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A Multi-Modal Virtual Walkthrough of the Virtual Past and Present Based on Panoramic View, Crowd Simulation and Acoustic Heritage on Mobile Platform

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***Abstract*—**This research presents a multi-modal simulation in the reconstruction of the past and the construction of present in digital cultural heritage on mobile platform. In bringing the present life, the virtual environment is generated through a presented scheme for rapid and efficient construction of 360° panoramic view. Then, acoustical heritage model and crowd model are presented and improvised into the 360° panoramic view. For the reconstruction of past life, the crowd is simulated and rendered in an old trading port. However, the keystone of this research is in a virtual walkthrough that shows the virtual present life in 2D and virtual past life in 3D, both in an environment of virtual heritage sites in George Town through mobile device. Firstly, the 2D crowd is modelled and simulated using OpenGL ES 1.1 on mobile platform. The 2D crowd is used to portray the present life in 360° panoramic view of a virtual heritage environment based on the extension of Newtonian Laws. Secondly, the 2D crowd is animated and rendered into 3D with improved variety and incorporated into the virtual past life using Unity3D Game Engine. The behaviours of the 3D models are then simulated based on the enhancement of the classical model of Boid algorithm. Finally, a demonstration system is developed and integrated with the models, techniques and algorithms of this research. The virtual walkthrough is demonstrated to a group of respondents and is evaluated through the user-centred evaluation by navigating around the demonstration system. The results of the evaluation based on the questionnaires have shown that the presented virtual walkthrough has been successfully deployed through a multi-modal simulation and such a virtual walkthrough would be particularly useful in a virtual tour and virtual museum applications.

***Keywords*—**Boid algorithm, crowd simulation, mobile platform, Newtonian laws, virtual heritage.

I. Introduction

IN the present society, people live in two distinct worlds which are the real world and the virtual world. The advancement of Virtual Reality (VR) becomes crucial in multidisciplinary areas such as simulation for education, entertainment, medical application and gaming. Heritage is defined as our legacy inherited from the past, our traditions that we practice today, or our immaterial possessions that we are passing on to the next generations. Each heritage building possesses its own history. The history could be properly documented or passed down verbally through generations. On the other hand, virtual heritage can be simply defined by a kind of computer technologies that denotes to a preserved architecture, natural value and tradition, craftsmanship or history. Virtual heritage is also an artificial environment of not in an actual world created by an interactive computer technology which uses digital tools and techniques in order to provide 3D emerging realism experiences in virtual heritage. Although people do not get to visit some of the places before, they can have clearer image of the heritage with the creation of virtual heritage. Virtual heritage can also be an innovative platform for educational purpose and for learning process regarding the historical elements and certain events. Panoramic view is a widely used technique to present virtual heritage since it gives a sense of immersion in the scene.

Crowds of people can be an impressive spectacle and are often employed effectively by films to convey occasion and grandeur. Crowd simulation is a process of replicating or imitating the movement of a large number of real objects or characters that involve specific human behaviours, actions or expressions by using a variety of mathematical models and algorithms. In other words, crowd simulation is also defined as virtual human interacting with other virtual humans. Although posing a unique set of challenges, bringing crowds to the 360^0 high quality panoramic view can greatly enhance the perceived realism of a virtual heritage environment. However, current attempts commonly fall short of increased user-expectations with the sense of immersion quickly dispelled when crowd simulation cease to appear unrealistic and indistinct. In addition, there is no such research on crowd simulated in panoramic view. With the data and the photography collection in this research, it is also possible to include simulation of animation and movement of crowd in the virtual heritage ultimately in panoramic view in order to bring lives into the historical sites which portray the cultural and social activities, and behaviours. With the creative proposed method, transformation of 2D crowd to 3D crowd can be displayed, as fully interactive panoramic view as the virtual heritage. Movement is defined as locomotion of one start location to the destination location. Animation is defined as agent's actions. Interaction is defined as any kind of

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behaviours that involve other agents. As there is higher expectation of natural human-like example behaviours for simulating of crowd animation and movement in virtual heritage, the aim of this research is in developing a suitable model for mobile platform for realistic simulation of crowd in virtual heritage application such as crowd movement, animation and interaction of crowd behaviour in order to add a new level of realism to the virtual agents.

In this paper, the research aims to present a technique for simulating past and present lives in digital heritage. 2D crowds that are represented by particles, that are capable of recognizing the 360^0 immersive panoramic view as the virtual heritage. This procedure will help the agents to move smoothly without colliding with other agents. Besides, each agent is supposed to behave according to human-like behaviours by having personal physiology and psychology human personal traits. With these traits, the agents are able to recognise static obstacles such as the 360^0 scrolling panoramic view as well as dynamic obstacles that are moving from all directions. 3D crowds are used to portray the past life on the other hand. Both crowds are deployed using classical Boid Algorithm and Newtonian Laws to display the steering behaviours. Finally, a virtual walkthrough demonstration system is developed with the incorporation of acoustical heritage.

II. Related Works

The migration or transformation from cultural heritage to digital heritage with modern technologies is conceptualized to lessen the artifacts at risk [1]. Some of the significant divergences are digital Sudan [2], urban heritage in south of France [3], digital temples of Angkor Wat [4], recreating old cities in Pompeii [5] and smart cities in Sweden [6]. The digital heritage research community has been showing an increasing interest for multi-model simulations for virtual walkthrough application that coupled with the necessity to convey contents with regards to the cultural aspects of a heritage site [7]-[11], [18]. A prior work by [12]-[14] have introduced a virtual crowd into real-time 3D constructions for huge heritage buildings while [15] added a lifelike companion agent, an Egyptian priest, who will follow the user, answer questions and make suggestions in the virtual Egyptian temple. Reference [16] proposed an optimization framework for rendering crowd simulation in virtual heritage environment to preserve the realisms of the scene using particle system technique. Particle-based crowd simulation models were extended by [17] to model crowds walking in narrow ways and gathering around street performances in African markets. The interactions between two populations of different nature were studied by [18], with the simulation of pursuit and evasion behaviours on a complex terrain. Contrary to the goal of this research, each of the populations is assigned with constant behaviours over time.

Other recent works focused on using the personality trait theory to simulate heterogeneous crowds where each individual is assigned with specific behavioural parameters [19]. Similarly, in this research, some varieties are allowed within each population to form varies types of individualized behaviours. Other applications of crowds in cultural heritage applications include the simulation of demolished Pennysylvania Station in New York City, with mostly reactive behaviours [20]. In [21], the paper mainly focuses on individual behaviours and path-planning as some districts in Pompeii are restricted to a certain class of people, but not on various interactions among different populations. In [22] the CrowdBrush is used to facilitate the design and their work does not focus on simulating the crowd. [23] has simulated past inhabitants in the city of Uruk where the behaviours are concentrated on eating, sleeping, working and communicating with one another. On the other hand, the simulation of this research focuses on the activities that involve trading with different kinds of populated crowds.

In parallel with virtual walkthrough application, works are further extended to bridging the museum with digitalization project with VR installations [24], digital archiving [25], serious game [26], and QuickTime VR (QTVR) and panoramas [27]. [5] has also proposed a museological research through digital revolution by introducing the concept of 'postdigital'. However so far, there is no direct attempt of applying multi-model simulations for virtual walkthrough application with crowd modelling and the improvisation of 360^0 panoramic views and acoustical heritage. Hence, our challenge here is to bring the present and past life through the domain applications of digital cultural heritage specifically in virtual walkthrough on mobile platform.

III. System Modules

In the virtual walkthrough of the demonstration system as illustrated in Fig. 1, the aim is to show how the proposed models, schemes and methods bring the present life in digital cultural heritage in 360° panoramic view with acoustical heritage and crowd modelling, and the past life in digital cultural heritage through heterogeneous crowd simulation. Since it is only for the purpose of demonstration system, the primary interest is not to develop a complete virtual walkthrough but rather the proposed application needs to be visually credible enough to be used as a learning tool before physical visit to these heritage sites. For the panoramic view, seven examples that are City Hall, Fort Cornwallis, Goddess of Mercy Temple, Kapitan Keling Mosque, Khoo Kongsi, Masjid Melayu Lebuh Acheh and Town Hall are provided. Instead of presenting a psychoacoustic effect by merging different kinds of modulations in a single interface, they are presented part-by-part which includes the modulations of loudness, pitch and speed. The modulations of loudness are different from the tapping at X- and Y- axes, and based on distance. By having a separate interface for the manipulation of sounds, it could help the users to determine the modulation of the acoustical heritage effects in a clearer manner. Fig. 2 shows the flow for the navigation of Fort Cornwallis as one of the examples. The user is allowed to navigate the 360° panoramic view with the proposed model in multiple perspectives such as the main view, lighthouse view, cannon view, Francis Light statue view and cell view. Each of them is

attached to a small number of audios, panoramic views and information related to the particular heritage sites to aid the understanding of the user. For heterogeneous crowd simulation, pre-simulated and pre-rendered of past life of an old trading port (Weld Quay) is generated in a PC before converting them into iPad for demonstration purposes.

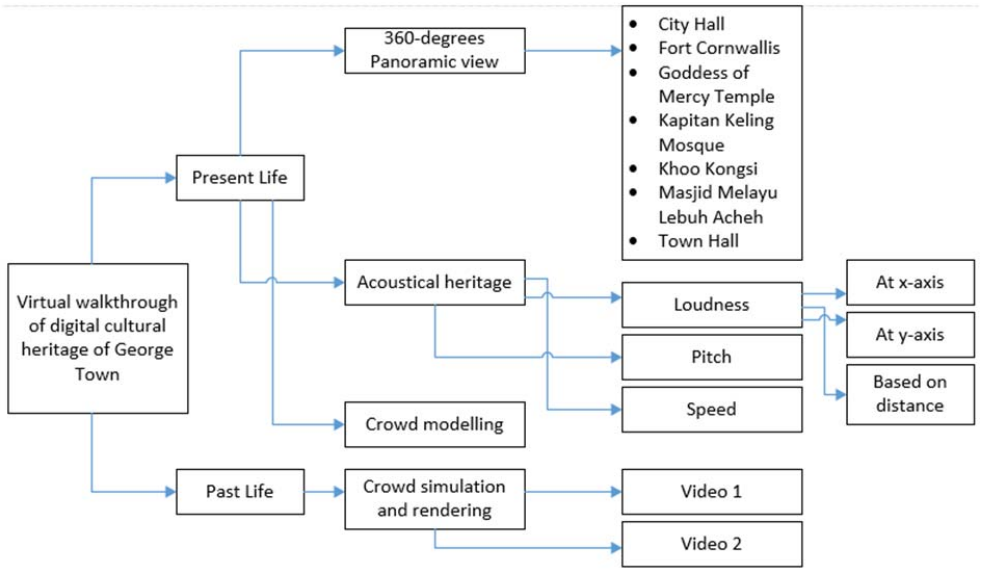


Fig. 1 A virtual walkthrough demonstration system tree

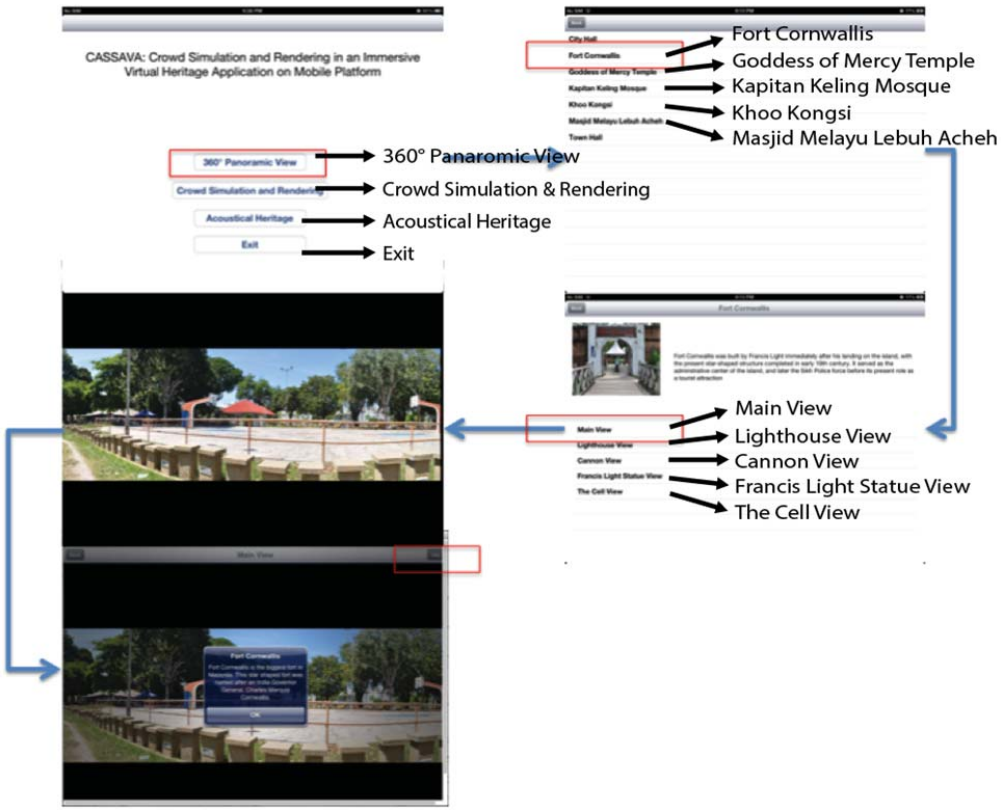


Fig. 2 Virtual walkthrough- an example of the flow of the navigation for Fort Cornwallis

IV. Implementation Data

A. Virtual Environment Setting

There are two types of virtual environment that are setup to reach the final output of virtual walkthrough using mobile device. Since for the virtual present module is based on 360^0 panoramic view, the environment will be based on 2D effects while the virtual past module is based on 3D models. Fig. 3 shows the present virtual environment while Fig. 4 shows the past virtual environment of Georgetown City Hall.

Fig. 3 Present virtual environment of Georgetown City Hall

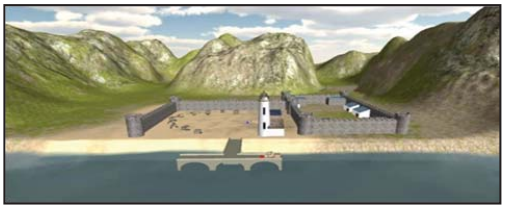
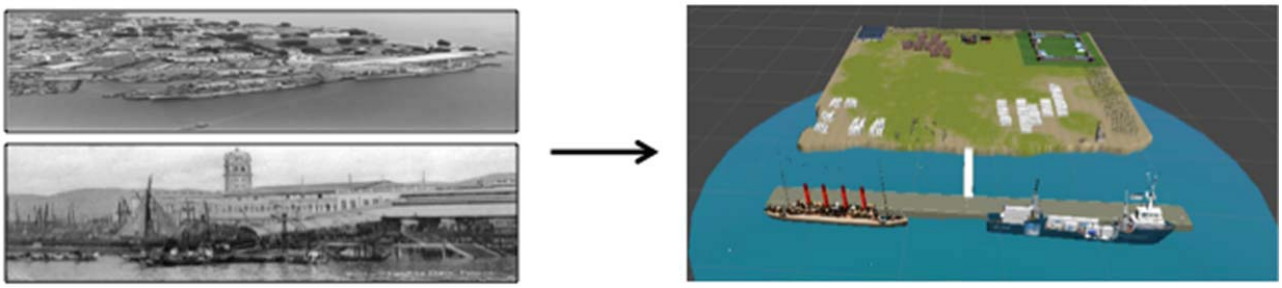


Fig. 4 Past virtual environment of Georgetown City Hall

In the construction of the virtual environment of an old trading port, Weld Quay in George Town has been selected as the point of reference. Along the quay, one of piers called the Swettenham Pier and a fort called Fort Cornwallis will be used as examples in illustrating heterogeneous crowd simulation involving multi-ethnic interaction. The environment is represented based on the knowledge and the data gathered on the place. The environment is modelled using Unity 3D by approximating the actual scale of a T-shaped berth of 450 meters long and 9 meters depth. Fig. 5 (a) shows an illustration of the actual environment and Fig. 5 (b) shows the corresponding virtual environment consisting of some shipping containers, a market place, some plantations, a lighthouse and scattered floating houses around the Swettenham Pier. Along the floating houses, the sampan boats are used as transportation to go from one pier to another pier for loading and unloading of smaller quantity of goods.

B. Human Template Models

As the activities and visual aspect of the people are different for each ethnic group, the goal in this research is to model the different kinds of occupations each ethnic group had in the early 1900s. Fig. 6 shows the rendering of 2D human model compiled from various postcards into virtual 3D humanoid model of the four different ethnic groups respectively.



(a) (b)

Fig. 5 Illustration of the actual environments (a) of the T-shaped Berth that is modelled into virtual trading port (b)

A. The Art of Narration of Main Populations

An effective narration is best practiced before developing the scripts. The writing of the narration involves the initial venue, primary, secondary and tertiary goals of each ethnic group or group of people. Table I through to Table IV summarise the sequence of goals for the Malay, Indian, English and Chinese ethnic groups respectively.

B. Ship as Another Particle

The ship obeys the path-following behaviour which is driven by a list of way-points that determine the next target where the ship will sail to. When the ship is almost reaching a way-point, it performs the arrival behaviour where the ship slows down and stops besides the pier for 600 seconds or depending on the number of goods downloaded. After a period of time, it will sail to the next way-point and so forth in a circular motion until it gets back to the pier. However, the number of goods is later used to determine if the ship should sail or stay at the pier because 600 seconds is an arbitrary number that cannot precisely determine that the coolies have finished uploading the goods from the pier. To enable a smooth motion of the sail, more way-points are set and the forward direction of the ship is maintained while the velocity is changed at each time step as given in Fig. 7.

Fig. 8 shows the simulation of the boat guided by the illustration of the actual ship. To enable a smooth motion of the sailing, more way-points are set and the forward direction of the ship is maintained while the velocity changes at each time step. Besides, the next target distance is 2.5 before the ship sails to the first way-point and it drastically increases to

the value of 25 when it searches for its next way-point to give a circular turning and not resulting in erratic and static horizontal-vertical turning through the manipulation of good parameters.

TABLE I
SEQUENCES OF GOALS FOR THE MALAY GROUP

Initial Venue	The Market
Primary Goal:	To sell foods and approach people of any population that are the nearest to them. • Seeking: They will approach anyone that is near to them based on closest target. – If they have successfully approached the target, they will interact with them for certain duration, trying to sell the goods to them. – If the Indians are carrying their duties (goods on the back of the shoulders defined by the decrements of speed of the character or the increment in mass), they will not approach them. They will disregard those Indians as their closest point (not a potential buyer as they are busy). – They will only approach the Chinese after the Chinese finish their task with the English at the fort. – They will remain near the goods to make sure that others do not take the goods. – They will be more likely to approach the English and Chinese than the Indians as they have more buying powers. • Separation: As they are doing personal business, selling local products, they usually go around individually and not in a group.
Secondary Goal:	To propagate the event of robbery. • During their interactions with their potential customers, their goods might be stolen. • The vendor has to notify the policeman to go after the thief.

TABLE II
SEQUENCES OF GOALS FOR THE INDIAN GROUP

Initial Venue	Anywhere in the harbour except the fort, the sea and the ship.
Primary Goal:	To load the goods from the ship into the containers. • Wandering without goal: They should not be in a group (more like individuals that appear or come out at different times). Initially, they are just walking around and ready to be on duty. • Path following: When the ship arrives, they will rush to the ships, load the goods on their backs/shoulders (increment in mass, decrement in speed), aiming the containers as their target. There will be a change in their weight before and after the loading of goods. • Arrival: They will follow other Indians in front of them when they are uploading and downloading the goods with slower motion. – They can only load the goods under the supervision of the Chinese storekeeper is supervising near the containers. – When the Chinese follower is near the container, this is an indication that the container is still not fully loaded. – When the goods are loaded into the container, the Indians will accelerate in speed and walk back to the ship in a loop or non-polynomial form until all the goods are fully loaded. – When the entire Chinese are dismissed from the terrain, there will be no more jobs for them and they will just wander around. – When there is no ship, more people will be at the market. – If they are colliding with other people when they are loading, their mass will also induce a change in a way they react to the force. • Queuing behaviour: In general, when there is a ship, the Indians queue to get the goods. When there is no ship, the Indians queue at the market to buy foods.
Secondary Goal:	To relief their hunger. • If they see the Malays, provided that they are being approached and they are not carrying the goods, they will stop to buy. • As they are poor, they will not often buy things. So it is more likely that they approach the Malay whenever they need to buy food rather than the Malays always approach them.

TABLE III
SEQUENCES OF GOALS FOR THE ENGLISH GROUP

Initial Venue	The Fort
Primary Goal:	To carry out business transactions in a proper manner. • Seeking: Any Malay vendor can approach the English if they are near to them based on closest target. • Path following and leader following: When any ship arrives, they will come out from the fort and walk in a group in a leader-follower manner to the designated ship to basically greet and socialised with their customers. They will escort their customers from the pier back to the fort.
Secondary Goal:	Ensure the security of their territory. • When there is no ship arriving at the pier, majority of them will stay in the fort zone. • Basic flocking: Most of the time, they will perform general monitoring to ensure the safety of the inhabitants and customers by walking around to monitor the environment within the pier. • Cohesion: They usually walk in a group because they are not comfortable walking alone for security and authority reasons. • When they receive signal from the natives that robbery occurs, the nearest among them (the police) will steer (change of target of location) and run towards the robbery scene in an increased speed. • Seeking: They will demand the robber to freeze, but the thief continues to flee from the police. • The English will chase after the robber if it is still within his region of capability, otherwise if the robber evades too far from the police, the police will stop chasing and let the thief goes free. • If the police manage to catch the thief, they will stop and the police will interrogate the thief. • Leader following: The police will demand the thief to follow him back to the prison for further investigation. • At the same time, the police will demand other colleagues to escort the thief side-by-side until they reach the prison.
Tertiary goal:	To relief their hunger. • They will be stopped or approached by the Malays for food.

TABLE IV
SEQUENCE OF GOALS FOR THE CHINESE GROUP

Initial Venue	Coming out from the ship when the ship arrives near the harbour
Primary goal:	To go back into the ship and dismiss it by sailing away. • Goal oriented: When the loading of goods is all settled, all of them will go back to the ship and the ship will sail away.
Secondary Goal:	To perform trading transaction. • Leader following: As for the kapitan, he will follow the English to the fort for a business deal. – Multi-target steering: One of the Chinese followers will be elected as storekeeper and he will go to the containers while the rest of the followers will be following the kapitan to the fort. – The storekeeper will stand randomly near the containers to calculate the stocks and to make sure that the coolies have fully loaded all the goods to the containers. – Once they are alerted that the goods have been completely downloaded, they will rush to the pier no matter what kind of state they are in. A meeting or target- ted point is predefined right in front of the pier.
Tertiary goal:	To relief their hunger. • They will be stopped or approached by the Malays for food.

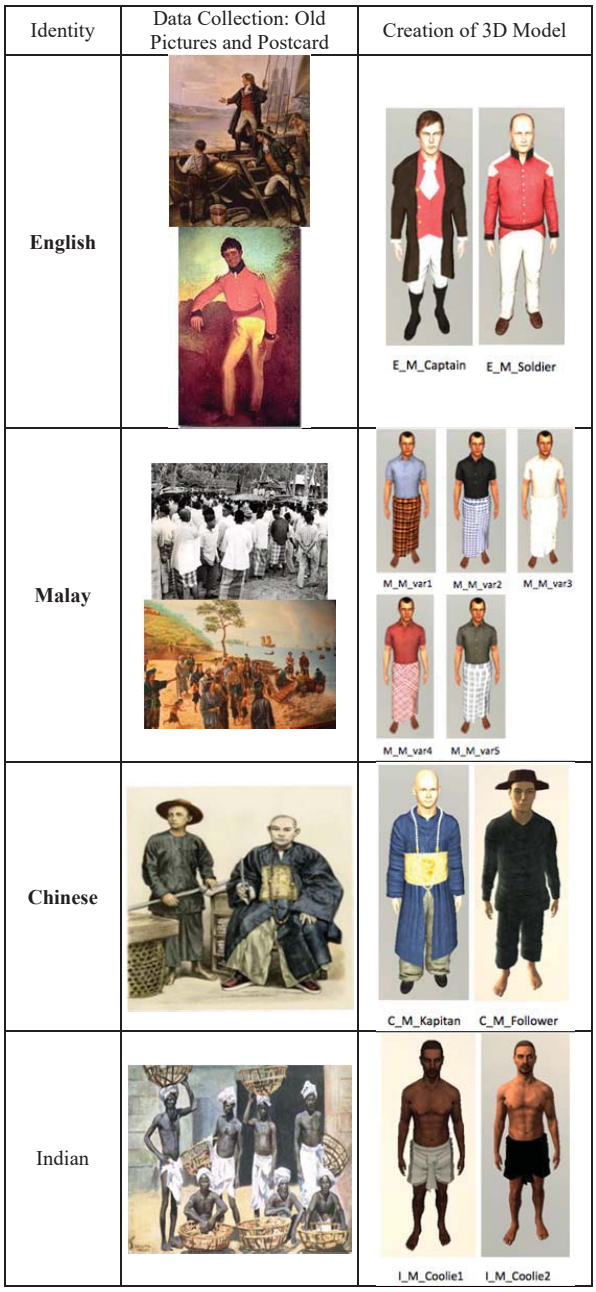


Fig. 6 Rendering of 2D human model compiled from various postcards into virtual 3D humanoid model

```
START_UPDATE
IF boat is not at the pier and there is a boat sailing THEN
        IF remaining time is more than 0 THEN
        COMPUTE remaining time EQUAL TO remaining time MINUS delta time
        ELSE
        DEQUEUE boat that is sailing
        RESET boat waiting to FALSE
        RESET boat path point to starting path point
        RESET targets
END_IF
IF boat is not at the pier and there is a boat sailing and the boat that is sailing is at the pier
        RESET at the pier to TRUE
        PROCESS boat arrived function through general manager
END_IF
IF boat is at the pier and there is a boat sailing and the boat that is sailing is at the pier
        RESET at the pier to FALSE
        RESET boat sailing to NULL
        COMPUTE remaining time EQUAL TO randomized number between 0 to
        waiting time
        PROCESS boat left function through general manager
END_IF
END_UPDATE
```

Fig. 7 Algorithm for the simulation of ships with its conditions

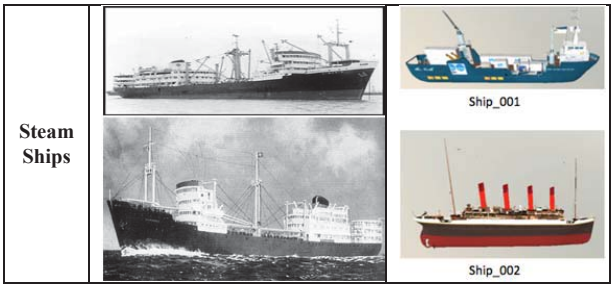


Fig. 8 Rendering of 2D Ship Model from Postcards into Virtual 3D Ship Model

C. Crowd Models and Variety

The term rendering is the act of taking a picture of your scene through your virtual camera using the lighting, material and meshes you have set up. A reasonable number of displayable characters or virtual agents with some individualised behaviours are being rendered in virtual heritage on mobile platform. As mobile platform can only support lower CPU memory, smaller resources and character IDs are minimized. A low cost rendering method with lower quality could compensate the low capability of mobile platform [28]. The size of the crowd is categorized into sparse, medium, dense and massive. Crowd consisting of 200 agents is relatively large on mobile platform. Therefore, in this research, only used five characters were used as proof of concept in the prototype. A thorough data collection of well-

suited crowd model to represent the culture of Malaysia is as depicted in Fig. 9.

Fig. 9 Example of Data Collection of Crowd Model Representing the Culture of Malaysia

Four behaviours were being analysed and modelled as the core part of the implementation. The information about the appearances and their activities in a specific geographic area of these four populations were gathered. During the data collection, it is important to explicitly state the goals and motion rules for each ethnic group. Besides, specific body motions are needed to link with their current body positions and trajectories. The body motions are automatically associated to different part of the skeletons. Using Unity3D, the skeleton is step by step changed to a new 3D model by referencing the controllers from the RocketBox Unity Package. Fig. 10 shows a procedural example in improving and producing a variety of crowd models. A new model of .fbx file format that is without the animator elements is imported to the scene. The existing prefab from the RocketBox is made side by side with the new character as shown in Fig. 10 (a). In order to replace the new model with one of the sample RocketBox character's skeleton, align both the model to the same coordinate (position, rotation and scale) as shown in Fig. 10 (b). Then the both character would be able to overlap each other.

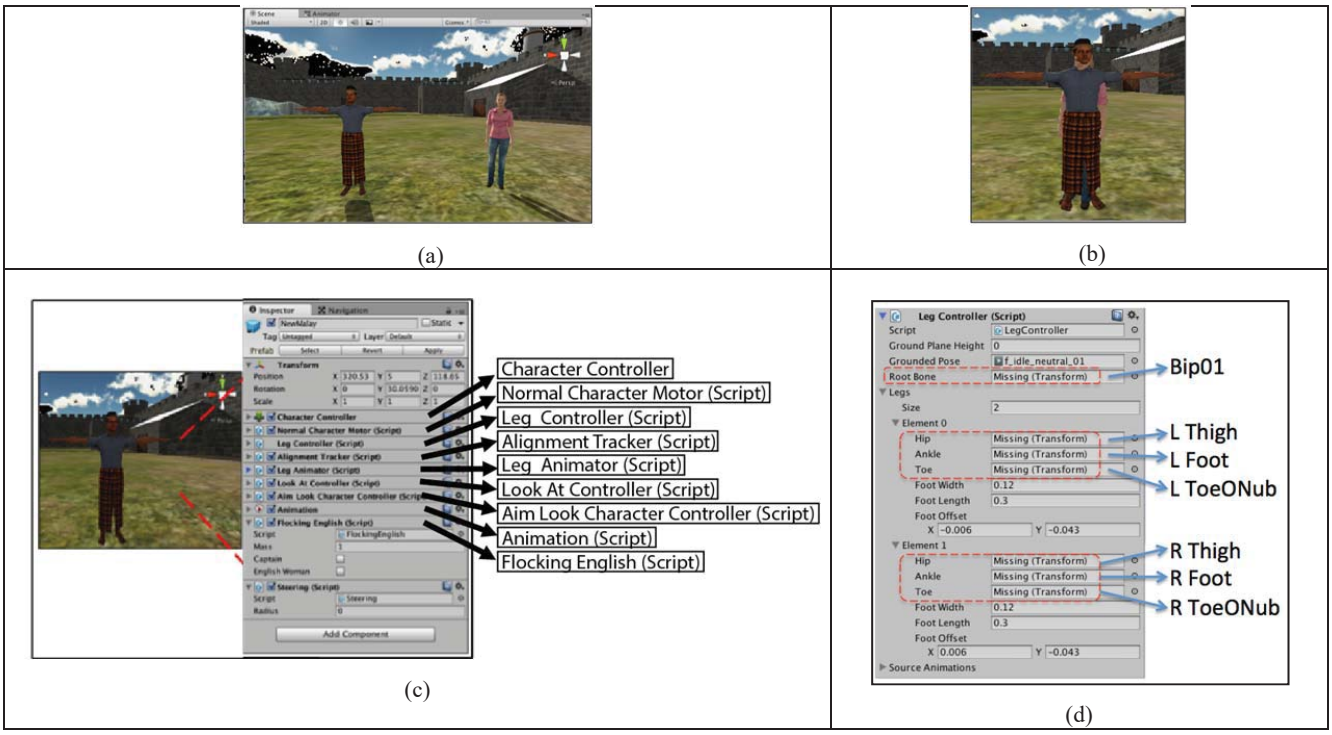


Fig. 10 A Procedural Example in Improving and Producing a Variety of Crowd Models (a) A Newly Drawn Model Using 3D Studio Max (right) and A Referenced Model from RocketBox Unity Package. (b) Two Overlapping Models with Similar Transforms (Position, Orientation and Rotation). (c) A Newly Rendered Model with A List of Components in the Inspector. (d) Missing Transforms is Replaced with Dedicated Transforms

Next, at the Hierarchy, new elements from the new model are needed to be drag and drop into the referenced model because the new model has no animation controller. By doing so, this process outhelps in increasing the variety of the 3D models that are attached with various animation clips in the most rapid way. The elements, namely the hipoly and bip (blue color) are then replaced and deleted. Usually a pops-up block is appeared to confirm that this action will lose the prefab connection, the button 'continue' is clicked because the new model wants to build a new connection with the referenced model. When both elements from the referenced model are successfully deleted, the new model is found to be perfect without the overlapping reference character and it is now with a list of controllers in the Inspector as shown in Fig.

10 (c). The final step of creating variety of animated crowd is to reset all the seven Transforms at the Leg Controller (Script) where the scripts can be obtained from the previous referenced model. All the seven missing transforms can be placed with the dedicated transforms as depicted in Fig. 10 (d). Once the Leg Controller (Script) is completed, drag the new model (3D Game Object) from the Hierarchy into the Project to make it as a Prefab and delete the new model from the Hierarchy. When the simulation is run, the new model would be able to animate accordingly to the body parts.

D. Crowd Characteristics

There are several factors affecting natural human behaviour in a crowd model such as the cultural and sociological factors based on different situations, the psychological factors based on mental state and personality, memory, Body Mass Index (BMI) and waist to hip ratio, and the physical factors based on social forces, agent awareness, priorities, aggression, authority, protection and guidance, speed and space syntax. For instance, walking is a general kind of movement for tourists especially when crowd is choosing path, it is adequate to merely walk. By speculating a basic understanding of human personal traits such as fat peoples move slower than thin peoples and shy peoples avoid crowded places while curious peoples tend to move closer to crowded places in this paper, the crowd will attract, disperse and remerge themselves towards one another based on a combinations of characteristics.

In order to form individualised agent characteristics and heterogeneous crowd, each human template is assigned with some agent parameters. Each of the agents is constructed in the sense that they have a particular set of data, representing the characteristic of the crowd (scripting/property list). e.g. Agent information such as Agent ID (this specific field is unique and auto-assigned), walking speed, Body Mass Index (BMI), MaxTurn or vision angle, level of freedom or level of intellectual, team or self and identity as a leader or follower. Database that is the property list in Xcode consists of simple identifiers in which the data is generated and stored in integers or strings to give randomised behaviours to the agents. However, emotion of the agents is not considered in this research. Hence, this section is concerned about developing crowd model and integrating the platform with other behaviour information. The BMI factor is computed considering the weight divided by the square of height. The criteria used for BMI to generate preferred walking speed for each individual crowd using 'a' as an arbitrary value of maximum walking speed for short distances is as shown in Table V.

TABLE V
GENERATION OF PREFERRED WALKING SPEED BASED ON BMI

BMI	Category	Preferred Walking Speed (a = 2.5m/s)
Less than 18.5	Underweight	WalkingSpeed←(arc4random()%(a+1))+3a
18.5 to 24.9	Normal	WalkingSpeed←(arc4random()%a)+2a
25 to 29.9	Overweight	WalkingSpeed←(arc4random()%a)+a
30 and above	Obese	WalkingSpeed←(arc4random()%(a-2))+1

E. Crowd Interaction and Animation in Virtual Heritage

The area of applications of crowd simulation and rendering is usually for education, entertainment such as epic battles in video gaming, emergency training and evacuation, urban planning and architectural design in virtual city, virtual park, field, streets and theatre scenes, traffic engineering of pedestrians at railway stations, subways, stadiums and shopping centres, and policy making for marathon and more. However, crowd simulation and rendering in this research is significantly in a virtual heritage environment. A 360^0 panoramic view is used as the virtual heritage for present life. The panoramic view is sub-divided into tiles. Sub-divided tiles of panoramic view allow collision detection and avoidance for the agent not to collide with buildings or other heritage artifacts or another moving agents [29]. When the 360^0 view is scrolled, the crowd is still able to be dynamic in animation and movement. The movement of crowds obeys the three Newtonian Laws and this paper proposed the motion planning for crowd as shown in Fig. 11.

```
Algorithm: Motion Planning
Begin
    CROWD STRUCTURE
    Number_of_Characters: 200
    Density: no-crowded agents
    Directions: LEFT_LOCATION(-x,-y)
                RIGHT_LOCATION (x,y)
    BASIC HUMAN-LIKE BEHAVIOURS
    Newtonian 1st Law: An object at rest will stay at rest;
    an object in motion will stay in motion at
    At constant velocity unless acted upon by an
    unbalanced force.
    Newtonian 2nd Law: F=ma where F is the
    Force(Newton), m is the mass(kg) of the object and a
    is the acceleration(ms-2).
    Newtonian 3rd Law: For every action, there is an equal
    and opposite reaction.
    MOTION PLANNING
    Input: (int)ballname :(int)X_init :(int)Y_init :(int)agentSpeed
          :(int)agentRadius :(int)initRotate
    Output: values (?,?,?,?,?,?,?)
    For all agents in the database do
      X←(arc4random()%(PictureWidth-MaxDiam))+MaxRadius;
      Y←(arc4random()%(PictureHeight/2-MaxDiam));
      Radius←(arc4random()%(MaxRadius/2))+(MaxRadius/2);
      Speed←(arc4random()%6)+1;
                if(speed >3)
                speed←speed-7;
End
```

Fig. 11 Algorithm of Motion Planning for Present Crowd

V. RESULTS AND DISCUSSIONS

This research is elaborated through a virtual walkthrough application. In order to evaluate the application, a questionnaire is designed to obtain some feedbacks from various parties. With the questionnaire, the effectiveness of bringing the present and past lives of into digital cultural heritage to the user can be judged. The questionnaire consists of four parts 1) Construction and reconstruction of lives, 2) Graphical user interface, 3) General usability and 4) Audio learning. The respondents were required to rate their satisfaction based on a scale of 1 to 7 where the value of 1-3 is the lowest, 4-6 is the average and the value of 7 is the highest

degree of satisfaction in all of the parts. The first part consists of four questions 1) Are the intangible data collected for construction of present life and reconstruction of past life sufficient?, 2) Level of satisfaction in bringing present life through combination of virtual environment, acoustical model and dynamic crowd in the panoramic view?, 3) Level of satisfaction in bringing past life through the integration of social behaviours?, and 4) Level of satisfaction of the overall learning experience in bringing lives into digital cultural heritage through mobile platform?. The second part consists only one question which is on the level of satisfaction on the user interface of 360^0 panoramic view while the third part consists of three questions; 1) Are the virtual keys set on the testing mobile device user-friendly? 2) Does it have any potential to be used as a virtual tour application?, and 3) What is the possibility that you would download this application?. Finally, the last part is to evaluate the audio learning: How do you like the incorporation of acoustical heritage?.

In the evaluation of the virtual walkthrough application, a hundred participants were invited to evaluate the cultural heritage contents. The respondents comprise the public who are tourists, anthropologists, curators, managers from the hotel industries, the artists from the handicrafts and souvenir shops, and people who are interested in digital cultural heritage. The group consists of 52 males and 48 females with an average age of 21-33 and a proficiency in English. The result of the evaluation is summarised in Table VI. The respondents have given an average of 6.3 for Question (1), 6.2 for Question (2), 6.6 for Question (3), 6.5 for Question (4), 5.6 for Question (5), 6.0 for Question (6), 5.3 for Question (7), 6.5 for Question (8), and 5.8 for Question (9). The average rating is calculated based on (1) where n is the total number of respondents.

$$\sum_{i=1}^{100} = \frac{xi}{n} \quad (1)$$

TABLE VII
RESULTS OF THE VIRTUAL WALKTHROUGH APPLICATION

Questions	Average Rate of 100 Respondents
1) Are the intangible data collected for construction of present live and reconstruction of past life sufficient?	6.3
2) Level of satisfaction in bringing present life through combination of virtual environment, acoustical model and dynamic crowd in the panoramic view.	6.2
3) Level of satisfaction in bringing past life through the integration of social behaviours.	6.6
4) Level of satisfaction of the overall learning experience in bringing lives into digital cultural heritage through mobile platform.	6.5
5) Level of satisfaction on the user interface of 360^0 panoramic views?	5.6
6) Are the virtual keys set on the testing mobile device user-friendly?	6.0
7) Does it have any potential to be used as a virtual tour application?	5.3
8) What is the possibility that you would download this application?	6.5
9) How do you like the incorporation of acoustical heritage?	5.8

The primary idea of this research is to advertise historical monuments in an effort to attract tourists to the country. From the evaluation, the respondents have rated 6.3 on the sufficiency of the data collected for the two categories of present and past lives while 6.2 on the present life in digital cultural heritage. The respondents have also rated 6.6 on the past life in digital cultural heritage with integration of social behaviours. The overall question of past and present lives as the respondents also rate a new learning experience 6.5. The respondents have rated 5.6 for the 360° panoramic views of heritage sites as the images show the inner and outer surrounding of the heritage buildings explicitly, giving the users a better visual experience of the heritage sites. The respondents also rated 6.0 for the user-friendliness of the application as iPhone virtual keys using gestures such as scrolling and tap that are already common to the users. The respondent commented that the proposed application could also be used as a virtual tour for the tourists with the rate of 5.3. The respondents also rated 6.5 for the possibility of downloading this application, as it is easy to use and always available at App Store. Besides, the respondents have rated 5.8 for the incorporation of the acoustical model into virtual heritage application on mobile platform since it creates a balance and concise immersion for the users by providing a first-hand sensation of the environment before their physical visit.

From the evaluation, some feedbacks are gathered with respect to the nine questions. Many respondents agreed that the idea of managing the digital content like an archive is one of the good ways to make the walkthrough more enjoyable and interesting. Besides, the integrated in- formation from listening with prior knowledge can really address and enhance learning purpose as part of bringing present life into digital cultural heritage. The respondents also commented that for the past life, the resulting system generates a variety of real-time animations, all reflecting adequate social behaviours of the past life. Such a system would be particularly useful in a virtual tour application. In short, the respondents thought that the benefits of properly designed and implemented virtual walkthrough are enormous. At the basic level, a virtual visit gives equal chances for all learners irrespective of their time and place without physically being there. Therefore, a virtual walkthrough application can be an excellent guide for knowing and appreciating the present and past lives in digital cultural heritage. However, it is also clearly highlighted through the expert review that no particular comment is perfect from one particular comment, and thus any reasonable and conflicting feedbacks should also be combined in order to make the App more effective. Other questions which are mainly concerned with the user- friendliness of the virtual keys, interfaces and whether the App can be used as a virtual tour before visiting the country got very positive feedbacks from the respondents. In addition, users prefer to download the App if it is made available on the AppStore for free or for a minimal amount of charge. The respondents are also impressed with the psychoacoustic background sound that provides them better immersive fantasy or impression of the physical heritage sites they will soon visit.

VI. Conclusion and Future Work

As a conclusion, this paper has focused more on the proposed schemes, models and methods of bringing the present and past lives into digital cultural heritage as a demonstration walkthrough. The virtual walkthrough consists of rapid and efficient generation of 360° panoramic view [28] and acoustical modulation around the 360° azimuthal zones in panoramic view. Besides, crowd modelling has been introduced in 360° panoramic view in this paper.

Avatars are virtual characters that are often used in 3D computer graphics with key-framed animations at the interactive frame rates [18]. For future work, the avatars that can recognise each other and can be controlled by certain physical laws or rule-based behaviour models with an interactive scenario such as virtual exploration of the heritage sites. They can be introduced to allow the educational application to depict a particular place in a more flexible way as if the user is one of the avatars inside the virtual heritage application. Future work for crowd in 360° panoramic view, crowd can also be modelled in cubical panoramic view. Besides, animation of avatars involving more complex movements and interaction with other 3D characters [30] can be considered in the panoramic view of heritage sites. In other words, the avatar is created to deliver an imagination to the users inside the 360° panoramic views of the heritage sites as part of reconstruction of present life in digital cultural heritage.

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