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Simulation of Social Behaviors in Virtual Crowd

Wei-Ming Chao
National Chengchi University
g9608@cs.nccu.edu.tw

Tsai-Yen Li
National Chengchi University
li@nccu.edu.tw

Abstract

This paper presents a novel communication model to simulate various crowd behaviors such as riot. Our communication model is heavily based on the results from sociology research. Collective behaviors can emerge out of social processes such as emotion contagion and conformity effect among individual agents. The communication model has been implemented in our crowd simulation system, IMCrowd, in which each agent has a local perception and autonomous abilities to improvise their actions. Simulations on riot formation and riot control are demonstrated as an application example of IMCrowd.

Keywords: crowd simulation, communication model, emotion contagion, agent-based model

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 targetting 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 psychologcial and social factors, such as perception, emotional status, and communicaion mechanism, are either rarely concerned or greatly simplified. However, all of them are essential factors leading to crowd actions. Among them, the nature of the communication that collective behaviors involve is of particularly significant.

In this paper, we propose to use the theories in sociology and psychology to build the model of communications for creating a variety of crowd behaviors. We also propose to build a crowd simulation system, IMCrowd, that can simulate the social behaviors of heterogeneous agents under different communication settings.

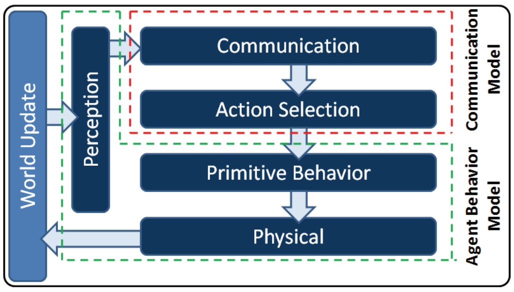

Figure 1. System architecture of IMCrowd

2. Agent Behavior Model

The system architecture of IMCrowd can be split into two models: *agent behavior model* and *communication model*, as shown in Figure 1. The agent behavior model mainly follow Reynolds's work [5][6] and adopt a collision avoidance technique to create autonomous agents moving on the continuous space.

The agent behavior model consists of three levels of modules in a simulation loop: *perception*, *primitive behaviour* and *physical*. In the perception module, a fan-shape area centered at the agent is used to model the perception region. Only the agents in the region are visible. We have used a grid-based partitioning algorithm to maintain the agents in nearby proximity in linear time. The primitive behavior module is responsible for calculating the desired trajectories to satisfy the goals set by the action selection module or to react on the forthcoming entities within the perception field. Several primitive behaviors have been implemented in this module such as seeking, fleeing, arrival, wandering, leader following, flocking, and obstacle avoidance. Each of them produces a steering force that drives an agent to move. Finally, the physical module requests the resultant steering force from the primitive behavior module as its input, and then calculates the agent's physical properties, position and orientation, by the Newton's equations of motion.

3. Communication Model

While the agent behavior model enables 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 comprised of two levels of modules in the simulation loop: the *communication module* and the *action selection module*. In brief, the communication module receives the surrounding information from the perception module, changes the internal state of the agent according to the perceived information, then passing the information and the internal state to the action selection module. The action selection module makes decisions and notifies the primitive behavior module to perform the selected action. As a result, the behaviors emerge out of the interaction among individual agents through this communication mechanism.

In IMCrowd, the agents can be basically grouped into two categories: *normal agent* and *special agent*. The normal agent can be further divided into agents of two roles: *leader* and *follower*. Every normal agent belongs to a friend group which contains one leader and some followers. A simulated crowd typically comprised a couple of friend groups. Additionally, a normal agent owns two possible minds. The first one is the individual mind which is goal-driven and self-determined. The second one is the collective mind, with which an agent loses its individuality, acts mainly relying on others around itself, and forms a sort of herd behavior. In the current implementation, there are three kinds of collective minds: *panic*, *gathering* and *riot*, triggered by different special agents and then spread throughout the crowd by the communication mechanism.

3.1 Communication framework

The communication framework is composed of six ingredients: *initial carrier*, *suggestive message*, *signal*, *channel*, *transmitter* and *receiver*. The **initial carrier** acts as a special agent carrying a unique **suggestive message** to stir up a certain crowd situation in the beginning of the simulation. A suggestive message can be encoded into three kinds of **signals** – *emotion stimuli*, *bandwagon pressure*, and *hysteria* – by their corresponding **transmitters**. The signals can be absorbed by the corresponding **receivers** of other agents through the face-to-face visual communication channel.

Every agent is equipped with all kinds of signal transmitters and receivers but may not always turn them on. According to the switch statuses of transmitters and receivers, we define four states for a normal agent to reflect the changes of communication ability in the course of the whole simulation: *clean*, *latent*, *engaged* and *disenchantment*. In the beginning of the simulation, every agent is at the **clean state** and behaves with the individual mind. In this state, no transmitter is turned on while the receiver of the emotion stimuli signal is opened up initially. Therefore, the agent passively absorbs the emotion stimuli signals through its channel until it switches to the latent state after receiving enough signals.

An agent is regarded as infected at the **latent state** because the suggestive message has been implanted into the agent. The agent at this state turns on signal transmitter of the emotion stimuli and becomes a new source to infect other surrounding normal agents. In addition, at this state the agent also switches on the signal receiver of the bandwagon pressure such that two kinds of signals, emotion stimuli and bandwagon pressure, can be absorbed.

The latent state works as a buffer state in which the agent has not been entirely dominated by the suggestive message and the agent still behaves with its individual mind in spite of contemplating on taking the collective behavior. On one hand, the agent needs to keep absorbing emotion stimuli signals to sustain the suggestive message alive; otherwise, the agent may switch back to the clean state when the suggestive message dies out. On the other hand, at this state the agent may detect the concentration of the bandwagon pressure, and transform itself into the engaged state when the concentration exceeds a certain threshold [3].

At the **engaged state**, the agent behaves with the collective mind hinted by the suggestive message, and turns on the other two signal transmitters: *bandwagon pressure* and *hysteria*. Through the bandwagon pressure signal, the agent at this state can not only infect nearby agents but also prompts surrounding infected agents to take actions with the collective mind. Furthermore, by transmitting the hysteria signal to each other, the agents can extend the lifespan of the suggestive message and prolong collective activities.

The last state is the **disenchantment state** where the agent enters when the suggestive message dies. At this state the agent terminates its collective action, closes all transmitters and receivers, and finally leaves from the environment.

3.2 Action Selection Module

The actions in the action selection module can be categorized into three groups: *leaving action*, *individual action* and *collective action*. The leaving action selects the nearest exit in the environment and activates the arrival behavior to drive the agent toward the exit. The leaving action is always adopted for agents in the disenchantment state. The individual action will be chosen when the agent is at the clean or latent state. In this state, a leader agent selects a random or specified goal and activates the arrival behavior to move toward the goal. The follower agents who take the individual action will just follow their leader.

The collective action is only executed when the agent is at the engaged state. However, the collective action could be quite different because of the distinct collective minds hinted by different suggestive messages. There are three kinds of collective actions in the current implementation of IMCrowd: *panic*, *gathering*, and *riot*. But in this paper, we mainly focus on the third collective action: riot. The riot in IMCrowd is the particular situation happening between two antagonistic groups. According to [2][4], we regard the collective action taken by an agent in the riot situation as one of five actions: *assembling*, *bluster*, *vandalism*, *assault* and *flight*. And the action selection module selects one of five actions through a decision tree described below.

According to the literature in sociology [2], 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 only. (2) Emotional supporters provide

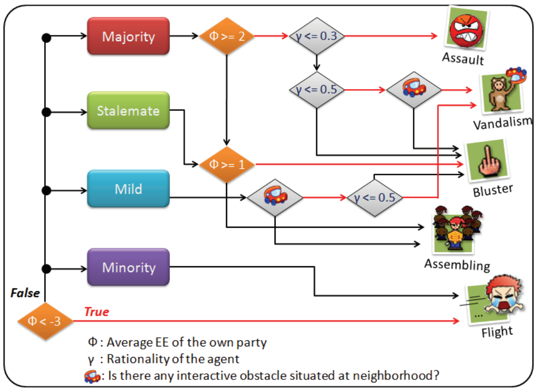

Figure 2. The decision tree for an agent to select a proper collective action in riot situation.

Emotion Energy (EE) to the violent few for going into action against the enemy. (3) Bluster is often the first step in a fight. The confrontation is usually bluster and gesture that usually lead to little real harm. (4) Fighting is always in a form of attacking the weak. (5) Violence is the most dependent situational contingencies – the solidarity of one side suddenly breaks up into little pockets so that an individual or two are isolate and beat up by the opposite group.

We design the decision mechanism of the collective behaviors according to the above features. First, the agents can determine the status (*mild*, *minority*, *stalemate* and *majority*) according to the relative circumstance of its surrounding. Secondly, different actions contribute differently to the EE of its own party and an agent needs to have sufficient EE to take any collective action. Thirdly, according to a rationality model used in our previous work, an agent may take actions with various degree of violence [1]. For example, the assault action is more violent than the vandalism action. The decision tree that we have designed for an agent to select the proper collective action in a given riot situation is shown in Figure 2.

4. Experimental Results

We design a scene where two antagonistic groups of agents, blue party and green party, congregate respectively and an instigator in the midst of the crowd tries to provoke a riot. As soon as the simulation starts, the initial carrier, the instigator, starts to spread the emotion stimuli to infect the surrounding normal agents. The normal agents gradually turn into the latent state through infection and begin to release the emotion stimuli to infect other nearby nor-

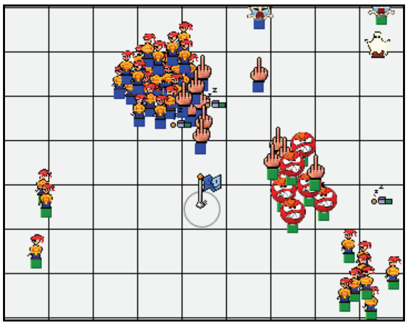

Figure 3. The emerging confrontation between two parties.

mal agents. When more and more normal agents get into the latent state, some agents with low threshold, high-risk group, may enter the engaged state and take the lead in acting with the collective mind. Their action produces the bandwagon pressure to give rise to the bandwagon effect. In addition, they produce hysteria signal to feed each other for enduring the period of collective actions. In the simulation, some agents demolish or turn over the car, and some chase and attack their opponents. Although moments of violence in a riot are scattered in time and space, the emerging confrontation between two parties can always been observed, as shown in Figure 3.

To experiment with the control of riot, we put another special agent –police, for observing its effect on the crowd dynamics in the riot situation. In IMCrowd, a police is an autonomous agent with local perception and they act individually without global coordination. The distinctive ability that a police has over other special agents is that it can disperse agents and ensure that there is no violent activity around its vicinity. We have also designed a policing strategy called entropy strategy for automatically moving the police toward to the stalemated confrontation between the two parties, separating them and averting the violence, as shown in Figure 4.

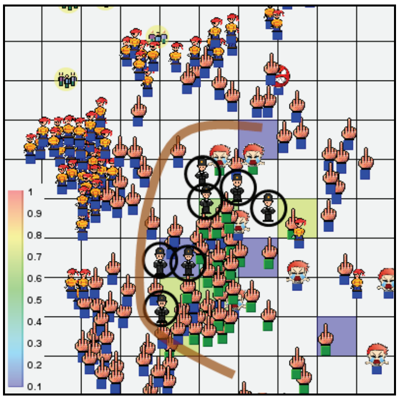

Figure 4. The polices with entropy strategy automatically build a sort of wall to separate two parties.

5. Conclusion and Future Work

In this work, we have developed a novel communication model implemented in IMCrowd to simulate the crowd dynamics based on the social psychological processes such as emotion contagion and bandwagon effect. In addition, we have designed a decision tree based on Collins' micro-sociological theory about violence [2] for an agent to select a proper action in a riot situation. We demonstrate the effectiveness of this model by interesting plausible riot scenes.

The communication model 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. For example, we will design quantitative indices to measure the collective behaviors in the course of a riot. The personality and social relation among the individuals are also factors to consider in the future.

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References

[1] W.M. Chao, T.Y. Li, 2008, "Simulating Crowd Behaviors with a Communication Model," *Proc. of Computer Animation and Social Agents*.

[2] Collins, R. 2008. *Violence: A Micro-Sociological Theory*. Princeton University Press.

[3] Gladwell, M. 2000. The Tipping Point: How Little Things Can Make a Big Difference, London: Little, Brown and Company.

[4] McPhail, C. 1994. "The Dark Side of Purpose: Individual and Collective Violence in Riots," *The Sociological Quarterly*, Vol. 35, pp. 1-32.

[5] Reynolds, C.W. 1987. "Flocks, Herds and Schools: A distributed behavioral model," in *Proc. of the 14th annual conf. on Computer graphics and interactive techniques*, pp. 25–34.

[6] Reynolds, C.W. 1999. "Steering behaviors for autonomous characters," in *Proc. of Game Developers Conference*, pp. 763-782.