An Investigation of Workability Experiment for Crowd Modelling in 360° Panoramic View in George Town, Malaysia on Mobile Platform

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***Abstract*—In the computer graphics industry, there is a great demand for cost and time effective simulation and rendering while meeting an acceptable level of realism. Hardware based simulation and rendering has been taken to another degree of low level of details in environment modelling with grandeur of peoples. This paper presents an investigation to find out the feasibility of deploying crowd in 3600 panoramic view using the mobile platform as the case study. Crowd modelling within panoramic view is the first attempt in adding extra information i.e. crowd to the heritage sites in panoramic view. First, the crowds are modelled through some modifications to the Newtonian Laws, inclusion of proxy agents, speed control and turning. Second, workability tests experiments are carried out concerning the preferred parameters for each agent, improvement on random movements of the crowd and dynamicity, with the capability of collision avoidance. Finally, this investigation is discussed and has proposed some solutions in handling crowd in 3600 panoramic view on mobile platform.**

***Index Terms*—Crowd Modeling; Crowd Simulation; Panoramic View; Digital Heritage; Mobile Platform.**

I. INTRODUCTION

Crowd are commonly modelled and simulated in environment of a virtual city, stadium, theater, museum, airport, religious ceremonies and others. Crowd simulation has also already been used to animate historical cities such as Tawaf [5], Rome [22] Nicosia [4] and Pier Swettenham [12]. However, it is not normally available in panoramic views. People or crowd in panoramic views is usually static since they are captured together with the environment and the crowd is not animated. Although posing a unique set of challenges, bringing crowds into the 360° high quality panoramic view can greatly enhance the perceived realism of a virtual heritage environment. However, current attempts such as IT Crowd commonly fall short of increasing user-expectations since the sense of immersion is quickly dispelled when crowd simulation ceases to appear dynamic, realistic and distinct. Besides, most virtual walkthrough applications are restrained within the usage of mobile applications. In order to strengthen the contextual information in the 3600 panoramic view, dynamic crowd modelling is vital to augment the user's perception and interpretation of the current life in the case study of digital cultural heritage sites on mobile platform. In this paper, a force-driven crowd model based on Newtonian Laws is investigated specifically for 3600 panoramic view in order to bring another aspect of present life into digital cultural heritage on mobile platform and it is evaluated later on through experiments and scenario-based visual observations. Through the investigations, improvement of movement of crowd in virtual heritage within an environment of 3600 panoramic view is proposed on mobile platform model in three folds:

- MOVEMENT {None, Go to random places}
- ANIMATION {Stop, Walk, Turn, Look around}
- INTERACTION {Detect, Avoid}

Panoramic view is usually generated in three forms which are cylindrical, spherical and cubical. Any kind of generations are still facing problems of distortion and the complexity of the steps to construct panoramic view. However, panoramic view is clearly known to be able to contribute to both conservation of historical sites while displaying enough information for the user to perform their visit remotely through mobile devices. With the data and the photography collected for this research, it is also possible to include crowd simulation of the virtual heritage ultimately in panoramic view in order to bring lives into the historical sites which portray the cultural activities, trends and traditions. Therefore, there is a need for modelling dynamic crowd in 360° panoramic view since there is no reported work on dynamic crowd simulation in panoramic view. As a proof of concept, the proposed methods are applied only in the case study of the UNESCO heritage zones of George Town, Penang. A combination of digital archiving of images through panoramic view and computer graphics technology through crowd simulation help in preserving cultural heritage sites and objects by taking the heritage sites and its relics into the virtual world.

II. PRELIMINARY STUDY

All animation, movement and interaction of crowd are dependent on certain specific rules. There are many researches done on generating realistic and natural steering movement for virtual humans. Some of the methods are path-planning [19], cellular-automata [23], individual-based intermodal simulation [24], CityFlow [26], bionic intelligence algorithm [29] and density-based evolutionary framework [30]. On one hand, when determining the rules to motivate movements, social and psychological aspects are considered. Interactions between agents can be more interesting when the complexity of the behaviours is increased [2,18,15,16]. In modelling crowd in 3600 panoramic view on mobile platform, the application of rule-based [1,17,20] particle based [21] and social-force based models [6] have produced different types of movements over years. [3] also proposed the ground truth for the individual trajectories of every pedestrian in the crowd to form variety of crowd sequence. More natural trajectory with very few collisions in difficult test scenario can be produced with additional of static and dynamic conditions [7]. Kneidi proposed hybrid multi-scale model to improve the navigation for realistic modelling of human [9] while, further proposed to solve bottleneck in a more reliable way by removing failure node and redistributing them [14].

Some agent can walk faster while some agents walk slower. The agent has a force and will walk and stop when there is no more motivating force. The force can be renewed and the agent will continue walking again. On the other hand, the animation process will show a clear interaction between crowds that they are able to move and reach their heterogeneous goals in as random as possible manner. Therefore, there is a need to propose a crowd model in which the movements of the crowd can be incorporated into the collision detection and avoidance interactions within the 3600 panoramic view. Besides, various scenarios for instance in digital cultural heritage sites can be simulated by applying randomness to the models for active crowd management in 3600 panoramic view.

In term of crowd evaluation, [8] proposed that Test cases are the best to measure the flow rate of the crowd while [10] proposed experimental approach which is an elaborated and calibrated model for microscopic crowd analysis. Other approach in evaluating simulated crowd is through data-driven approach [11,31]. Previous study by [25, 27, 31] proposed to quantitatively compare the crowd models between the simulated ones and with the real world data through observations of the crowd movements.

III. Methodology

This section presents a three phases methodology that begins with the preliminary study and followed by the implementation, and workability test and discussions as shown in Figure 1.

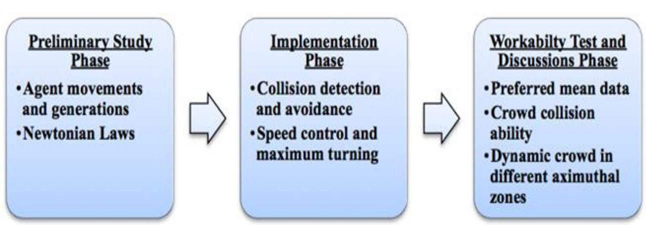


Figure 1: A methodology phases for proposed crowd in 3600 panoramic view

In the first phase, background of the agent movements and generations are studied in detail. There were three Newtonian Laws that are strictly included and later used in the implementation phase. Some modifications were made to the Newtonian Laws to meet the goal of modelling the crowd in panoramic view on mobile platform. The modifications are as follows:

1st Law: An object at rest will stay at rest; an object in motion will stay in motion at constant velocity, unless acted upon by an unbalanced force. Modification made is that assuming that there is a force of friction (when Force comes to the end), some agents will stop for a while and then continue walking only when other agents around him “force” him not to stop and continue walking otherwise if more than an arbitrary number of agents pass by the other agent, then the agent will have to continue walking else, the agent is supposed to be stationary when the force is finished.

2nd Law: F (Newton) = m (kg) * a (ms-2) where F is the force, m is the mass of the object and a is the acceleration. In this case, each and every agent has their own body mass where some are fat and some are thin. The mass will be used to calculate the BMI and the BMI is used to get the value of acceleration, and finally the F is obtained. Since the force will eventually be force of fiction and the agent will stop for a while, a counter for F depreciating is included. The BMI is standard for the child, adult, old folks and regardless if is a male or female.

3rd Law: For every action, there is an equal and opposite reaction. In a condition of realistic avoidance, if two agents happen to knock each other, they will break away for a while before continue walking again. An ‘NSTimer’ calculates three seconds before the agents are allowed to walk again.

In the implementation phase, the collision detection and avoidance, speed control and maximum turning in 3600 panoramic view are concerned. In the final phase, simulation preferred mean of the crowd characteristics model is discussed, crowd implementation with and without panoramic azimuthal zones are compared and modelling of dynamic crowd in a series of non-equidistant frames from the azimuthal zones is tested.

IV. Implementation

A. Collision Detection and Avoidance

An important part of the system is there are areas of accessibility for walking around based on sub-divided tiles, coordinate and path planning. Collision avoidance allows an agent to be able to detect and avoid another character and the structured environment to reach a simple destination and then to other new sub-goals. Determination of directions is based on Theorem Pythagoras. The key idea of collision avoidance is that there is no two overlapping particles through a proxy agent inspired by [4]. However, the main difference of our proposed work is that the proxy is overlapping with the particle so that the collision avoidance does not form a big gap between two or more particles as illustrated in Figure 2.

In this case, each virtual agent (AV) has a center point (CP) whose radius are half the radius of the proxy agent (AP) and the trajectories (TJ) to eight different interest points (IP) as illustrated in Figure 3 and the equation is as follows:

$$DC = DO + (IP - rand() \% 0 + 7) * \Delta t \qquad (1)$$

where DC is the Change of Direction, DO is the Original Direction, IP is the Interest Point and Δt is the delta time.

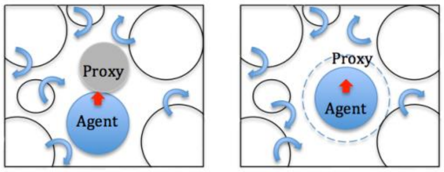


Figure 2: Comparison of (a) How proxy is applied (b) Proxy in our proposed method

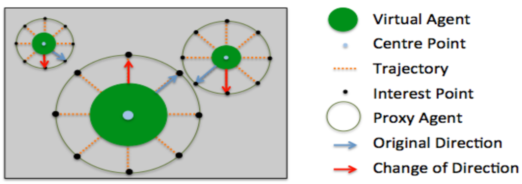


Figure 3: Illustrations of the parameters applied in a proxy agent.

Thus, the collision avoidance can be more sensitive to the other agents in the neighborhood area and yielding a result of smoother maneuver. This can be observed through the comparison of the simulation with or without the aid of the collision avoidance as shown in Figure 4.

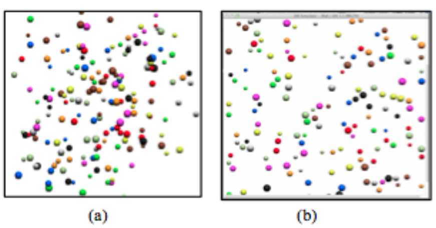


Figure 4: Result of simulation of virtual agents (a) Without collision avoidance and (b) With collision avoidance with the aid of proxy agent

B. Speed Control in 3600 Panoramic View

A hundred particles were initiated from the left and another 100 particles were initiated from the right horizontally. Both of these groups are supposed to travel to the opposite side. When there is no speed control, the virtual agents will move from right to left and vice versa in a constant speed and the particles do not look believable. Later, each of the particles is assigned with different acceleration rate and their speed will slow down and deteriorate to zero where the agents stop before the speed is recovered again. Figure 5 shows a simulation of agent walking from left to right until they lose their speed and eventually stop before they regain the original speed again.

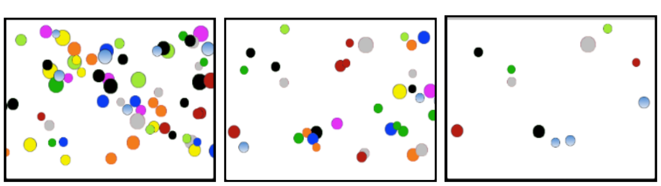


Figure 5: Simulation of speed control of the virtual agents

C. Maximum Turning

The rotation is implemented in clockwise and the angle of rotation is randomly generated and kept in a database. When the virtual agents detected the end of the edges, it will perform a flexible rotation based on the angle assigned to each agent. The maximum rotation is $\pm\pi$ as depicted in Figure 6.

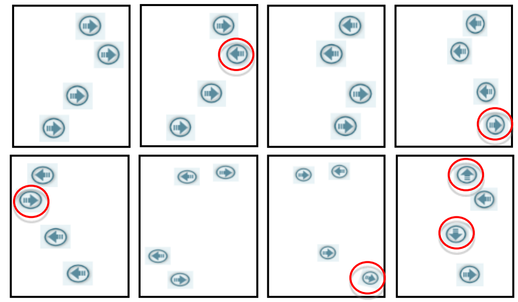


Figure 6: Simulation result per ten second with four virtual agents with the direction of movement (arrows) and the changes of direction (encircled) motivated by the $\pm\pi$ rotation.

D. Crowd Animation

Panoramic views without the inclusion of dynamic crowd is not satisfactory and dull. A solution is needed to overcome the problem of modelling crowd on limited capabilities of hardware support of mobile platform in order to allow the panoramic view to stand out in a more magnificent and dazzling manners. So, this stage is to model crowd and animate them based on accumulation buffer within 360° panoramic view as shown in Figure 7.

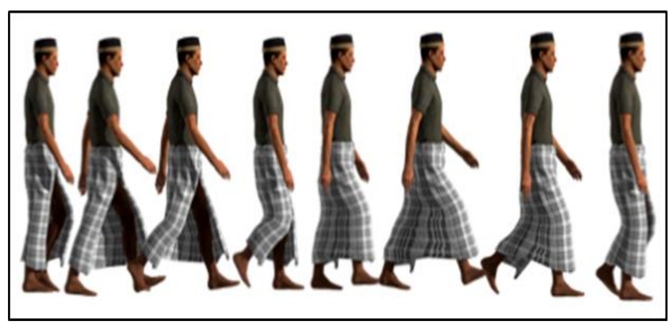


Figure 7: Model and animate crowd based on accumulation buffer within 360° panoramic view

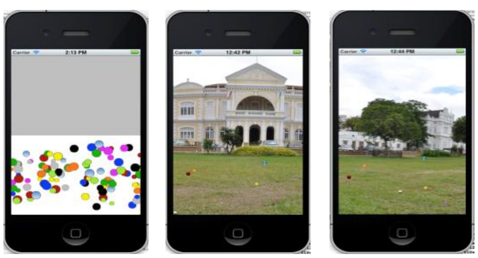
V. WORKABILITY TESTS AND DISCUSSIONS

For performance testing, three experiments are conducted to validate the system. In order to demonstrate the flexibility and usefulness of the proposed approach, crowd motions are created and tested in three different manners. For the first experiment, there were 200 agents where the Identity (ID) are initialized as 001-200 are then randomly assigned with different parameters within the predetermined range and the preferred mean data of each parameter are recorded and applied into all the 200 virtual agents. The result obtained from simulation of 99 rounds is as shown in Table 1. The 100th round is the obsolete stage where the panoramic view cannot be scrolled.

Table 1
The results of simulation preferred mean of the crowd characteristics model

Agent Information	Measurement based on Calculation	Results of Simulation Preferred Mean
Body Mass (kg)	48-90	67
Height (m)	1.48-1.90	1.65
Body Mass Index (BMI)	13.30–41.09	25.8
Walking Speed/ Acceleration Rate (m/s^2)	0.01–1.00 (0.00=Agent will stop)	5.00
Force (Newton)	0.48-90.00	69.2
Maximum Turning (MaxTurn)	1.000-3.142	2.004

For the second experiment, 200 virtual agents are modelled with particles of different colours in order to validate the proposed dynamic crowd in 360° panoramic view. Based on the visual observation, each particle is able to model their individualised behaviours while avoiding each other without any collisions as shown in Figure 8(a). The particles are able to move randomly under the proxy-based collision avoidance algorithm. As 360° panoramic view only concentrates on horizontal scrolling, unlike the 720° panoramic view, the agents only avoid each other within the horizontal neighbourhood boundaries as shown in Figure 8(b) and Figure 8(c) with different panoramic azimuthal zones.



(a) (b) (c)

Figure 8: Modelling of 200 virtual agents is represented by particles that move randomly under proxy-based collision avoidance algorithm in 3600 panoramic view. (a) Without panoramic azimuthal zones, (b) and (c) With different panoramic azimuthal zones.

In the third experiment, the circles are then replaced with actual virtual agents and animated using the sprite sheet and accumulation buffer. The crowd behaviour was evaluated by using a set of eight experiments as shown in Figure 9. The universe consisted of six agents that had random initial positions and velocities. The 360° panoramic view was scrolled and a series of dynamic animation of the crowd is captured based on various azimuthal zones within the 360° panoramic view. The initial distribution captured in the first frame at 3700 pixels and the second frame at 1100 pixels respectively and both have no display of crowd. The third frames were captured at 2000 pixels show the presence of crowd moving from the left to the right within the 360° panoramic view. At the fourth, fifth and sixth frames, the presence of crowd was captured at 2050 pixels, 2300 pixels and 2460 pixels. These three frames show the collision avoidance of the crowd coming from the opposite sides. The crowd seemed to be avoiding each other very well without any overlapping motions. The seventh and final frames were captured at 2700 pixels and 3860 pixels respectively. Two agents were captured appearing at the seventh frame while the last frame shows the crowd leaving to the next azimuthal zone within the 360° panoramic view. Based on the result after 99 simulations of the crowd in panoramic view, it was noticed that there were no collisions by merging of the crowd and the presence of crowd occurred randomly throughout the entire simulation. In many cases, the crowd regains the speed when the sliding frame is not scrolled. In addition, the decrease in speed is when the sliding frames are scrolled.

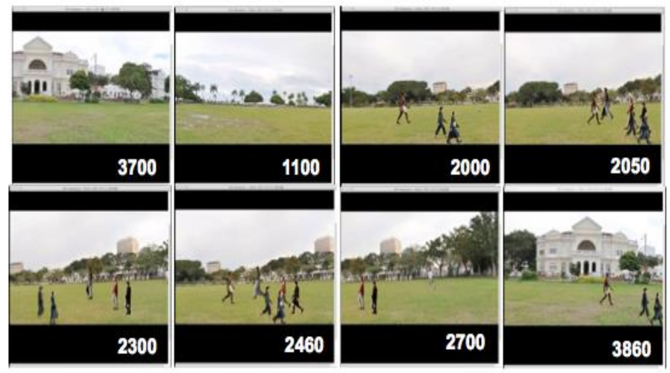


Figure 9: A series of non-equidistant frames from the azimuthal zones used for the modelling of dynamic crowd. The panoramic view is 2D images and the crowd was made like 3D to aid the dynamicity of the movement and this apparent overlapping does not necessary imply a collision.

VI. Conclusion and Future Work

Based on the experiments, there are two main modifications that are successfully done to the adaptation of simulating crowd in mobile platform through visual observations and system validations: (1) The bound radius of the containment force is no longer in an open area but within the 360° panoramic view and thus, the optimum boundary set in this case is a hundred frames of five azimuthal zones each for the horizontal boundary and half of the size of mobile frame for the vertical boundary, (2) As the scrolling of 360° panoramic view distorts the movement of crowd modelling, one solution is to truncate the speed of the particles when the panoramic view is scrolled. Therefore, it is possible to model dynamic crowd in 360° panoramic view especially on mobile platform. One limitation that should be addressed here is that the proportionality of the virtual agent in the dimension of z-axis is not considered within the 360° panoramic view at this point.

Besides, in modelling crowd in 360° panoramic view of the digital cultural heritage sites, the application of the rule- and social-force based models have produced different types of behaviour. In this research, the proposed crowd model has shown that the behaviours of the agents in the model have successfully been incorporated into the collision avoidance interactions within the 360° panoramic view. It is also found that even with lesser safe distance between each agents, the virtual agent are still giving good responses to the other virtual agents outside of their neighbourhood regions. This is because an optimisation model is applied so that checking for collision at each time-step is not necessary since it is very computationally intensive. Since only certain forces are applied to guarantee that the virtual agents steer accordingly and are still able to be collision-free, various scenarios can be simulated by applying randomness to the models for active crowd management in 360° panoramic view. Other future work is to include animation of avatars involving more complex movements and interaction with other 3D characters can be considered in the panoramic view of heritage sites [13].

ACKNOWLEDGEMENTS

This work presented is funded by Dana Pembudayaan Penyelidikan (RAGS/1/2015/ICT04/UPSI/02/1) under the research code of 2015-0172-109072.

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