MAMA: Multi-Agent MAnagement of Crowds to Avoid Stampedes in Long Queues

(Extended Abstract)

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ABSTRACT

In places of reverence, wherein large crowds gather to have small time duration for individual solace, there is typically a long queue of people waiting for their turn. There have been cases of stampedes with significant loss of life and trauma during such situations because of lack of management of crowds. In this paper, we present MAMA a set of robotic agents that (i) can move at a height to (ii) provide direction and control the crowds to (iii) avoid situations for stampedes to occur. We modeled the problem, and built a multi agent simulation system to conduct experiments that show results of agents managing crowds at appropriate times to avoid possibility of occurring of stampedes.

Categories and Subject Descriptors

I.2.11 [**Distributed Artificial Intelligence**]: Multi-agent Systems; I.6 [**Simulation and Modeling**]

General Terms

Design, Management, Performance

Keywords

Crowd Management, Congestion, Stampede

1. INTRODUCTION

Every day hundreds of events are held across the world which attract large crowd gatherings. Anything unusual at these gatherings, like mass impulsive behavior, or a situation of panic, combined with deficient crowd management, is very likely to cause stampedes. This may result in people getting killed or injured [3]. Hence, avoiding such a crowd disaster (stampedes [1]) is an important issue to be addressed.

In this paper, we refer to a scenario of long queues at temples which occur when people come to spend a small amount of time to offer prayer in front of a deity, in a first come first serve manner. When very few people are visiting the temple, there is no waiting with free flow of people and each person can spend substantial amount of time in front of the deity. On auspicious occasions, there are many anxious people wanting to pray that result in (i) the queue moving very slowly, (ii) people getting tired (some of them might be fasting) and (iii) severe congestion leading to stampede due to over enthusiastic people pushing themselves with force in to the queue. By the time the crowd management force (police or security) at temples notices the stampede, the situation would have already gotten worse. This motivated us to introduce (crowd managing) agents that move at a height above the queue to manage the crowd by detecting and reducing congestion as soon as it occurs. The purpose of these agents is that they move and communicate more efficiently than the members of a crowd management force (police or security). A crowd managing agent is a robot that (i) monitors the crowd (through a camera), (ii) estimates the congestion levels (through image processing) and (iii) takes proactive steps to space out people in the queue to reduce congestion. We do not delve into design, construction and image processing aspects of the robots. The input to our multi-agent system is the current location of robots and the congestion levels as determined by them. The multi-agent system will move the robots to act and reduce congestion, allowing people to spend more time in front of the deity.

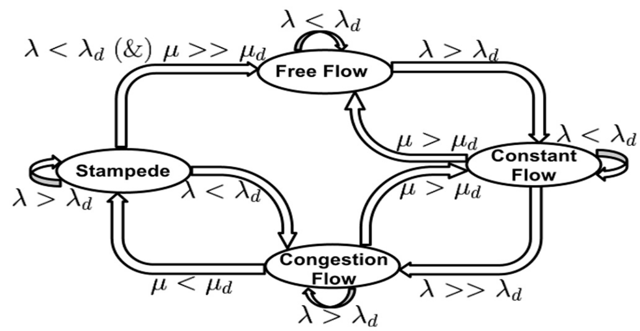

Figure 1: Different states of queueing at temples.

2. TEMPLE QUEUEING MODEL

In recent years, analyzing crowd dynamics has been an active area of research and numerous efforts have been made to develop models ([5, 4, 2]) to analyze crowd behaviors. Our simulator uses a force model based on the continuous social-force model by Helbing and Molnar [2], to simulate crowd behavior. The map of the environment is a continuous two dimensional grid with path of the queue and walls (queue fencing) on either side of the queue. A human agent H_i experiences three kinds of forces with which its parameters

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Table 1: A scenario where $\lambda_d = 2.4$ *agents/timestep*, $\mu_d = 3.2$ *agents/timestep*, $\delta_{max} = 200$ *timesteps* and $\delta_{min} = 60$ *timesteps*. δ and δ' are the time durations a person can spend to pray with and without introducing the crowd managing agents (CMAs) respectively.

λ	μ	State of Queueing	δ	Impact of actions taken by CMAs	δ'
0.5	3.1	Free flow	δ_{max}	No action required	δ_{max}
4.3	2.1	Congestion flow	89.3	$\mu \uparrow$=3.1	103.2
4.3	0.9	Congestion $\rightarrow$ Stampede	72.5	$\lambda \downarrow$=3.2 and $\mu \uparrow$=1.8	93.75
4.3	3.2	Constant flow	104.7	$\lambda \downarrow$=3.5	114.8
6	0.18	Stampede	δ_{min}	$\mu \uparrow$=2.3 and $\lambda \downarrow$=5.1	87.0
2.8	5.3	Constant flow $\rightarrow$ free flow	173.6	No action required	173.6

are updated, (i) force with which the human agent pushes itself into the queue ($\vec{F}_i^{des}$), (ii) force exerted by other human agents on this agent H_i ($\vec{F}_{ij}$) and (iii) force experienced due to the presense of walls ($\vec{F}_i^{w}$). The total force acting on a human agent H_i is given by, $\vec{F}_i = \vec{F}_i^{des} + \sum_{i \neq j} \vec{F}_{ij} + \vec{F}_i^{w}$

The different states of queuing at temples depends on the rate at which the people enter(λ) and the rate at which people exit(μ) the queue. Let λ_d and μ_d be the expected rates of people entering and exiting the queue, for which no stampedes are assumed to occur. Based on these parameters the states of queuing are (see Figure 1): (i) *Free flow:* When $\lambda < \lambda_d$, people tend to move freely with their maximum possible acceleration. (ii) *Constant Flow:* When $\lambda > \lambda_d$, people stabilize moving with either constant speed or negligible acceleration. Any increase in λ is very likely to result in congestion. (iii) *Congestion Flow:* When $\lambda >> \lambda_d$ and $\mu < \mu_d$, the crowd becomes agitated and people start exerting extreme forces on each other causing congestion in the queue. (iv) *Stampede:* When there is congestion in the queue and when $\mu << \mu_d$, this leads to stampede.

3. CROWD MANAGING ROBO AGENTS

Let there be γ crowd managing agents (robots) available for a temple. These are placed at equal distances along the whole queue. Each robot moves from one end to the other end of the area between two robots on either side of this robot. Once a robot detects congestion in the queue, it communicates the information regarding the congested area to other robots and crowd management force, who in turn alert the crowd to decrease their acceleration reducing the impact of congestion. The robots placed at entrance and exit are also guided to either decrease or increase the rate of people entering the queue (λ) and the rate of people exiting the queue (μ). That is, when congestion occurs, λ can be decreased so that there is no further increase in the congestion and μ can be increased creating space in between the queue to reduce congestion. A series of experiments are conducted using the simulator, with given parameters of a queue and varying the values of γ. The minimum experimental value of γ that resulted in a minimum stampede rate is the number of robots used when the system is deployed. The stampede rate is determined by the number of people who got injured, with respect to λ and μ in a scenario. The time duration(δ) a person can spend in front of a deity to pray usually varies depending on the state of the queue and can be calculated using λ and μ as estimated by these robots. If δ_{max} and δ_{min} are the maximum and minimum possible time durations, then $\delta = min(\ \delta_{min} + \frac{\mu}{\lambda}\delta_{min}\ ,\ \delta_{max}\ )$

The impact of the actions taken by the crowd managing robo agents depending on the determined arrival and exit rates are presented in Table 1. On an average δ' (with MAMA) is higher than δ (without MAMA). That is people get to spend longer in front of a deity than they get to spend without crowd management. The simulation results with and without MAMA are shown in Figure 2.

(a) **(b)**

Figure 2: Queue is flowing from left to right. (a) Without MAMA - Congestion leading to Stampede. (b) With MAMA - the impact of robots on detecting congestion (decrease in the arrival rate).

4. CONCLUSION

In this paper, we presented an approach of introducing the crowd managing agents which manage the crowd and communicate information more efficiently than the crowd management force, to achieve stampede free flow of people in long queues. The situation of congestion is put under control and people get to spend longer than the minimal time duration in front of the deity. Future work, includes methods to improve the efficiency of crowd managing agents and to use an optimal number of robots (at any point of time) to monitor the crowd in long queues.

5. REFERENCES

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