Crowd Flow Collisions Simulation

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***Abstract*—The study of crowd scenes has become an interesting research area. Crowd flow collision is a critical problem since it may cause injuries or death to people. Current research methods on crowd flow collisions are only confined in 1D and 2D straight line directions. In this paper, we propose a 3D simulation for crowd flow collisions in different directions within an entry and an exit at a gate. The simulation efficiency is decreased when a number of agents is increased. The simulation frames per second are dropped below 35 when the characters are more than 100.**

***Index Terms*—crowd; flow; collisions; simulation;**

I. Introduction

Crowd is defined as collection of small groups of people gathering and occupying a common area such as entry and exit from the gates, stadiums, city squares, etc. The crowd is characterized by gatherings of hundreds or thousands of people, in these common areas. Crowd understanding has drawn increasing attention from the computer vision community. Managing the crowd has become necessary for the public safety and security [1]. Crowd scene investigations and their monitoring is very evolving field of learning. Large crowds can easily cause congestion and increase the potential for the development of highly unstable conditions [2]. Figure 1 shows an example of a 3D simulation of a small crowd in a specific area.

Crowd simulation has become an important research topic in computer vision and virtual reality. Simulation is the process of imitating a real thing or circumstance or practical process. It generally contains some basic characteristics of the physical or abstract behavior of the system. It is used in many important contexts that serve humans, including simulation of natural and human systems models to expand perception and understanding the functions of these systems. Simulation can be used for industrial security, engineering processes, materials testing, training, education, scientific research to show the real effects of alternative situations for different workflows and actions. Crowd simulation can play a crucial role when it comes to the design of smart environments in which it can give insights on the flow of pedestrian in particular facilities [3]. Simulation of crowd is used to examine whether civil structures are safe or not for people during emergency evacuations. It is also used to identify the efficiency of places such as pedestrian bridges, big buildings, stadiums and metro stations. Simulation of crowd movement is also used in animations and entertainment software [4].

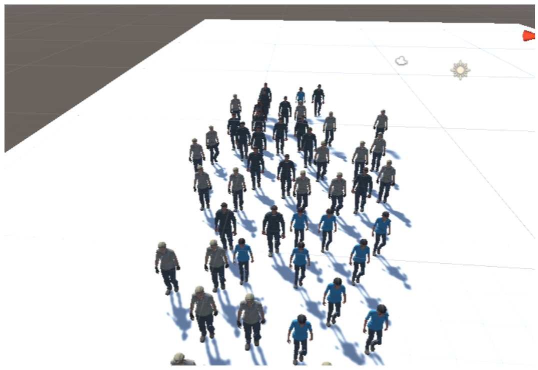

Fig. 1: An example of a 3D simulation of a small crowd in a specific area.

Crowd simulations can be represented into two ways [5]. The first way focuses on the realism while the second type focuses on the high- quality visualization. In the first type, the visualization of simulations such as evacuation and training applications is not crucial, and often a simple yet intuitive 2-dimentional (2D) simulation is sufficient. The visualization is only used to help users to better understand the simulation process. In the second way, applications are used in film production and video games. The emphasis on the second type is primarily on high- quality animation techniques to achieve convincing visual effects. Our work in this research is based on the second type of simulation. In this work, we build a 3D simulation for crowd flow collisions in different directions within an entry and an exit at a gate. Simulation frames are computed per second. The simulation efficiency is decreased when a number of agents is increased. The frames are dropped below 35 when the individual agents are more than 100.

The remainder of this paper is organized as follows. We present the related work in **Section II**. In **Section III**, we simulate crowd flow collisions in different directions within the entry and exit at the gate. Then, the simulation efficiency is measured in **Section IV**. Finally, we conclude our work in **Section V**.

II. Related Work

The study of crowd scenes has become an interesting research area. Survies on crowd had been published in [6], [7], and [8]. Zhan et al. [6] reviewed some crowd analysis works in computer vision from sociology, psycology, and computer graphics perspectives. Fang et al. [7] studied the crowd movement and dynamics model in China, more specificly in Wuhan during their busiest season. Grant et al. [8] analyzed crowd statistics and behavior understanding. Also, a summary of crowd activity video datasets is provided.

He et al. [9]. proposed a method to develop a crowd simulation model with dynamic group behaviors. A hierarchy composed of virtual groups and agents was adopted. The agents were divided into leader-agent and follower-agents. A database table of all groups was maintained. A respective dynamic database was used to store the state of all the agents for every group. Their proposed method was very useful on high-density crowds.

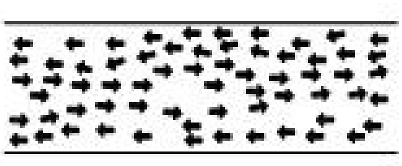

Fig. 2: Two-way crowd flow [10].

Wei et al. [11] proposed a system to develop a crowd simulation system based on agents, which uses a potential field model and a social force model to represent the interaction and interrelation of people to obtain the direction and speed of pedestrians. Perception of obstacles was the prerequisite for an agent to understand the environment and make decision autonomously. To emulate human's perception ability in simulation, geometric-based method was adopted to describe the region in which collision possibly occurred. For example, a rectangle or a circle was specified around an agent. This simplification reduced the precision but improved the computation efficiency. Therefore, it was more suitable for large-scale crowd simulation. In their simulation system, the agent was required to obtain information about the position and velocity of the surrounding obstacles before the movement. In their work, three types of collisions were categorized depending on the human state.

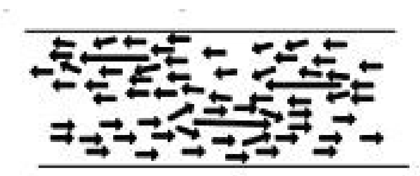

Fig. 3: Heterogeneous crowd flow [10].

Liu et al. [10] proposed a simulation on crowd risk to provide a reference for crowd security management in large gathering spots. Four common crowd flows were introduced including two-way flow, heterogeneous crowd flow, circular flow and arching phenomenon. They also analyzed on the basis of investigation of crowd route selection. The formation mechanism of crowd risk was consisted of four stages namely free movement, retention, congestion and stampede. Their simulation introduced different crowd flows in 2D as shown in Figure Figure 2, Figure 3, and Figure 4. Current research methods on crowd flow collisions are only confined in 1D and 2D straight line directions. In our work, we simulate the aforementioned cases in three dimensions within an entry and an exit at a gate.

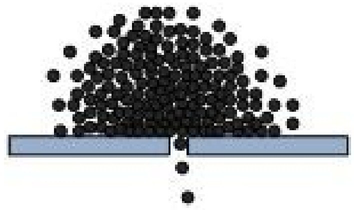

Fig. 4: Heterogeneous crowd flow [10].

III. Our Work

In this section, we present the three dimensions simulations for two-way and heterogenous crowd flow collisions. Then, we measure the simulation efficiency.

Four different agents are created to simulate the crowd flow collisions in three dimensions. Each agents has a speed and a weight. The agents have different structures. Unity platform provide the gravity by default. Different numbers of agents are used. A maximum number of agents is used is 100. In our simulation, each character has his own animation due to the variations of speeds and weights. Figure 5 shows types of agent are used in our simulation.

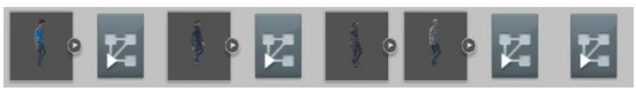

Fig. 5: Types of agent are used in our simulation.

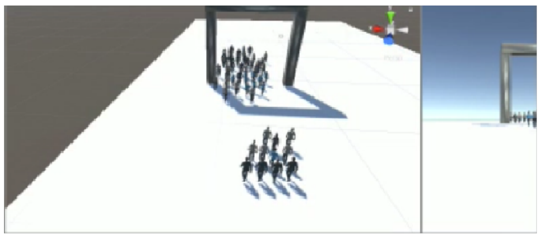

Fig. 6: A simulation for two-way case before collisions.

Fig. 7: A simulation for two-way case during collisions.

A. Two-Way Crowd Flow Collisions

The opposite movement of agents is often seen on streets and sidewalks. Agents with opposite movement directions form their own walking path are met at the gate. Figure 6 and Figure 7 shows simulations for crowd flow before and during collisions in a two-way case.

B. Intersection Crowd Flow Collisions

In this case, collisions may occur when one agent crosses an opposing path of traffic or side impacts when one agents crosses the path of an adjoining agents at an intersection. The formation of this collision can reduce the speed of the crowd. Figure 8 and Figure 9 shows simulations for crowd flow collisions before and during collisions in an intersection case.

Fig. 8: A simulation for intersection case before collisions.

Fig. 9: A simulation for intersection case during collisions.

C. Heterogeneous Crowd Flow Collisions

Agents movement behavior and walking speed is quite different. For example, the walking speed of the elderly, children, and frail agents is relatively slow. If population density is low, young agents pass the agents who walk slowly. There is a vortex around this character to pass other characters as shown in Figure 10. The red circle in the simulation for heterogenous case indicates the collisions.

Fig. 10: A simulation for heterogeneous case during collisions.

IV. Simulation Experiment

We have run many simulations using Unity [12]. Unity is a cross-platform and a tool to create a complex and varied content of crowd scenarios with a large number of virtual actors. A large-scale crowd scene the current crowd simulation software is able to be generated in real time. However, complex crowd scenes may require high and expensive computing resource to fasten the simulation process. Our results ran on a 2.00G i7 4750HQ with a NVIDIA GTX950M graphics card. Our experiment showed that many of agents could be simulated naturally in a normal scene. The simulation efficiency is decreased when a number of agents is increased. The frame per second is dropped below 35 when the individual agents are more than 100 as shown in Figure 11.

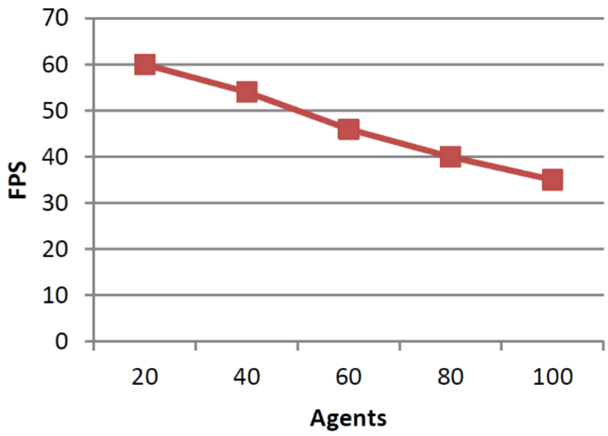

Fig. 11: Simulation efficiency using Unity.

V. Conclusion

In this paper, we propose a 3D simulation for crowd flow collisions in different directions within an entry and an exit at a gate. The simulation efficiency is decreased when a number of agents is increased. The simulation frames per second are dropped below 35 when the characters are more than 100.

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