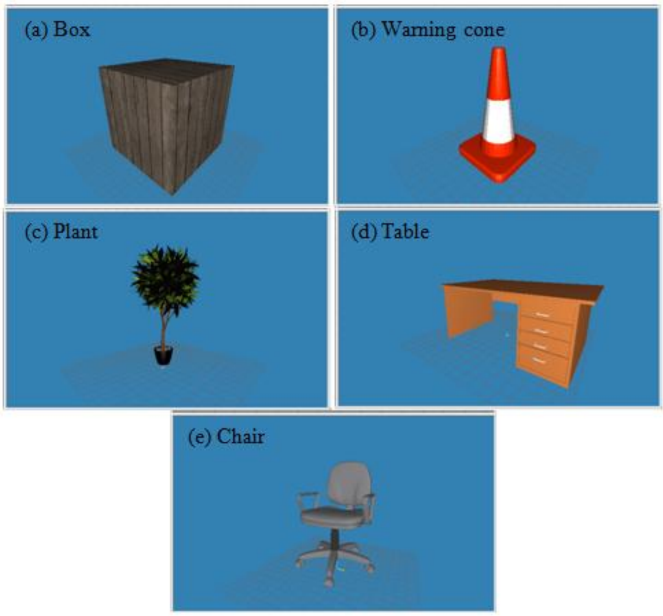

Figure 6. 3D objects obstacles.

By using Dark AI, there are few options that can be display when run the simulation. The options are display entities walking path, obstacles bounds, view arcs, and avoidance angles. Entity path will show the journey path of the entities to the destination where the path represent by red line in the stage as shown in figure 7.

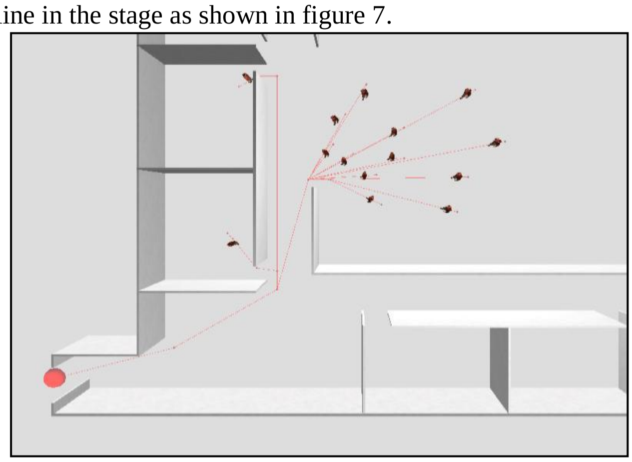

Figure 7. The entity path is shown in red line to the destination point.

Obstacle bounds are the boundary of the obstacles that the human entities must avoid as shown in figure 8.

Figure 8. The obstacles boundaries.

View arcs are the entities view angles to the environment as shown in figure 9.

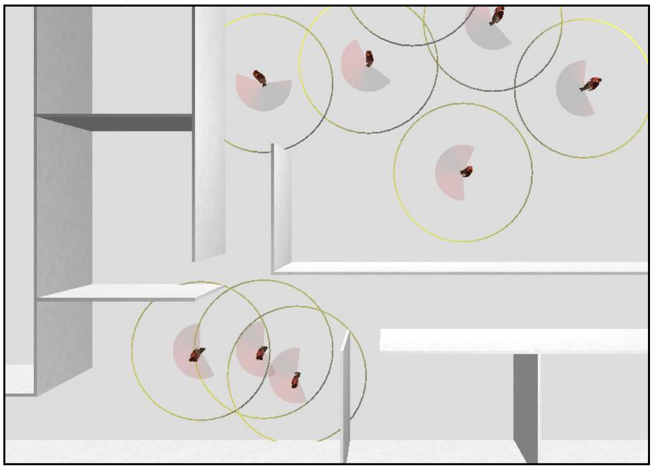

Figure 9. View arcs of entities.

Avoidance angles would be displayed in green colour when entities were avoiding other entities as shown in figure 10.

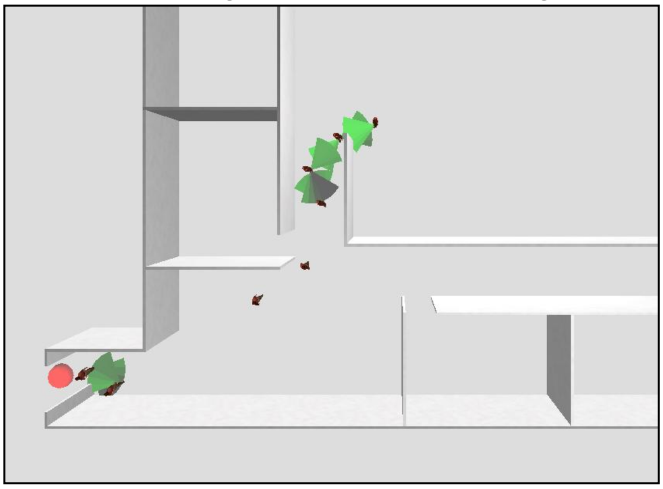

Figure 10. Avoidance angles of entities in green colour.

E. *Artificial Intelligence*

The human entities are defined as having artificial intelligence from Dark AI language which can find path, avoid collision and reach the destination automatically in most of the situation. Maximum humans AI that can be place in the simulation are 99 entities. The obstacles in the simulation can be either fixed objects or the moving entities themselves. When the human entities has detected another entity and will not move in blocked directions. This is shown in avoidance angle option in green colour and contains the area where the entity will not move as shown in figure 10. The human entities will avoid the area.

The static obstacles like wall of the buildings and object have the obstacles boundary. It shows the edges of all obstacles. The obstacle bounds appear in a darker green colour and will flash white about once a second to help visualise them against surrounding objects as shown in figure 8. The human entities will avoid collision with the obstacles and will not pass through the boundary. The human AI entities will find the shortest path to the destination point while avoiding the obstacles. If the path is blocked by obstacles, the human AI entities will find another path to the destination point as shown in figure 11. If the path to the destination point is blocked and no other alternative path to the destination point, the entities will walk around their confined area.

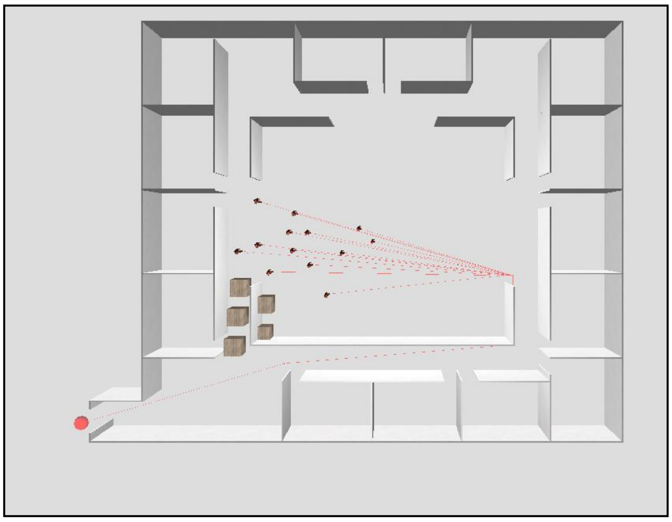

Figure 11. The shortest path blocked by boxes, AI entities finds another path to the destination point.

F. *Simulation Data Analysis*

The data analysis for the simulation would be the time taken for each of the AI entities to reach destination. The data collection are generated and recorded in DAT file by the simulation. The analysis of the simulation will base on the total entities on the stage versus their time taken to reach the destination. One way walking and two ways walking in empty space are simulated to find the effect of increase in human entities to the average speed of all the entities. Figure 12 and figure 13 shows the one way and two ways walking in empty space. The building design in figure 3 is simulated to find the total time for the evacuation to complete. Two ways walking are entities walking from two direction which are either from left to right or right to left opposite from each other.

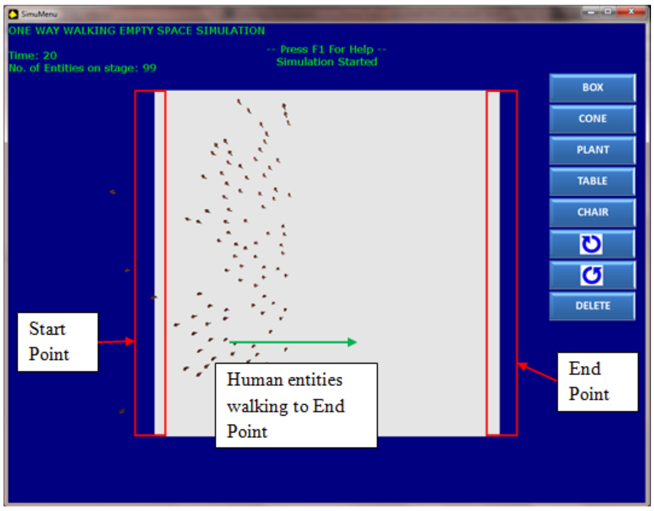

Figure 12. One way walking in empty space.

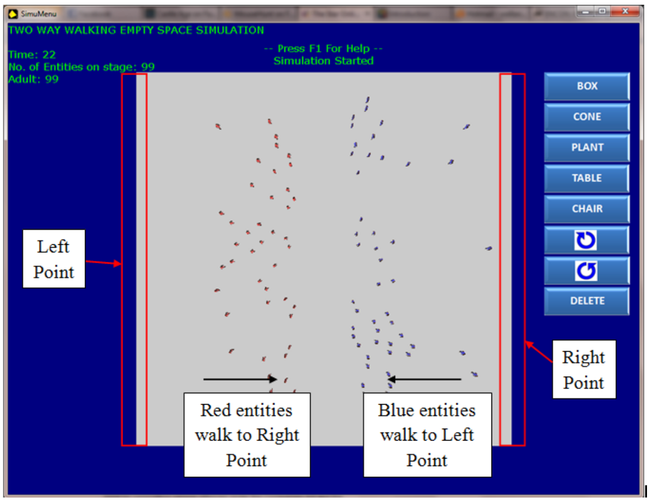

Figure 13. Two ways walking in empty space.

III. Results

The results of the simulation are always not the same due to complexity of human walking. Therefore an average was calculated to reduce the errors of results. The results of one way and two ways walking in empty space simulation are compared in the graph shown in figure 14.

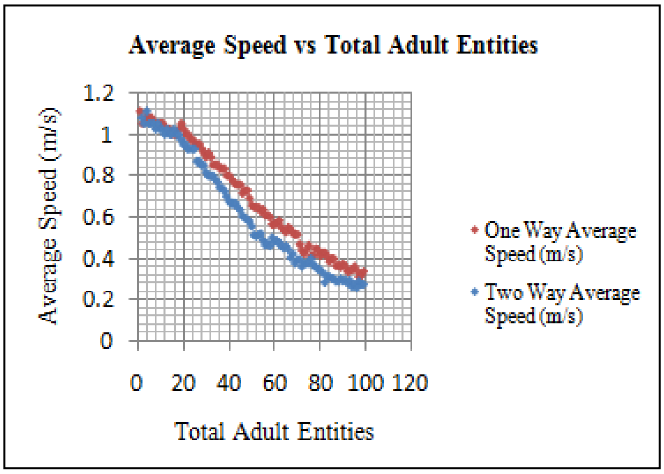

Figure 14. Graph of comparison between adult walking in one way and two ways in empty space simulation.

Both data from one way empty space simulation and two way empty space simulation show that the more entities in the simulation, the more slow of the average walking speed of the entities. When the situation is crowded, the entities walking speed would be reduced to avoid collision and changing direction.

According to the graph in figure 14, it shows that the average speed of one way walking simulation is higher than two way walking simulation. This is because of the entities in two ways empty space simulation are walking from opposite direction and they will decelerate to avoid collision when they meet each other. This will reduce the speed of the entities and increase their travel time. . In one way walking in empty space, when one entities walk in the simulation, the average speed is 1.111m/s and gradually decrease until 0.333m/s for 99 entities in the simulation. For two ways walking in empty space, when two entities walk in the simulation, the average speeds is 1.081 and gradually decrease until 0.274m/s for 99 entities in the simulation. Figure 15 shows the result of the emergency evacuation of the building for the total evacuation time and average travel time to reach destination.

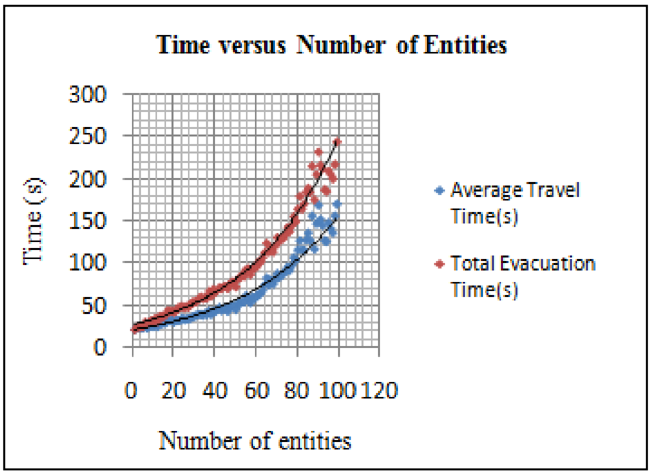

Figure 15. Graph of time versus number of entities for average travel time and total evacuation time.

The total evacuation and average travel time increase exponentially when increase of human entities inside the building for the building design in figure 3. One entity evacuate from the building need 21 second while 99 entities evacuate from the building required 245 second which is 4 minute and 5 second.

IV. Conclusion

This research paper discuss about the development for emergency evacuation simulation using DarkBasic Professional. Building design and obstacles are converted into DirectX format to compatible for DarkBasic Professional. There are four options in the simulation that can display to the user. The options are display entities walking path, obstacles bounds, view arcs, and avoidance angles. The human entities in the simulation are defined as having artificial intelligence from Dark AI language with the limitation of maximum 99 human entities. The human entities are able to avoid other human entities and obstacles. With intelligence from Dark AI, the human entities are able to find the shortest path to the destination point. Although the shortest path is block by obstacles, the human entities are able to find alternative path unless no other path to the destination point. This simulation was developed to simulate the evacuation performance in the buildings. Total evacuation time will be display in the simulation after all human entities have evacuated from the building.

The analyses for the simulation are the time taken for the entities to reach destination. From the experiment, it was shown that the average speed for both one way and two ways walking in empty space simulation decrease when increase of entities in the simulation. Two ways walking are slower than one way walking due to entities need to avoid the collision from opposite direction. For the building design from figure 3, the total evacuation time is increase exponentially when increased of human entities in the building.

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