Low Computational Cost Method for Crowd Simulation Rendering in Large Scale Virtual Heritage Environment

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ABSTRACT
In recreation of virtual cultural heritage sites and urban environment simulations, the rapid display of densely populated scenery is a common requirement. An empty virtual environment will diminish the immersive experience that the simulations suppose to present, that is why simulations of massive virtual characters are needed to deliver sensible immersive experience to the user. In recent years, the growth of research in this area has escalated and there has been many techniques developed in crowd simulations area, both for real-time and non-real-time rendering. In this paper, we present several significant related works in crowd simulation and crowd rendering. Our aims in this research is to address one of the crowd simulation problems which is crowd rendering in large scale virtual heritage environment. We were integrating range detection technique in order to produce low computational cost real-time rendering of virtual crowd in large scale virtual heritage environment. Since rendering large scale virtual heritage environment were already computational expensive, rendering crowd will add more load to the rendering process. Range detection technique was chosen because its ability to produce low computational cost compare to other rendering techniques.

Categories and Subject Descriptors
I.6.8 [Simulation and Modelling]: Type of Simulation – Animation, Combined, Continuous and Visual.

General Terms
Crowd Simulation, Crowd Rendering, Virtual Heritage, Virtual Environment.

Keywords
Real-Time Rendering, Large-Scale Simulation, Virtual Reality, Immersive.

1. INTRODUCTION
The wide use of computer graphics in education, entertainment, games, simulation, and virtual heritage applications has led it to become an important area of research. In simulation, it is important to create an interactive, complex, and realistic virtual world so that the user can have an immersive experience during navigation through the world [1]. As the size and complexity of the environments in the virtual world increased, it becomes more necessary to populate them with peoples, and this is the reason why rendering crowd in real-time has become crucial.

Generally, crowd simulation consists of three important areas. There are realism of behavioural [2], high-quality visualization [3], and convergence of both areas. Realism of behavioural is mainly used for simple 2D visualizations because most of the attentions are concentrated on simulating the behaviours of the group. High-quality visualization is regularly used for movie productions and computer games, this type of visualization give intention on producing more convincing visual rather than realism of behaviours. The convergences of both areas are mainly used for application like training systems. In order to make the training system more effective, the element of valid replication of the behaviours and high-quality visualization is added.

The purpose of this paper is to present some of the related work in crowd simulation, crowd rendering issues, a few types of crowd rendering methods that are usually used, and an overview on framework that will be used for developing crowd simulations in Ancient Malacca Virtual Walkthrough project. Afterward, we conclude our paper with some future research directions pertaining with the area.
2. RELATED WORK

In this section we will present an overview of the selected works related to the simulation of groups and crowds. We will also present project background that will be used in this research.

2.1 Real-Time Crowd Simulation

Real-time crowd simulation is a process of simulating the movement of a large number of animated characters or agents in the real-time virtual environment. Crowd movement in certain cases requires the agents to coordinate among themselves, follow after one another, walking in line or dispersing using different directions. All of these actions will contribute to the final collective behaviours of the crowd that must be achieved in real-time. Unlike non-real-time simulations which is able to know the full run of the simulated scenario, real-time simulations have to react to the situation as it unfolds in the moment. Real-time rendering of a large number of 3D characters is also a challenge, because it can exhaust the system resources quickly even for a powerful system [4].

Figure 1 show a timeline of the previous works that have been done in crowd simulation fields. A behavioural animation of human crowd was based on foundations of group simulations of much more simple entities, notably flocks of birds [5] and schools of fish [6]. Earliest procedural animation of flocks of virtual birds called Eurhythmy was developed from concept that was presented at The Electronic Theater at SIGGRAPH in 1985 and the final version was presented at Ars Electronica in 1989 [7]. The flock motion was achieved by a global vector force field guiding a flow of flocks. In his early work, Reynolds described a distributed behavioural model for simulating aggregate motion of a flock of birds. The idea was that a complex behaviour of a group of actors can be obtained by simple local rules for members of the group. The flock was simulated as a complex particle system, using the simulated birds, called boids, as the particles. Reynolds, later extended his work by including various steering behaviours as goal seeking, obstacle avoidance, path following, or fleeing [8], and introduced a simple finite-state machines behaviours controller and spatial queries optimizations for real-time interaction with groups of characters [9].

More recent work was studies on group modelling based on hierarchies. Niederberger et al. [10] proposed architecture of hierarchical and heterogeneous agents for real-time applications. Behaviours were defined through specialization of existing behaviours types and depend on multiple inheritances to create new types. An approach that has become more common now was geometry baking. By taking snapshots of vertex positions and normals, complete mesh descriptions were stored for each frame of animation as in the work of Ulicny et al. [11]. Another approach was through dynamic meshes, which was using systems of caches to reuse skeletal updates. A hybrid of baked meshes and dynamics meshes was found in Yersin et al. [12] where the graphics programming unit (GPU) was used to its fullest.

A real-time crowd model based on continuum dynamics has been proposed by Treuille et al. [13]. In their model, a dynamic potential field integrates global navigation with moving obstacles, efficiently solving for the motion of large crowd without the need for explicit collision avoidance. In addition, Mao et al. presented an effective and ready to use framework for real-time visualization of large-scale virtual crowd. Script that describes motion state and position information was use as input, provides convenient interface and makes the framework universal to almost all application of crowd simulation [14]. Recently, Berg et al. have introduced a multi-agent navigation algorithm using a simple and effective combination of high-level and low-level methods that model human spatial navigation. A pre-computed roadmap was used for global path planning and Reciprocal Velocity Obstacles was used for local navigation and collision avoidance [15].

2.2 Project Background

The Ancient Malacca Virtual Walkthrough [16] is a project that focuses on the modelling and visualization of Malacca city in 15th century. It is based on local and foreign sources, such as the Sejarah Melayu and the descriptions by Portuguese writer; Tome Pires described the city and the empire as an opulent and prosperous centre of maritime Malay civilizations. As a maritime empire, trading and commercial activities, both local and foreign, became the mainstay and the backbone of her economy. The focus area of visualization is Central Business and Administrative District of the Malacca Empire. The project is visualized in real-time rendering mode using SGI Onyx 3800 with 16 CPU, 32GB RAM and three Infinite Reality3 graphics pipes.

Figure 2 show a screen capture of Ancient Malacca Virtual Walkthrough. Currently, there is no crowd simulation done to this walkthrough project. The challenge of this project is to bring the visualization of crowd simulation to the project with low computational cost.
3. CROWD RENDERING
The complicated part when dealing with thousands of characters is the quantity of information that needs to be processed. Simple approaches, where virtual humans are processed one after another without specific order will produce high computational cost for both the central processing unit (CPU) and graphics processing unit (GPU). This is the reason why data that flows through the same path need to be grouped for an efficient use of the available computing power. Therefore, for the best simulation result, characters capable of facial and hand animation are simulated in the area near to the camera to improve believability, while for farther area, less expensive representations are used. Concerning efficiency of storage and data management, database must be used to store all the virtual human-related data. In this chapter we will discuss one of the major components in crowd simulation development which is rendering.

3.1 Crowd Rendering Issues
Figure 3 shows certain problems that arise when rendering crowd. For instance, collision avoidance problems for a group of peoples in the same place required different strategies in comparison with the methods used to avoid collision between individuals. Moreover, motion planning used in a group that walks together requires more information compared to individual motion planning. The trajectories computed for agents in the same group that walk together with similar speeds must be different even when they share the same environment and goals. In addition, other levels of behaviours can exist when treating crowd in this hierarchical structure. The group behaviours can be used to specify the way a group moves, behaves, and acts in order to fit different group structures (flocking, following, repulsion, attraction, etc). Individual abilities are also required in order to improve the autonomy and intelligence of crowd.

However, to render thousands of individuals, these complex behaviours cannot be provided individually due to the hardware constraints and computational time rates. Another problem relates on how to improve the intelligence and provide autonomy to scalable crowd, in real-time systems. Furthermore, the simulation of large crowd in real time requires many instances of similar characters, that why an algorithms to allow for each individual in the crowd to be unique is needed.

There are several techniques used to speed up rendering process in crowd simulation. Billboarded impostors are one of the methods used to speed up crowd rendering. Impostors are partially transparent textured polygons that contain a snapshot of a full 3D character and are always facing the camera. Aubel et al. [17] proposed dynamically generated impostors to render animated virtual humans. A different possibility for a fast crowd display is to use point-based rendering techniques. Wand and Strasser [18] presented a multiresolution rendering approach which unifies image based and polygonal rendering. An approach that has been getting new life is that of geometry baking. By taking snapshots of vertex positions and normal, complete mesh descriptions are stored for each frame of animation as in the work of Ulicny et al. [19]. Another approach to crowd rendering using geometry is through dynamic meshes as presented in the work of de Heras et al. [20], where dynamic meshes use systems of caches to reuse skeletal updates which are typically costly.

3.2 Types of Crowd Rendering Method
In recent years, researchers have applied several approaches, either separately or in combination, to develop crowd simulation in various graphics application. In this section, five of the crowd simulation approaches will be reviewed as shown in the figure 4.
Helbing et al. [25] have described that at medium and high densities, the motion of pedestrian crowds shows some striking analogies with the motion of fluids. For example, the footprints of pedestrians in snow look similar to streamlines of fluids or, again, the streams of pedestrians through standing crowds are analogous to riverbeds. Fluid-dynamic models describe how density and velocity change over time with the use of partial differential equations. Colombo and Rosini [26] presented a continuum model for pedestrian flow to describe typical features of this kind of flow such as some effects of panic. In particular, this model describes the possible over-compressions in a crowd and the fall in the outflow through a door of a panicking crowd jam. They considered the situation where a group of people needs to leave a corridor through a door. If the maximal outflow allowed by the door is low, then the transition to panic in the crowd approaching the door may likely cause a dramatic reduction in the actual outflow, decreasing the outflow even more.

**Particles**

The majority of pedestrian simulations take this particular approach, sometimes called the atomic approach. Early influential work was that of Craig Reynolds [5] who worked on simulations of flocks of birds, herds of land animals and schools of fish. Each particle, or boid, was implemented as an individual actor which navigates according to its own perception of the environment, the simulated laws of physics, and a simple set of behavioural patterns. Later work Reynolds [8] extends the concepts to the general idea of ‘autonomous characters’, with an emphasis on animation and games applications. Bouvier et al. [27] describe a generic particle model and apply it to both the problem of pedestrian simulation and to the apparently distinct problem of airbag deployment. They present software allowing the statistical simulation of the dynamic behaviour of a generic particle system. In their system, the particle system was defined in terms of:

1. The particle types - mass, lifetime, diffusion properties, charge, drag, interactions with surfaces, visualisation parameters
2. The particle sources or generators - size, geometry, rate and direction of emission
3. The 3D geometry, including obstacles
4. The evolution of particles within the system

**Agent Based**

Agent based are computational models [28] that build social structures from the “bottom-up”, by simulating individuals with virtual agents, and creating emergent organizations out of the operation of rules that govern interactions among agents. Bonabeau [29] supported the following point of view: in agent terms, collective panic behaviour is an emergent phenomenon that results from relatively complex individual-level behaviour and interactions among individuals; the agent based seems ideally suited to provide valuable insights into the mechanisms and preconditions for panic and jamming by in-coordination. In the last few years, the agent based technique has been used to study crowd evacuation in various situations. Agents based are generally more
computationally expensive than cellular automata, social force, fluid-dynamic or particles models. However, their ability to allow each pedestrian to have unique behaviours makes it much easier to model heterogeneous humans, which are groups that contain individual with difference characteristic.

4. CROWD RENDERING FOR VIRTUAL HERITAGE LARGE-SCALE ENVIRONMENT

Propose of this research project is to crowd simulation into the Ancient Malacca Virtual Walkthrough. Ulicny et al. [11] has proposed Crowdbrush as an approach to create complex scenes involving thousands of animated individuals in a simple and intuitive way. By employing a brush metaphor, analogous to the tools used in image manipulation programs, they can distribute, modify and control crowd members in real-time with immediate visual feedback. They define concepts of operators and instance properties that allow creating and managing variety in populations of virtual humans. An efficient technique allowing rendering up to several thousands of fully three-dimensional polygonal characters with keyframed animations at interactive framerates is presented. Millan et al. [30] present another technique suitable to render large crowds of characters that takes advantage of existing programmable graphics hardware. Impostors are used for low-detail representation, while pseudo-instancing is used for higher detail. Their technique also used a LOD map to select between both representations, based on a customizable threshold.

Figure 7 shows the overview of our framework for crowd rendering in Ancient Malacca Virtual Walkthrough [31]. In the beginning, user will run the walkthrough using user interface provided. Database will store all the models and objects, either static or dynamic in database manager. Before rendering start, view frustum culling will be used to cull any unneeded objects from the walkthrough system. View frustum culling that will be used here is a new improved technique that is developed to reduce the computational cost of virtual heritage application. This technique is named as Range Detection Technique (RDT) [32]. It is based on the View Frustum Culling (VFC) method. The conventional VFC method tested the intersection of six planes using the plane equation to determine the visibility scope. Unlike conventional VFC technique, RDT is based on camera referential points and test the 3D objects whether they are in the viewing range or not. RDT execute the testing with the combination of bounding volume.

The database manager will be called to render all objects after crowd rendering starts. A fragment program will read the character pixel buffer as a texture, and then will update the attributes for characters. The new position and heading will be then copied to a new character pixel buffer. Both character pixels buffers can be swapped after the rendering procedure has finished. This pass can also include the update of the animation frame for characters.

This framework will utilized particle system technique for simulating crowd behavior in crowd rendering part. Particle system will calculate and recalculate each character destination during the simulation. From this calculation, the crowd can move randomly throughout the Ancient Malacca terrain within the boundaries that has been set earlier in the particle system. Using collision detection, each character that collides with other character will turn around randomly into another direction and continue walking to a new destination that has been calculated in particle system. Collision detection and height-map are added into the crowd rendering to add realism of the crowd movement. Using height-map, the crowd can move ups and downs along the terrain provided in the Ancient Malacca Virtual Walkthrough. Lastly, the system will update the simulation for user visualization.

5. CONCLUSION & FUTURE WORK

In this paper we have presented some of the related work in crowd simulation, crowd rendering issues, a few types of common crowd rendering methods, and an overview of the framework that will be used for developing crowd simulations in Ancient Malacca Virtual Walkthrough project. For the future work, there are rooms of improvement to the framework developed. As the framework will be using CPU for the entire processing task, we can also make use the power of nowadays GPU to take part in the processing task. This will make the application not only rely with the CPU but also distribute the task to GPU. As conclusion, we hope that this research is useful for the virtual walkthrough system developer. Consequently, it can also benefit the virtual heritage community.
6. ACKNOWLEDGEMENT

We would like express our appreciation to Malaysian Ministry Of Science, Technology and Innovation under eScienceFund grant (01-01-06-SF0472) for financial support of this research. We also like to thanks Creative Application Development Centre (CADC), Multimedia Development Corporation, Cyberjaya, Malaysia for allowing us to use the 3d model taken from Ancient Malacca project and permit us to explore the potential improvement of the project.

7. REFERENCES


