A Review of Collision Avoidance Technique for Crowd Simulation

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Abstract— **Crowd systems are widely being exploited in a number of virtual environment applications such as games, virtual world and entertainment. These kinds of applications can provide the immersive feeling into the static scenes and therefore enhancing the reality of the systems. The problems involved in crowd modelling when we only focus on the crowds. For instance, the collision avoidance among a large number of individuals in the same area requires different resolving strategies in comparison with the methods used to avoid collisions between just two individuals. Collision avoidance is an important element that needs to be tackled if we want to simulate the crowd system. By utilizing the collision avoidance, it will produce higher level of realism of crowd system as well as to make the system becomes more interesting. This paper investigates the importance of collision avoidance for crowd system in virtual environment. The comparisons among previous techniques have been presented here in order to aid the selection of our future research direction.**

Keywords-collision; crowd; collision avoidance; crowd simulation;

I. INTRODUCTION

Crowd systems are widely being exploited in a number of virtual environment applications such as games, virtual world, and entertainment. These kinds of applications can provide the immersive feeling into the static scene and therefore enhancing the reality of the systems. Realistic and believable crowd simulation is one of the important parts in computer graphics application. Normally, crowd simulation is separated by two type of categories which are real-time crowd and none real-time crowd applications [1]. We always seen real-time crowd application in games, which means real-time crowd application allows us interact with them. As known, real-time in games means actions that user have done is reflected by the actor in the game simultaneously. While, none real-time crowd simulation is normally used in film productions as a simulation. In none real-time crowd application, there is no interaction with users and the crowd simulate without any controller by user. In order to ensure that this element deliver the best result, fast and efficient collision avoidance is required.

In crowd simulation, high quality rendering alone could not guarantee user satisfaction. In commercial games, sometimes there are things that we being taken for granted. For example, in certain crowd simulation it is common to see a crowd with no or lack collision between object. It will look like a city of ghost where the objects penetrate each other. Although it may seem slightness, it gives an impression that you are not really there at all. There are also example where collision avoidance not working properly; resulting in unexpected behaviour. Therefore efficient collision avoidance is important in crowd simulation and need to be conducted properly in order to produce a believable crowd simulation.

II. CRWOD SIMULATION

At the present time, crowd simulations become a popular issue that needed to concern. This issue has been simulated in virtual environment with different purposes. Nowadays, there are lot of applications that used crowd modelling such as entertainment, simulation, and virtual heritage applications. Crowds mean hundreds or thousands humans or pedestrians which is must be rendered in real-time [2].

Crowds are part of our life. In real world most crowds are safe and some can be dangerous. There are some incident about the dangerous crowds when the crowds is crushed during the Hajj, and crushed at the Lantern Festival in Beijing. Crowd effects are not only limited in exterior settings, for example architects design a large hall, they also needed to concern about the crowd exit behaviour in any situation to avoid disaster [3]. In this condition, they need to simulate the crowd in their architects design to testing their design fitting for big crowd and situation.

On the other hand, crowd simulation also used in urban engineering to evaluates the authenticity or risk of pedestrian space in urban environment such as public building. Henein and White (2004) said that, good models of crowds can be very helpful to many professionals [3].

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III. COLLISION AVOIDANCE IN CROWD SYSTEM

Nowadays, there are various computer applications growth rapidly such as computer game and training simulation. Through these issues, the need of simulation perform in real-time is increase such as crowd simulation. One of the main issues that needed to focus in crowd simulation is collision avoidance. The advantage of using collision avoidance rather detecting collision is no overhead cost. While detecting and resolving collision in crowd also highly difficult depends on the size of crowd.

There are many researchers used collision avoidance approach to model flock, herd, and large crowds of people. Flocking is one of the pioneer techniques that used to model a crowd of animals or humans [4]. There are three rules of thumbs that must be followed; steer away from neighbour and obstacle, steer towards the centre of nearby entities, and steer in the average velocity with group of entities and maintain the direction with the neighbours.

In crowd simulation, there are two types of obstacle that we must concern, which are static and dynamic object. Static object refers to the motionless object such as building, furniture and trees, while dynamic objects refers to the lively objects such as human, animals, and vehicles. Handling collision avoidance among large number of individuals in the same area requires different resolving strategies in comparison with the method used to avoid collision between just two individuals. In crowd simulation, human avoid others and obstacle in their environment in a complex way. Sometimes their response is waiting and give the others to move first and sometimes their move aside while continue walking.

Collision avoidance is one of the crucial problems in crowd simulation. Without collision avoidance crowd simulation doesn't look realistic. For example, can you imagine the world without collision avoidance, it's so horrible. Seeing like the city of ghost. All human penetrate each other and other obstacle. So, to make a realistic and efficient crowd simulation; collision avoidance must be applied. There are many collision avoidance techniques that have been done by previous researchers. For example short-term avoidance algorithm [5], Multi-resolution collision detection algorithm [6], and flocking system[4]. All this technique already proved in their research area.

IV. THE NEED OF COLLISION AVOIDANCE IN CRWOD SIMULATION

Human avoid the others and objects in the street using a complex way. Sometimes they wait, sometimes they move aside while walking and sometimes they change their direction to avoid the collision in their path. In order to make an efficient and believability crowd simulation all the behaviour that mention above should be implemented. The better performance of crowd simulation shows in lots of film production such as, The Chronicle of Narnia and The Lord of The Ring series. From that film, you can see a realistically crowd simulation implemented in it.

Nowadays, crowd simulation is widely used in real-time application, such as computer games. In this application the realistic and believability crowd simulation is really needed. The lack of crowd simulation implemented in it can make the player be trapped in bored situation. If that happen, the game become worst and not interesting at all. In order to create a believability crowd simulation, collision avoidance must be implemented. Collision avoidance is used to handle the collision before it's occurred in crowd simulation. The lack of collision avoidance system in crowd simulation can make the crowd looks horrible.

Creating simulation of pedestrians walking in urban simulation is an example that shows the importance to implement the collision avoidance in crowd system. Unrealistic crowd simulation will occurred if there is no implementation of collision avoidance.

V. TMELINE OF IMPLEMENTED COLLISION AVOIDANCE IN CROWD SIMULATION

Crowd simulation is a process of simulating the movement of a large number of animated characters, agents or pedestrians in the virtual environment [7]. Crowd movement in certain situation requires the agents monitoring among themselves, follow each other, walking inline or avoid the obstacle using different directions. All of these actions will contribute to the final collective behaviour of the crowds that must be achieves in order to create efficient crowd simulation. Figure 1.0 shows the timeline on previous work about collision avoidance in crowd simulation.

The technique that suggested by Reynolds (1987) is rule-based technique. This technique presents the way to handle and produce natural looking group of agents. The simple steering behaviours such as separation, alignment and cohesion are used to simulate groups of agents. The behaviour rules can automatically control the agent from conflicting with each other [4].

Musse and Thalmann (1997), proposed a model of human crowd behaviour to simulate the motion of generic population in a specific environment. In this model they also proposed a multi-resolution collision avoidance to handle the collision in their crowd animation. This techniques use some concepts of multi-resolution in order to decide which method of collision must be applied. From that they implemented two types of collision avoidance, which are collision avoidance type 1 and collision avoidance type 2. Collision Avoidance Type 1 represents the technique that involves intersection of two lines and distance between two points in order to detect possible collision events. If two virtual humans are potentially colliding, only one will be allowed to go on first with its path. The latter method is also simple. This method is based on the direction change. Human in this method can predict the collision event by knowing the position of the next virtual human. A simple calculation is used to detect the intersection of two lines. From that the virtual human can avoid the collision by changing its direction using angular velocity. After

sometime, the virtual human returns to their old direction. These two types of collision is complement each other. From the study in this technique, they proposed this two types of technique based on two situations. Collision avoidance type 1 is preferred when the virtual human does not have enough time to change their direction due to the distance between two collision points is to close while collision avoidance type 2 is used in a situation where the agent is far from the others [6].

Reynolds (1999), is extended research from [4]. In this research they add several of steering behaviours, obstacle avoidance and path following, or fleeing. The collision method that used in this simulation is based on path finding. In this case, path finding is used to detect another object in their trajectory. From that we can calculate the distance between two objects using mid-point of each object and compare that distance with the sum distance of two objects. If the new distance is large than old distance, the boids continue their movement. If the new distance is small than old distance, the boids must change their direction to avoid the collision occur [8].

Feurtey (2000), proposed an algorithm for collision avoidance in crowd simulation. Based on his study, he mentions that each agent is able to plan a safe trajectory from their current position till end using the information about position and speed of the obstacles to forecast their way. The calculation in this technique is based on the predicting and modifying trajectories in (x, y, t) space. From that they using a cone to delimitate the available space based on the analysis of others' trajectories and speed. Even though this technique almost perfect, but it is not scalable to a large group of human (over 100 people) [9].

Tecchia and Chrysanthou (2000), proposed a simple and fast collision detection method with an application to densely populated urban environment. In this method they used two different approaches for detecting and avoiding collision of the moving objects. The principle is same in both cases. They assigned the direction for each particle moves, then they check the presence of obstacles in front of it using the information that stored in the height-map. In the first case they check the position that the particle is going to occupy after the current movement, then that position is computed and mapped onto the height-map. After that, if height between two particles point is really close, the particle movement is considered valid and it's allowed to move there. While, the new trajectory need to found if the difference of height between two points is too large. In the second case we shift the collision detection task ahead of the current particle position [10].

Based on Loscos et al. (2003), one of the behavioural that they concern is collision avoidance behaviour. In this type of collision behaviour, they used collision map to detect collision detection. In this method, they check up five tiles ahead to avoid unpredicted collision. The checking collision detection in this technique is based on the information that stored in a grid. They proposed three main cases of collision between two agents, which are front, following and perpendicular. In this technique, they compare the direction of each agent, the velocity factor and the distance between agents. Based on this parameter, they make a decision. Either to change their direction or to slow down the agent or to completely stops the agent. In these cases, the option to change the direction is depending on the distance to the other agent [11].

Metoyer and Hodgins (2003), said that the intelligence model should produce correct 2D motion in terms of avoiding obstacles and find their goals. As 2D real-time pedestrian simulation, the pedestrian is highly potential to collide each other and the user is visually alerted to the situation. The user can stop the simulation and provide direction from the following set of navigation primitives: yield, cut-in-front, go-around-right, go-around-left, and no-action. Based their research, they are only concern with two of these tasks which are monitoring and yielding. These two tasks chosen because these task are relevant to avoid collision between two pedestrians. Monitoring refers to act of observing pedestrians in the nearby area to determine their navigation intentions. While, yielding refers to the act of adjusting velocity (magnitude or direction) in order to avoid a potential collision. Yield primitive design to alter the velocity of the pedestrian so that it allows another pedestrian to move pass safely. They divide the handle the yielding primitive in two situations which are cut-in-front and go-around primitive. Once the collision danger has passed the pedestrians change back to their original desired velocity [12].

Lamarche and Donikian (2004), proposed the collision avoidance algorithm which is used a linear trajectory extrapolation for collision prediction and a local optimization algorithm for the computation of a new speed avoiding collisions. This algorithm is configured with collision reaction modules describing possible typologies of reaction. In collision prediction, there are four types of collision that used to configure the local avoidance algorithm with a subscription of collision avoidance to different types of collision. In collision reaction modules, the reactions adopted when avoiding collision can be classified in two categories: speed modification and direction modification [13].

Sung et al. (2005) proposed a new technique to detect collision in crowd simulation using motion oriented bounding box (MOBB tree), based on the motion capture data. This algorithm is for identifying potential collision between motion clip and hence animated characters. In this technique, they check the interaction between characters on every frame and exploit the data driven animation. In this case, they can check entire motion for collision before it occurs. Based on this technique, they considers collision problem in two motions. First collision problem is along with motion is their transformations that place their starting points in space. Each motion may have a time offset, and collision must be detected at anytime during the duration of

the motions, the bounding cylinders for the characters associated with the motions overlap. If the character is spatially disjoint, or at the same place at different time, there are no collision happen [14].

On the other hand, Sakuma et al. (2005) also introduced a technique to detect collision in crowd system. Collision avoidance behaviour suggested that the environmental information should be stored in virtual memory. If no collision information is found in the memory, the agent can keep walking along the vector field. The optimum avoidance behaviour is to select either its urgent or smooth avoidances, when the future collision is detected. There are several rules to be followed:

- **Urgent avoidance** - The agent swiftly slow down or harshly turn by side stepping when another agent is detected in the critical area of personal space.
- **Smooth avoidance** – if they have enough time to avoid collision, they can move to the other side slowly.

After collision avoidance situation, the agent tries to find some space and make a decision to return to a normal walking. Otherwise, the collision avoidance technique will make the agent to move to other side once confronted with each other. If there is no space in front of the agents, the waiting behaviour is restored to initial position [15].

Morini et al. (2007), proposed new method for collision avoidance, short-term avoidance. The goal of this method is to handle thousands of pedestrians in real-time. In this paper they divide the scene into multiple regions of varying interest, defined at initialization and modified at runtime. They define the regions with a level of interest. This method used a simplified low-level agent-based approach which is used to efficiently avoid the local inter-pedestrian collision in two regions. The avoidance in this method is based on two values: a security distance and emergency distance. These two values are already fixed [5].

Based on Yersin et al. (2008), they proposed an improved short-term collision avoidance algorithm and simple efficient group behaviour, but this section only focuses on collision avoidance technique. This technique based on the path planning and the path selection criteria are the avoidance of congested zones and minimization of distance and travel time. In this technique, they provide long and short term avoidance. Long-term avoidance predicts possible collisions and inhibits them. While short-term avoidance intervenes when long-term avoidance cannot prevent the collision. This improvement short-term algorithm is also based on two values; security distance and emergency distance [16].

VI. CONCLUSION

In crowd simulation, collision avoidance becomes an important aspect in order to determine the realism and believability of virtual crowd conceptually. Generally, avoiding object interferences has variety methods, such as short-term avoidance and multi-resolution technique. To answer the question which one is the most effective collision avoidance method in order to solve the intersection problem still indecisive. Accurate collision avoidance algorithm makes the computational cost more expensive compare with the speedy collision avoidance.

Most collision avoidance method that has been used in crowd simulation is concentrate on using three parameter values which are distance, direction and velocity. Based on study of various papers regarding collision avoidance in crowd simulation, collision avoidance covered only small parts of the simulation as most crowd simulation project just concentrate on modelling and rendering the crowd system. [5], is one the successful crowd simulation using short-term avoidance technique. However, three parameters values that mention before commonly used in general virtual environment and not in specific conditions like crowd simulation. Thus, this motivated us to introduce new collision avoidance technique that can be used in crowd simulation.

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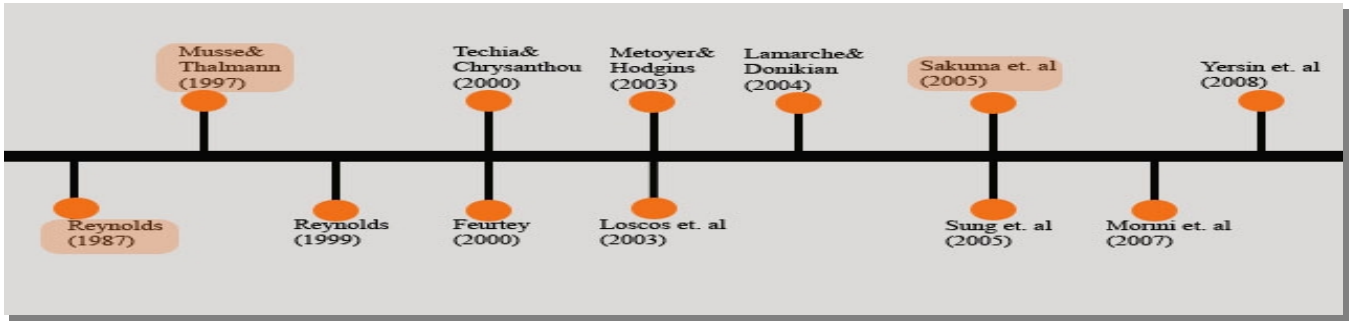

Figure 1. This figure shows timeline on previous work for crowd simulation that concern on collision avoidance.