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TAWAF CROWD SIMULATION USING SOCIAL FORCE MODEL

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Graphical abstract

Abstract

This paper presents a crowd simulation system which simulates the movement of pilgrims in performing one of Hajj rituals, which is Tawaf. Tawaf is a unique case study due to its capacity and various set of pilgrims. Furthermore, the density of the crowd is extremely high. Tawaf also consist a certain set of rules and regulations that must be followed by the pilgrims. Social Force Model had been chosen to give each agent in the simulation a specific behavior to be followed. The algorithm also specifies how the agents interact with each other to generate collision free movements. To make the simulations as close as possible to real world scenarios, each agent varies in term of age, gender and behavior. The subjective evaluation of the system revealed that it can be used in pilgrim training before performing the actual Tawaf.

Keywords: Component, crowd simulation, Hajj, tawaf, agent, Kaabah

1.0 INTRODUCTION

Crowd simulation has becomes an important research area, which has a wide application in education, entertainment, architecture, training, urban engineering and virtual heritage (L. Sun and W. Qin, 2011). Generally, there are two main approaches in the field of crowd simulation. The first approach is controlling all the people in crowd as one large unit, and then move it the next desired place which is macroscopic approach. The second approach is to make the people among the crowd has their own characteristic and decide by themselves where they want to go or what they want to do. The first approach is the easier and has a low hardware requirement however it lacks of realism when simulating a large crowd due to ignorance in personality of each individual. The second approach is more realistic but need a very high hardware requirement due to its high computational cost (T. Dong *et al*., 2011).

Social force model are the most famous approaches to simulate a large density crowd. The social force model of pedestrian motion is a very advanced microscopic approach for simulating pedestrian motion. It solves Newton's equation for each individual and considers repulsive interaction, friction forces, dissipation and fluctuations. This model can be successfully applied to simulate real world scenarios in pedestrian movement. Relative to other models, social force models describes pedestrian behavior more realistically. However, they are designed to be as simple as possible. Every agent is represented by a circle with its own diameter and the model describes continuous coordinates, velocities and interactions with other objects. Each parameter has a natural interpretation, is individual for each pedestrian, and is often chosen randomly within some empirically found or otherwise plausible interval.

2.0 RELATED WORK

There a lot of research had been done by other researcher in order to simulate larger crowds such as during Tawaf. They use various approach for the same target which is to simulate the Tawaf rituals as realistic as they can. Some of them are using the Cellular automata technique: for example researcher from UnivesitiSains Malaysia (S Samardy*et al*., 2011). The research is focus on the small scale movement of the pilgrims. It is the main reason why they choose cellular automata although it cannot simulate a very large and dense crowd realistically.

Most of other researchers prefer using social force model as their base model to simulate the Tawaf ritual; for example researchers which also from Universiti Sains Malaysia (Z. Zainuddin*et al*., 2010) use to simulate the flow of pilgrim in the Tawaf Area. They simulate the flow of pilgrims getting inside into the mosque and getting out from the mosque. The flows of the pilgrims are bidirectional and towards each other and it show a congested area in the main entrance. Thus, these researchers are proposing a new design for the entrance.

The other researchers that use the same model are researcher from Chapel University (S. Curtis *et al*., 2010). They also integrated a high-level finite-state machine (FSM) with a low-level local collision avoidance (LCA) algorithm into their model to simulate the crowd behavior in a better way.

Although most of the previous researches show promising result but none of them are simulating the actual event realistically. All of them are just show result in 2 dimensions which cannot be used for training purposes in real-life. The previous researches also don't integrate the Tawaf rites and ritual into the simulation, they just simulate the flow of the pilgrims circling the Kaabah. However, most of the researchers are implementing intelligent agent into their model so that the movement of the pilgrims are not the same for all agents.

3.0 METHODOLOGY

The proposed method will be discussed in 3 sections which will be start by capturing and analyzing parameters. Next, is creating an artificial brain for each agent in the simulation. Finally, developing a new crowd simulation model that will be use to complete the Tawaf simulation.

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3.1 Capturing and Analyzing Parameters

Before starting the development process, the preliminary research need to be done to capture all the parameters needed which will use in the development process. In order to capture the parameters needed several testing using the current crowd simulation techniques need to be done. This is because by analyzing the experiment result we will know which parameters needed to be recorded in order to improve the current simulation model.

3.2 Creating Artificial Brain For Each Agents

An artificial brain need to be created for each agent in this proposed method. It will be used to decide which path is the best path to take for each agent in the simulation. Each artificial brain consists of its characteristic, desire and experience.

Characteristic mean that each agents are different from one and another in order to simulate the real situation where pilgrims are consists of various backgrounds. However to simulate the real situation are impossible due it have a limitless possibilities of characteristic, thus only a few main characteristic will be choose such as age and gender. The age will be distributed into 3 groups; children, adult and elderly. These characteristic will determine the agents' movement speed. The younger agents will move faster than the older agent, while male agents will move faster than the female agents.

Next is desire or tendency which means each agent will be given the desire according to its situation. For example each agents will have the desire to get as close as it get to the Kaabah and it will have a desire to kiss the black stone when it get close to it. The desire also important to make sure that at the 7th times of circling the agent has to get out from the crowd and exit the mosque, since this research are applying the rules into the simulation.

The next thing that will embed in the artificial brain is experience. Each agent will be given experience according to its surrounding, so that it will know how to response to the situation quickly after whatever happened around them. For example, if the agent traps in the crowd during its try to get out from the crowd after the 7th rounds, the agents will use more force in order to get out from the dense crowd.

Crowd simulation algorithm:

1. *Start*
2. *Enter Kaabah*
3. *Circumambulate Kaabah*
4. *If meet older pilgrims (Decrease walking speed)*
5. *If meet younger pligrims (Increase walking speed)*
6. *If meet same sex pilgrims (Decrease distance)*
7. *If meet opposite sex pilgrims (Increase distance)*
8. *Get closer to the epicenter (Closer to Kaabah)*
9. *Untilcircumambulate 7 times*
10. *Get out from Tawaf area*
11. *If fail to get out (Increase pushing force)*
12. *End*

Algorithm above shows the agent's workflow which will be applied to the each agent as the base of the

artificial brain process. In order to implement this workflow into each agent, fuzzy logic method will be use.

3.3 Implements Crowd Simulation Model

Human movements are usually started because of desire and intentions for a specific reason. As in this research the pilgrim wants to perform Tawaf by circumambulating Kaabah 7 times. This intention results into a decision and a series of actions. These actions follow the ritual rites of performing Tawaf. Performing Tawaf is a macroscopic movement, which needs navigation and way finding behaviors. During these movements, movements like collision avoidance and shortest path selection which is the microscopic movement will take place. Other than that, a new decision and action may trigger due to some environmental events and parameters. Thus, to simulate a realistic simulation of this ritual, the crowd simulation model must have the concept of desire, characteristic and experience. It also must include macroscopic and microscopic movements

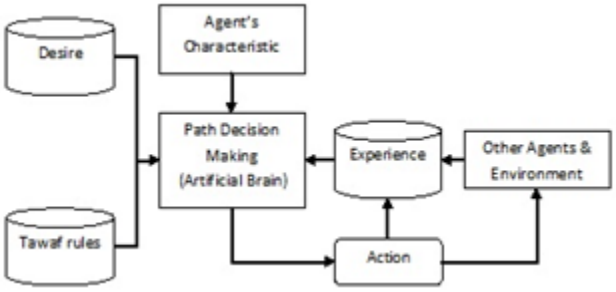

Figure 1 Proposed crowd simulation model

The proposed method combines all the parameters (characteristic, desire, rules and experiences) in order to simulate the Tawaf ritual as realistically as shown in Figure 1. Differ from other Tawaf crowd simulation model, which lets the agents move freely as they can, this model will restrict the agents' movements according to the rites and rules of performing Tawaf. The agents in this model also will react with another agent so that some grouping of pilgrim can handle since most of the pilgrim are not performing this rituals alone

4.0 IMPLEMENTATION

A simulation was design to test the proposed method of circumambulation of the Kaabah. All the agents were given the direction to move around the Kaabah. For simplicity, the entrance into the Tawaf area is limited to one only.

5.0 RESULT AND DISCUSSION

Based on the testing records with 80 characters the application has shown good result on simulating Tawaf ritual using crowd simulation. The FPS relatively high and the cpu times is small, this mean the device still able to handle the crowd number with high performance. The experiment is simulated using 80, 300 and 500 characters to see the performance of the simulation. This experiment is using social force model as the testing method. By referring to the figure below (Figure 2) we can see that the simulation is not realistic enough to simulate the actual situation, it need more improvement in the algorithm to make it more realistic. The testing simulation are lack of agents interaction without any intelligent path decision making, grouping movements and Tawaf rules are not implemented. However, these testing still show some promising results which can be further improve.

Figure 2 Testing with 500 agents

As we can see in Figure 3 shows that increasing number of characters in the simulation will caused the CPU time and the FPS become low. It is due to the high computation cost to compute the movement of 500 characters simultaneously on an average specification computer. There are two ways in order to overcome this problem; firstly by using a more powerful specification computer or the other way is to optimize the use of the computation source by implemented it in the system codes.

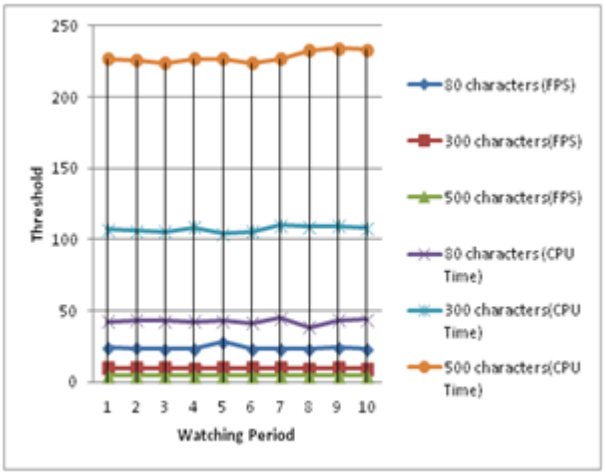

Figure 3 Performance evaluation on vaarious numbers of agents

6.0 CONCLUSION

Hajj pilgrimage is one of the largest religious people gathering in the world that occurs every year. Thus it is not easy to simulate this scenario through a virtual environment. Each hajj rituals have its rules and procedures. For example in Tawaf pilgrims have to move in a specific pattern and a certain number of rotations must be achieve which in this case the pilgrims must circle the Kaabah for seven times to complete the Tawaf ritual. This research will implement the crowd simulation according to the rules of performing Tawaf. The early findings results shows that it is able to simulate the rituals and the crowds to a certain level of precision Of course, there are still a lot of improvement need to be done and the algorithm needs to be revised. Nevertheless, the testing has shown a promising result on representing the crowd during hajj.

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