Simulating Riot for Virtual Crowds with a Social Communication Model

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Abstract. In this work we attempt to build a communication model to simulate a large variety of collective behaviors in the course of riot formation for virtual crowd. The proposed crowd simulation system, IMCrowd, has been implemented with a multi-agent system in which each agent has a local perception and autonomous abilities to improvise their actions. The algorithms used in our communication model in IMCrowd are based heavily on sociology research. Therefore, the collective behaviors can emerge out of the social process such as emotion contagion and conformity effect among individual agents. We have conducted several riot experiments and have reported the details of the correlation between the severity of a riot and three predefined factors: the size of the crowd, relative size of the parties, and initial position distribution of the crowd. We have found that crowd density and party size symmetry do affect the number of victims at the end. However, the initial distribution of the two parties does not significantly influence the index (number of victims) at the end.

Keywords: Virtual Crowd, Collective Behavior, Social Communication, Agent-Based Simulation, Computer Animation.

1 Introduction

Many applications can be benefited from crowd simulation, including entertainment, urban planning, emergency evacuation, and crowd behavior research for social sciences. However most previous efforts in crowd simulation focused on generating plausible animations for applications targeting more on visual effects without considering how communication among the agents could affect the behaviors of a crowd. These models are in general not adequate for investigating complex crowd behaviors because psychological and social factors, such as perception, emotional status, and communication mechanism, are either rarely concerned or greatly simplified. In [3], we have developed a system, IMCrowd, to simulate collective behaviors of virtual crowds. IMCrowd is built with an agent-based modeling approach and allows user to customize suggestive messages and other parameters to yield different kinds of collective behaviors and scenarios.

In this paper, we conduct several riot experiments to study how the related factors affect the end result of casualty numbers. In the next section, we will review the

P. Jędrzejowicz et al. (Eds.): ICCCI 2011, Part I, LNCS 6922, pp. 419–427, 2011.

literature related to collective behaviors and crowd simulation. Section 3 and 4 describe the system architecture of IMCrowd and the experimental environment, respectively. Section 5 presents the result of the riot simulation while Sections 6 are the conclusions and future work.

2 Literature Review

Psychologists and sociologists have studied the behaviors of groups of people for many years. They have been mainly interested in the collective behaviors which emerge from individuals under the influence of others in unexpected, sudden and unusual situations, named mass or crowd. In this case, people who are in a crowd act differently towards people, compared to those who are alone. They seem to lose their individual identities and adopt the behavior of the crowd entity, shaped by the collective actions of others.

LeBon Gustave [9] claimed that there were three steps of consensus process for the "casual crowd" behavior. The first step is that a crowd is prone to accept suggestions from others via communication. The second step is emotional contagion, which means the emotion of an individual can be infected by other nearby people in the crowd. The third, after they are infected by each other, an individual may substitute his or her self-consciousness with the group consciousness at certain situation. That explains why some individuals do something irrational in a crowd but they never do that when they are alone. Although the propositions of LeBon were made from observations, emotion contagion has been verified to some degree by modern psychologists [1][5]. Furthermore, Blumer's work argued that contagion occurred through "circular reaction" wherein individuals reciprocally respond to each other's stimulation [2]. That is, when individuals are exposed to a contagion environment, they reflect others' state of feeling and in so doing intensify this feeling as a form of positive feedback.

Granovetter proposed a threshold model [7] to explain why similar crowds may behave differently. He regarded that each rational individual's decision about whether to act or not depends on what others are doing. The threshold in this model means the number or proportion of other persons who take the action before a given person does so. It depends on personality as well as surrounding situations. The perception of other agents' behaviors via various ways of communications may have a "domino" or "bandwagon" effect on crowd behavior when the tipping point is reached (above the threshold value).

Referring to the work of Collin [4], we know that violence simulation is difficult but there are some interesting features that can determine whether violence will happen or not:

1) Violence is always in the form of a small proportion of people who are actively violent and a large number of the audience who behave nominally violent or emotionally involved such as making noise or just looking. 2) Emotional supporters provide Emotion Energy (EE) to the violent few for going into action against the enemy. In other words, the violent few could not be launched without the prior EE. 3) Moments of violence in a riot are scattered in time and space. The visual scene of a riot falls into four categories: *standoffs*, *attacks*, *retreats* and *victories*. Standoffs are

generally dense and unviolent yet. When actual fighting breaks out, in attacks and retreats, the scene always breaks up. And the victory part tends to reunite. 4) Bluster is often the first step in a fight, but also an attempt to scare the enemy or avoid being dominated for averting violence. So, the confrontation is usually bluster and gesture but usually leads to little real harm. 5) In a riot, people always act with a combination of rational calculation and socially based emotion. In addition, fighting is always in a form of attacking the weak. 6) Violence is the most dependent situational contingencies – the solidarity of one side suddenly breaking up into little pockets so that a superior number of the other side can isolate and beat up an individual or two separated from the opposite group.

Jager et al. [8] modeled clustering and fighting in two-party crowds. A crowd is modeled by multi-agent simulation using cellular automata with three simple rules: a restricted view rule, an approach-avoidance rule, a mood rule. A restricted view rule means that an agent can only monitor nearby agents. The approach-avoidance rule governs whether an agent moves toward the agents of other party or of its own party. The mood rule indicates that the approach-avoidance tendencies are susceptible to an aggression motivation. Simulation consists of two groups of agents of three different kinds: *hardcore*, *hangers-on* and *bystanders*. These different types of agents scan their environment with a different frequency, and this causes them to cluster and increases their aggression motivation in different speeds. The results show that fights typically happen in asymmetrical large groups with relatively large proportions of hardcore members.

3 Introduction to IMCrowd

As shown in Fig. 1, IMCrowd is a multi-agent system consisting of two main components -- Agent behavior model and Communication model. The agent behavior model implemented Reynolds's Steering force model [12] and flocking model [11] as well as the pedestrian behavior model [13] such that they can improvise their individual and group behaviors such as goal seeking, fleeing, obstacle avoidance, collision avoidance, and group movement in the continuous space. While the agent behavior model enables the agents to move autonomously, the communication model enable them to make social interaction with others and decide what action to take. The communication model is inspired by Quorum Sensing [10], which is a process that allows bacteria to communicate with others for collectively regulating their gene expression, and therefore their collective behaviors. With the communication model, agents can propagate their emotion, react to the conformity pressure, and take a proper action according to their surrounding situations.

In IMCrowd, there are two kinds of agents: *regular* agent and *special* agent. The regular agents belong to a group that moves together by following a designated leader. A regular agent may act with either individual mind or group mind. When an agent acts with an individual mind, it pursues specified goals in sequence while avoid collisions with other agents. When an agent loses its individual mind and assumes a group mind, it acts according to the collective behaviors assumed by other agents in the scene. In the current implementation of IMCrowd, three collective behaviors have been designed: *gathering*, *panic*, and *riot*. These behaviors are initiated by special agents carrying the group emotion and attempting to infect other agents they encounter. In this paper, we focus on the experiments of simulating riots, which include complex collective behaviors such as *assembling*, *bluster*, *vandalism*, *assault*, and *flight*. We use the observation of Collins [4] to design a decision tree for action selection under the group mind in a riot as shown in Fig. 2.

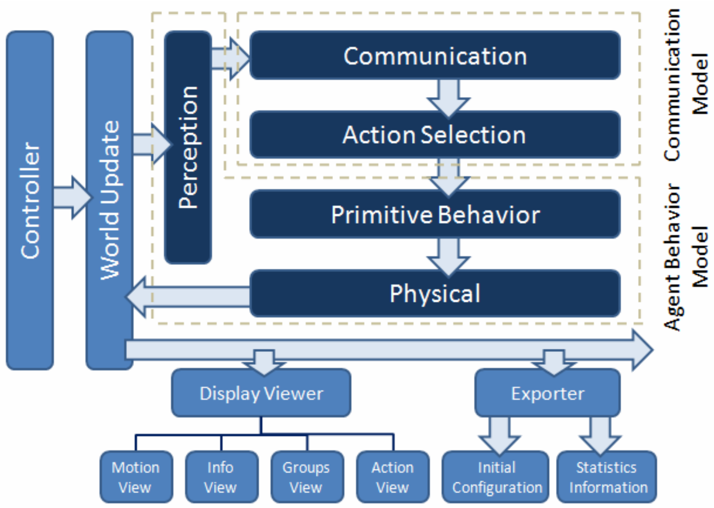


Fig. 1. System architecture of IMCrowd

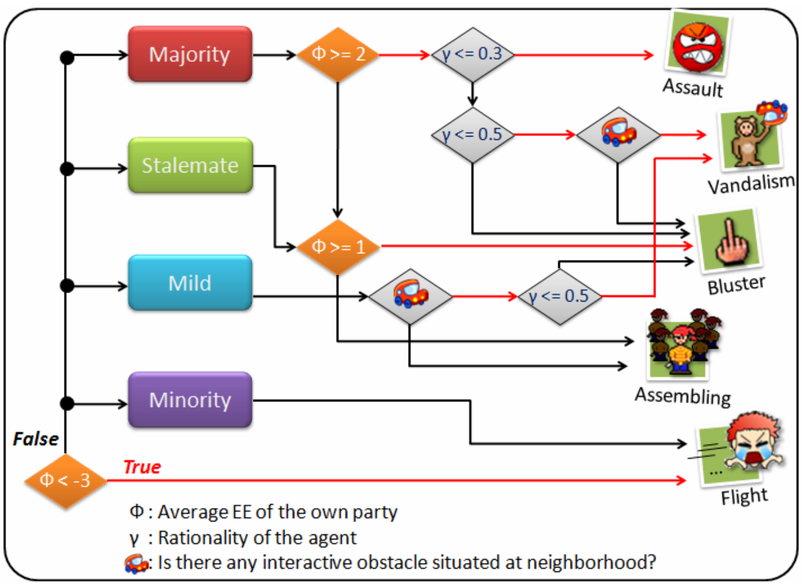


Fig. 2. Decision tree for action selection in a riot

The simulation environment for virtual crowd is in a continuous space that wraps over at the boundaries. The space is also overlaid with a 40 by 40 grid that is used to compute statistic information such as density, entropy, and superiority. IMCrowd provides an interactive interface for the placement of targets, obstacles and agents as shown in Fig. 3. There are two types of obstacles: *movable* and *unmovable*. Movable obstacles, such as cars, garbage cans, are objects that can become the target of vandalism while unmovable obstacles are environmental objects such as trees and fountains. The movable objects are used to simulate the window-breaking effect that causes the agents to reduce their rationality when they see objects being destroyed.

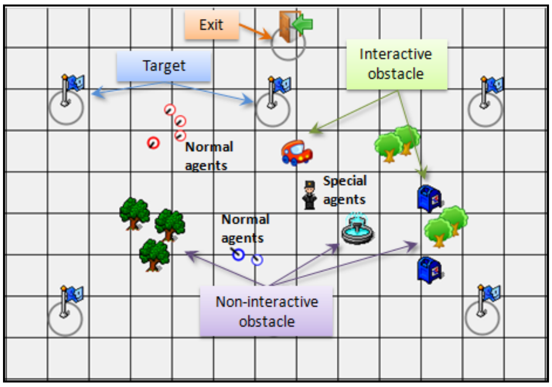


Fig. 3. Sample environment for crowd simulation in IMCrowd

4 Experiments of Riot Simulation

We have designed several experiments to study how various crowd factors affect the simulation results of a two-party crowd. These factors include *crowd size*, *symmetry of relative sizes*, and *initial distributions*. Two typical values are chosen for each factor. For example, two crowd sizes (*small*:100 and *large*:200) are used in the experiment, and the relative sizes are set with two values: *symmetric* (1:1) and *asymmetric* (3:1). Two types of initial distributions are also used: *well mixed* and *clustering*. Eight cases with variation of these three factors (2x2x2) were designed and labeled as shown in Table 1. For each case, we have designed ten scenes and run the simulation for 25,000 frames to collect experimental data. A major index on the behavior of the crowd in a riot is the number of the victims caused during the riot. The mean of this index out of the ten runs is computed for each case.

Table 1. Design of eight experimental cases

Crowd Size / Position Distribution	100		200	
	Symmetrical (50 v.s. 50)	Asymmetrical (75 v.s. 25)	Symmetrical (100 v.s. 100)	Asymmetrical (150 v.s. 50)
Well-Mixed	A	C	E	G
Clustering	B	D	F	H

In Table 2, we show the comparison of the means on the number of victims under the eight cases. For the effect of crowd sizes, we found that large crowds always cause more victims than small crowds. This is due to the fact that large crowd means higher density in a limited space and higher density increases the speed of emotion cognation and the conformity effect in IMCrowd. It could also trap the agents into a positive-feedback loop that sustains their collective actions of riot and results in more casualties.

Table 2. Simulation results (number of victims) of the eight cases

		The Size of Crowd	
		100	200
Symmetrical	Well-Mixed	A **11.5**	E **55.9**
	Clustering	B **11.8**	F **57.2**
Asymmetrical	Well-Mixed	C **7.8**	G **21.0**
	Clustering	D **8.6**	H **25.1**

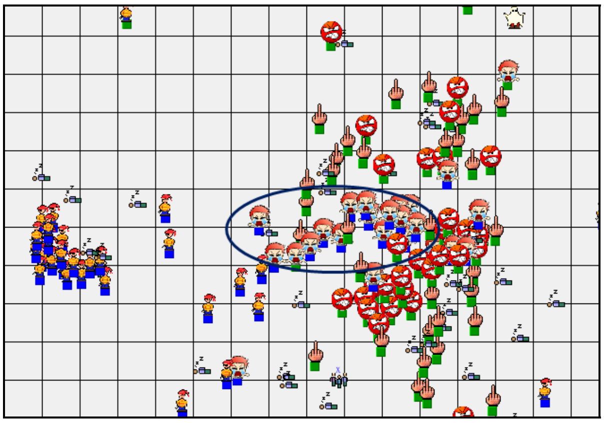


Fig. 4. Snapshots showing that the blue party is gradually surrounded by the opposite party after some confrontation

We also compare the symmetry on the sizes of the two parties. We found that when the size of crowd in each part is about the same (symmetric), there are more casualties than the asymmetric crowd, which is the opposite of the result reported in the literature [8]. From the simulation process, we observed that when the sizes of the two parties are about the same, it is more likely for them to gain local superiority in turn during the simulation. Due to high emotion energy and low rationality in such a situation, the agents are more likely to misjudge the global situation and select aggressive actions such as vandalism and assault and cause more casualties as a result. In Fig. 4, we show a situation where the agents in the blue party in the middle of the environment turn into relative inferiority in numbers, and they are gradually encircled and suppressed by the opposite party. Consequently, some of those agents who are locally inferior in numbers become victims. In contrast, if the size is asymmetric, the agents in the inferior party are more likely to select the flight action and avoid confrontation with the superior party. A snapshot of the simulation showing the inferior green party taking a flight action is shown in Fig. 5.

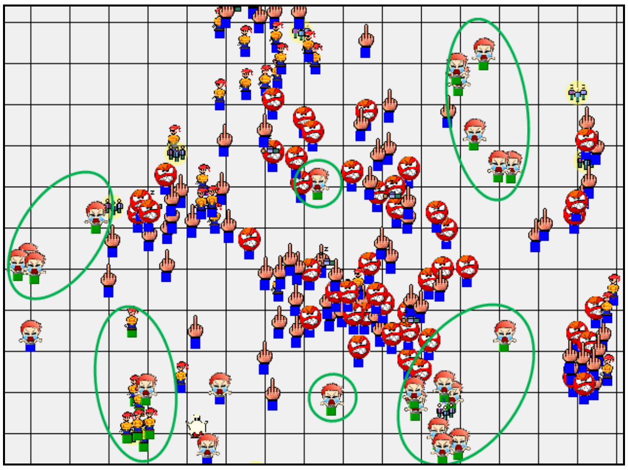
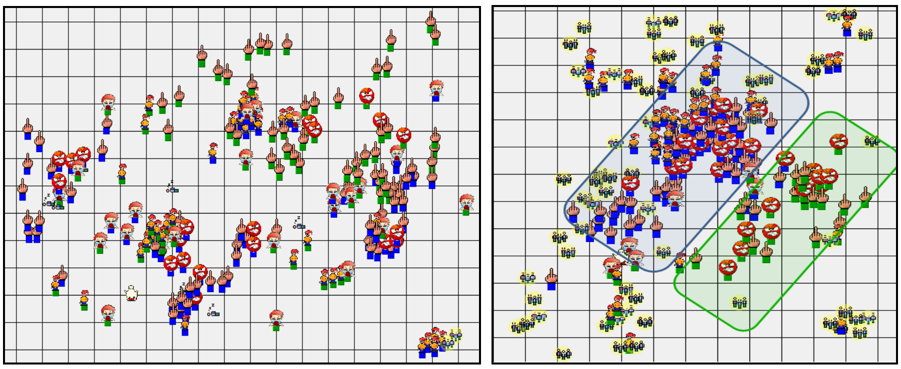


Fig. 5. Snapshot showing that the green party is taking a flight action because they are inferior in number



(a) (b)

Fig. 6. Snapshot showing that (a) both parties are initially well-mixed and scattered in the environment and (b) both parties are initially separated into two clusters and the agents at the confrontation are more likely to assault the agents in the other party

We also have investigated the condition of different initial position distributions of the crowd: *well-mixed* or *clustering*. The well-mixed condition was produced by randomly assigning the position of each agent for both parties while the clustering condition was created manually to arrange the agents in a given region for each party. The experimental results show that the initial distribution has limited effects on the subsequent simulation as well as the resulting number of victims. By observing the simulation process, we found that this is due to the fact that the agents have high degrees of mobility under the individual mind and there is enough time for the agents in each party to form groups before transforming to the group mind. Nevertheless, if the agents are initially cluttered, the number of victims is slightly higher than the situation of well-mixed. The situation is more significant when the density of the crowd is higher (200 agents) due to the fact that the mobility of the agents becomes less. A snapshot of the simulation in Fig. 6(a) shows that both parties are initially well-mixed and scattered in the environment. After some time, both parties are trapped into the melee and not able to congregate separately. On the other hand, the snapshot in Fig. 6(b) shows the situation where both parties are initially separated into two clusters and the agents at the confrontation are more likely to assault the agents in the other party.

5 Conclusion and Future Work

In this paper, we have presented a virtual crowd simulation system, called IMCrowd, that can simulate collective behaviors for virtual crowd with a communication model. We are able to simulate realistic crowd because we have enabled the agents with abilities at various levels such as spatial perception, autonomous movement, collision avoidance, emotion cognation, and group conformity. Based on the work of Collins on riot study [4], we have designed a decision tree model for the selection of actions for collective behaviors in a riot situation. We have designed eight cases in our experiments to study how three factors (size, symmetry, and initial distribution) of a crowd affect the severity of a riot. An interesting observation on the experiments that is different from the report by Jager [8] in the literature is that asymmetric/unbalanced group sizes do not necessarily result in more casualties if the agents in the inferior party are modeled with the ability to take the flight action and avoid confrontation.

Social scientists have developed several different theories for explaining crowd psychology. However, the simulation in IMCrowd is mainly based on the contagion theory and social imitation process for presenting the spontaneity of a casual and short-lived crowd without considering the cultural expectations, social background, and the motives and beliefs of participants. In addition, the individuals in IMCrowd only act with the rules we predefined and do not have the ability to learn new rules or establish new norms that emerges as the situation unfolds. Therefore, IMCrowd is not capable of simulating the social movements, racial hatred or the hostile that has been simmering for some time among groups of people. Instead, IMCrowd primarily focuses on the motion information or patterns in crowd dynamics such as panic, gathering and football hooligan riot.

The communication model that we have been presented in this work can be considered as the first model being used to reveal the emotion contagion and bandwagon effect in the dynamics of crowd simulation. Hence, many elaborations are possible. One of these possibilities is to differentiate the communication ability of the agent. As mentioned in the literature review, Gladwell [6] claimed that a few critical people who have distinctive personalities play the decisive role in inciting the social or behavioral epidemics. These key people usually have remarkable social skills and social contacts to effectively disseminate their influence. Collins [4] also mentioned that most of people are not good at violence and what they manage to do depend on the emotion energy provided by other people. Nonetheless, a small portion of people is competently violence and has talent to whip up the emotion in the crowd for dominating their enemy. And this small group of people usually can disproportionally make a riot out of control. Therefore, we could try to equip the agents with different communication skills such that not all agents contribute the same influence to study the process of emotion contagion and bandwagon effect.

Acknowledgments. This research was funded in part by the National Science Council (NSC) of Taiwan under contract NSC 98-2221-E-004-008 and by the Top University Project of National Chengchi University, Taiwan.

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