System Issues in Multi-agent Simulation of Large Crowds

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Abstract. Crowd simulation is a complex and challenging domain. Crowds demonstrate many complex behaviours and are consequently difficult to model for realistic simulation systems. Analyzing crowd dynamics has been an active area of research and efforts have been made to develop models to explain crowd behaviour. In this paper we describe an agent based simulation of crowds, based on a continuous field force model. Our simulation can handle movement of crowds over complex terrains and we have been able to simulate scenarios like clogging of exits during emergency evacuation situations. The focus of this paper, however, is on the scalability issues for such a multi-agent based crowd simulation system. We believe that scalability is an important criterion for rescue simulation systems. To realistically model a disaster scenario for a large city, the system should ideally scale up to accommodate hundreds of thousands of agents. We discuss the attempts made so far to meet this challenge, and try to identify the architectural and system constraints that limit scalability. Thereafter we propose a novel technique which could be used to richly simulate huge crowds.

1 Introduction

Simulating large crowds in rescue simulation systems throws up many challenges. For one, crowd events and their associated phenomenon are difficult to model. Crowds demonstrate a variety of emergent behaviours based on the behaviour of individuals in the crowd. Crowd dynamics have been extensively studied in the past and various socio-psychological and physiological theories have been put forth to explain crowd behaviour. The complexity also stems from the fact that compared to a simulation with limited parameters, the level of detail that could be incorporated in the model for a realistic social simulation can be quite high. Analyzing crowd dynamics has been an active area of research. Different types of crowd simulation systems have been developed, ranging from those based on force-modelling approaches [1, 2] to cellular automata based simulations [7, 8, 9] and rule-based architectures [5, 6]. Recently, many agent-based architectures have been proposed [13, 18, 19]. The multi-agent paradigm is adequately suited...
to a crowd simulation application. Social factors can be better modelled as human characteristics can be objectively mapped to agent behaviour.

In this paper we present a multi-agent based crowd simulation system developed on a continuous field force model. Our model supports - heterogeneity in agents to model the demographics of a population, a complex navigational behaviour including obstacle avoidance and navigation in a terrain with partial information and flocking behaviour. As scalability is a vital criterion for the system to realistically model a disaster scenario for a large city with hundreds of thousands of people, we evaluate the issue of scalability for multi-agent based crowd simulation systems. The organization of the paper is as follows. We discuss the environment model that we use for our simulations in Section 2. We then move on to propose a novel technique for simulation of large crowds in Section 3. We present our results in Section 4.

2 Background and Related Work

Amongst the different approaches to model crowd behaviour, one which has been widely put to use is the force based model developed by Dirk Helbing et al.\cite{helbing1,helbing2}. This model tries to simulate the motion of each individual in a crowd (henceforth referred to as a civilian) under forces that are exerted by other civilians and inanimate objects. Each civilian feels, and exerts on others, two kinds of forces, “social” and physical. The social forces are not exactly physical forces such as a push or a pull; they reflect the intentions of a civilian to avoid collisions and to move in a chosen direction. The movement of the civilian can be tracked by equations defining his motion under the sum of all forces. Further refinements were suggested in\cite{helbing3}. One problem with Helbing’s model is with its computational complexity. Every civilian must be tracked with respect to every other civilian to calculate the net force acting on it. Alternative approaches proposed\cite{helbing3} avoid computing every agent’s effect on all the others. While the model has been successful in simulating a number of crowd behaviours demonstrated by real-life crowds, particularly arch formation at exits in egress situations, scalability issues were not tackled. The model by itself does not incorporate navigation models, or any form of social interaction.

Cellular Automata based models have also been proposed most notably in\cite{cell1,cell2,cell3}. Cellular automata based simulations also model forces on a civilian, but are discrete in space and time. Efforts have been made to build multi-agent based systems for crowd simulation. Prominent among these are\cite{multiagent1,multiagent2,multiagent3,multiagent4,multiagent5}. However, scalability issues in multi-agent based crowd simulation systems have not been rigorously analyzed.

2.1 Background

We have attempted to develop a crowd simulation model which preserves the granularity of simulation at the individual level and at the same time is scalable and can richly simulate behaviour of huge crowds. The problem that we are trying to address is scaling up in terms of the number of civilians that can be