Simulating Escape Panic Based on the Mechanism of Asymmetric Information Distribution

Jian-xun Chu[1]* Jing-jing Li[2], Meng Xu[3] and Li Zhao[4]

[1] Dept. of Sci-Tech Communication and Policy, University of Science and Technology of China, 230026, Hefei, Anhui, PR China

[2] Intelligent Computation Laboratory, Institute of Intelligent Machines, Chinese Academy of Sciences, 230031, Hefei, Anhui, PR China

[3] Dept. of Molecular Biology, University of Science and Technology of China, 230027, Hefei, Anhui, PR China

[4] Dept. of Automation, Tsinghua University, 100084, Beijing, PR China

Email: [123]{chujx, leejj, ameng}@ustc.edu, [4] zhaoli04@mails.tsinghua.edu.cn

*Corresponding author

Abstract

In this paper, we propose a new method to study escape panic. Different from traditional approaches using physical and psychological forces to characterize collective behaviors, our emphasis is mainly placed on the differences between every individual of the large crowds by introducing the concept of asymmetric information distribution, namely some individuals hold more information while others do not, to investigate the efficiency of escape under such scenario. Based on this concept, some new patterns during escape can indeed be found in our framework, which could also be used as a strategy for guiding the escape.

Keywords: Escape Panic; Multi-Agent System; Asymmetric Information Distribution; Super Agent

Ⅰ Introduction

We human beings are now living in a somewhat insecure world, with unpredictable attacks caused by terrorists, natural catastrophe, like recent *Katrina* hurricane and so forth. Behind those tragedies, many people believe there might exist some underlying laws dominating those events and by studying those unknown principles, some regularities could probably be found out to guide people how to most effectively escape from the dangers. Therefore many *wet* experiments and mathematical analyses have been conducted to characterize people's panic behaviors in emergencies in the hope of finding a method to minimize the total loss in those situations.

Generally speaking, the investigation of escape panic can be roughly classified into two categories. On one hand by studying the panic behavior of mice in panic, some regular patterns have been identified, such as scale-free behavior and self-organized queuings[1], which can be readily generalized to humans. On the other hand, instead of conducting wet experiments, some numerical simulations [2-4] have been proposed to mimic people's panic behavior, which is the topic we will address here.

At most cases, to model people's response to emergencies *in sillico*, a multi-agent system is a natural representation approach, in which every agent represents an individual and the panic behavior can be summarized based on a set of physical or psychological equations to mimic the dynamics of the whole system. By using this model and the concept of social forces [5-7], the research conducted by Helbing et al [2] reveals many intriguing phenomena, and also the relationship between escape efficiency and architecture configurations can be easily studied. However, Helbing's approach is a continuous model which would be infeasible to characterize human's behaviors in real-world applications; apart from the multi-agent model, some discrete models have also been proposed and the models of cellular automaton[3] and lattice gas[4] simulation are good examples. Although those discrete models would be easy for computation, the repulsive and frictional forces among the people in panic crowds can hardly be introduced.

It is true that those numerical simulations can indeed discover many intriguing dynamical properties, which therefore could be used as guidelines to evacuate the panic crowds, however close scrutiny reveals that such investigation are essentially incomplete since one fundamental problem in modeling is wholly neglected: the differences among agents. Conventionally, in the multi-agent model as Helbing et al employed, all the agents are homogeneous, so each agent is driven by the social forces defined by pre-specified equations as rules without their own judgments and decisions. Common sense tells us this assumption may not be true at most cases since, for example, a frequenter would be more familiar with the locations of the exits of a cinema and so if the cinema is on fire, the person would have a greater chance to escape from the cinema and during the escape, the behaviors of this person would also influence others' decisions so the results would be not that simple as revealed in Helbing's model. In what follows, we will show that the mechanism of asymmetric information distribution, in other words, someone hold more information than others, would greatly influence the escape efficiency and by introducing this concept, the results would be much more helpful in real-world application.

This remainder of this paper is organized as follows. Section 2 gives an overall introduction of our methods and parameters in constructing the multi-agent system. In Section 3, the experimental results are demonstrated. Finally, some concluding remarks and directions for future research are included in Section 4.

Ⅱ Methods

To characterize the collective behavior of panic crowds, the following generalized force model (eq.1) was employed according to Helbing's suggestion.

$$
\begin{cases}
m_i \dfrac{d\vec{v_i}}{dt} = m_i \dfrac{v_i^0(t)\overrightarrow{e_i^0(t)} - \overrightarrow{v_i(t)}}{\tau_i} + \sum_{j(j\neq i)} \overrightarrow{f_{ij}} + \sum_W \overrightarrow{f_{iW}} & \text{(eq.1)} \\
f_{ij} = \{A_i \exp[(r_{ij} - d_{ij})/B_i] + kg(r_i - d_{ij})\}\overrightarrow{n_{ij}} - kg(r_{ij} - d_{ij})\Delta v_{ji}^t \overrightarrow{t_{ij}} & \text{(eq.2)} \\
f_{iW} = \{A_i \exp[(r_i - d_{iW})/B_i] + kg(r_i - d_{iW})\}\overrightarrow{n_{iW}} - kg(r_i - d_{iW})(\vec{v_i} \cdot \overrightarrow{t_{iW}})\overrightarrow{t_{iW}} & \text{(eq.3)}
\end{cases}
$$

in which m_i is the mass of the individual *i*; v_i is the actual velocity the person adopted during escape. Each of the pedestrians tries to escape with a desired speed v_i^0 in a certain direction $\overrightarrow{e_i^0}$ and therefore tend to correspondingly adapt his actual velocity v_i within the time interval τ_i. Besides, the term $\sum_{j(j\neq i)} \overrightarrow{f_{ij}}$ stands for the physical interaction between pedestrians, given by eq.2 and similarly the last term of eq.1 is used to represent the interaction forces between pedestrians and walls, given by eq.3. Suppose the coordinate of any individual *i* is $\vec{r_i}$, therefore $d_{ij} = \| r_i - r_j \|$ denotes the distance between pedestrian *i* and *j* and $\overrightarrow{n_{ij}}$ is the normalized vector pointing from *j* to *i*. In eq.2, if the distance between two pedestrians is smaller than the sum $r_{ij} = (r_i + r_j)$ of their radii r_i and r_j, two additional interaction forces are introduced to characterize the interaction of pedestrian *i* against *j*. Similar to eq.2, eq.3 represents the interaction forces of pedestrian *i* against the walls. For more details, interested readers are invited to refer to the references[2][4].

The simulation parameters are similar to Helbing's simulation of pedestrians moving with identical desired velocity. We consider here the scene of escape panic in a dimension of 15m×15m smoky room with a 1-meter-wide exit. We have a fixed initial population of pedestrians, whose size is 80. Each pedestrian is denoted as a filled circle with uniform distributed sizes, from 0.5m to 0.7m.

Quite different from conventional approaches, to make our model closer to reality, each agent, the pedestrian, has its own eyeshot (the range of the vision, q). Let the coordinate of the agent i and the exit e be $\vec{r_i}$, $\vec{r_e}$ respectively the moving rule of each agents are set as follows:

- ✧ Randomly walking with a probability of 0.6 or following the mean direction of his neighbors with the probability of 0.4 if $\| \vec{r_i} - \vec{r_e} \| > q$

- ✧ Rushing for the exit e with the desired speed of 5m per second in the direction $\frac{\vec{e} - \vec{r_i}}{\| \vec{e} - \vec{r_i} \|}$ if $\| \vec{r_i} - \vec{r_e} \| \leq q$

The above rule is evaluated at each step when the agents are moving and in our experiment, the q is set to be 2m.

In Helbing's model, all agents are homogeneous and the information is equally distributed among the pedestrians. However, considering the fact that in reality, people often hold different information about a certain place, for example as we have mentioned above, a frequenter would be more easily escape from a cinema on fire, therefore the concept of *super agents* is introduced to characterize the mechanism of asymmetric information distribution.

A *super agent*, inspired by the concept of *spy* proposed by Han *et al* [8], is one that has known the exact location of the exit in advance, namely, those agents have infinite range of the vision. Therefore, as soon as they are aware of the occurrence of the disaster, they will rush for the exit without hesitation regardless of their coordinates. However, the problem is under such a scenario, during their escape, the moving of *super agents* is also controlled by (eq.1), so it is obvious that through their moving, the information would probably be implicitly spread among the pedestrians by the direct or indirect interaction forces with those *super agents*. So we are curious about how those super agents can influence the overall behavior of the crowds.

Ⅲ Experimental Results

Without introducing the *super agents*, all the agents has to be found with a mixture of individualistic and herding behavior, and thus at the exit, arcing and clogging can be observed, shown in fig.1.

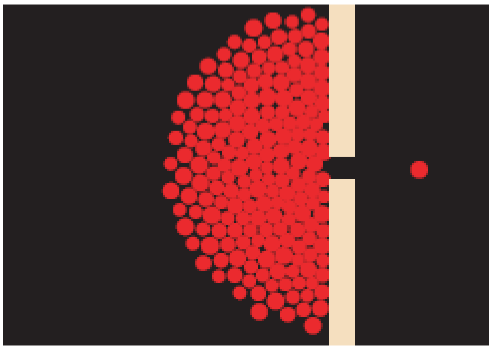

Fig.1 a snapshot of our simulation without the notion of super agent, where arcing and clogging can be seen at the exit.

To introduce the *super agents* into the system and study their influence over the whole population, at each time, one more pedestrian was randomly assigned to be the *super agents*, and others remain unchanged; therefore at the first step, there was no super agent; and at the second step, one *super agent* and 79 common agents, and so forth, finally the system was composed of 80 *super agents*; So there were totally 80 different situations in our experiments and each situation was run 100 times to reduce the randomness. The simulation result is shown in following fig.2.

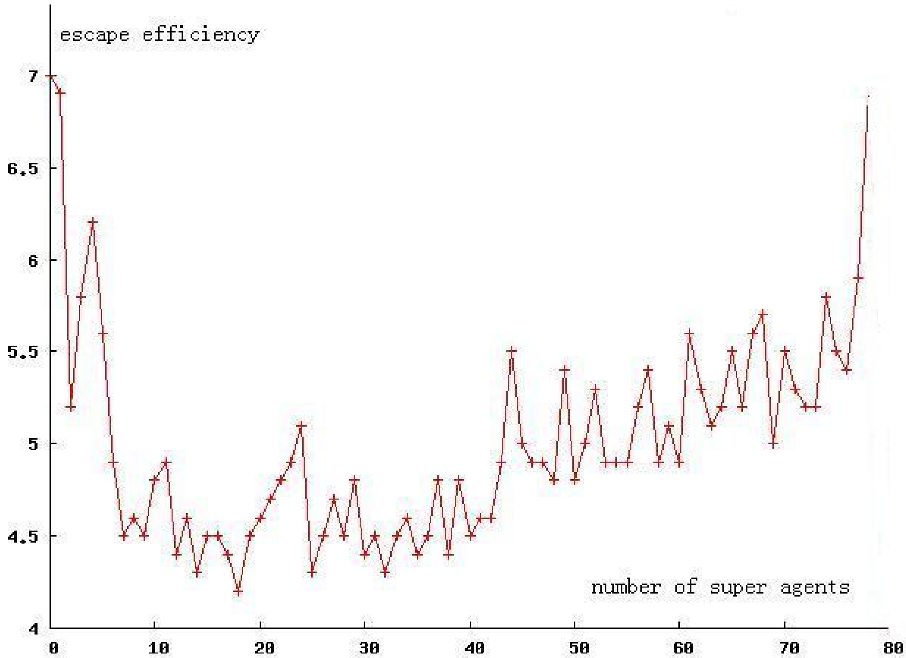

Fig.2. the simulation result of our model with the notion of super agent

Interestingly, from the above figure, we can clearly see that the heterogeneous distribution of agents can indeed improve the escape efficiency to some extent, however if all the agents are *super agents*, it is not surprising that the situation is almost the same as all agents are not *super agents*. When the number of *super agents* reaches 18, the overall efficiency drop to the minimum, indicating that 18:62 is the optimal ratio of *super agents* to common agents that can evacuate the panic crowds most efficiently in our experiments.

Initially, in the case that there are not many *super agents* in the whole population, the escape efficiency has not been much improved since those agents typically escape quickly as soon as the program starts therefore their behavior cannot immediately imposed on the whole population. When super agents are the majority of the population, when the program begins each one is rushing for the exit, therefore the arcing and clogging are easily formed, which would greatly impair the escape efficiency, shown in fig.3. When not too many *super agents* appear in the whole population, on one hand during their escape, their behavior could influence others' decision by altering the mean moving direction in their neighborhood; on the other hand, since the *super agents* are not too many, the agents far from the exit would remain randomly walking, the arcing and clogging at the exit would be alleviated so that the escape efficiency would be dramatically increased, shown in fig.4.

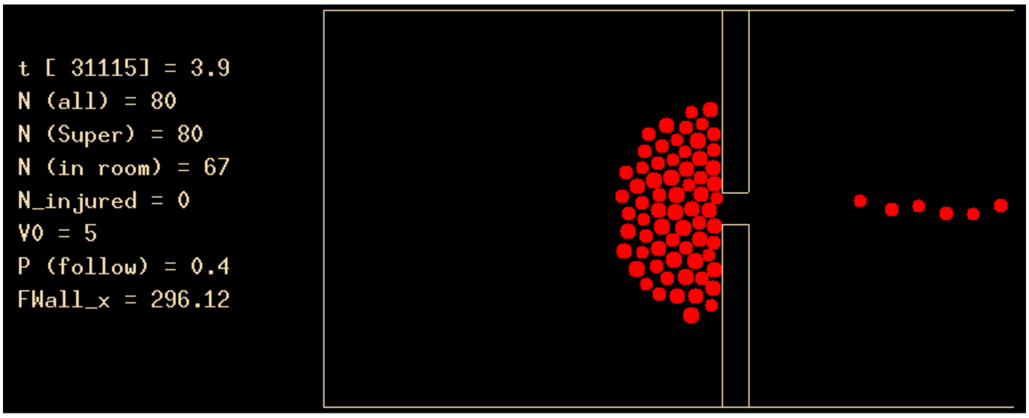

Fig.3. clogging and arcing are emerging when all the agents are super agents.

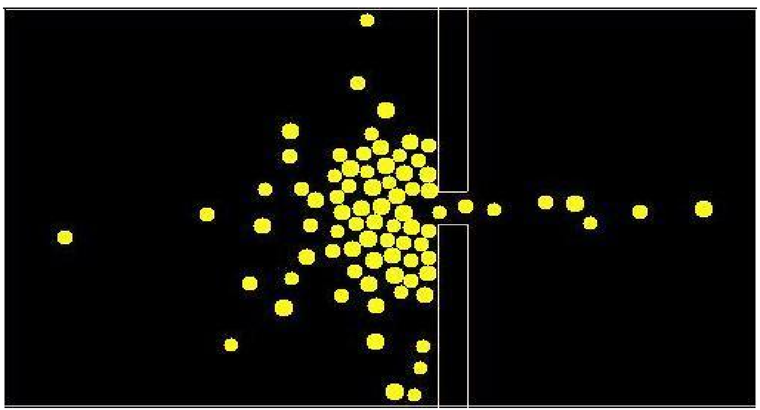

Fig. 4. a snapshot of the escape panic with 18 super agents; from the figure no obvious clogging and arcing could be observed

Ⅳ Discussion

In this paper, we have discussed the escape panic with the notion of *super agent* to characterize the mechanism of asymmetric information distribution. Our experimental results demonstrated that by introducing those *super agents* knowing more than common agents, the behavior of the whole population and therefore the escape efficiency can be greatly affected, which provides us a hint that in real world applications, the behavior of people familiar with the configurations of the space where the disaster occurs, would influence the escape efficiency of panic crowds.

However, there still exist other problems in modeling escape panic. Helbing *et al* have shown that in a space with multi-exit, people usually clog at one exit and ignore the other alternatives, so what the situations would be if each agent could make their own judgments, rather than simply randomly walking or following his neighbors. It would be also interesting to investigate the relationship between the sizes of the exit and escape efficiency. Furthermore, in our model, each *super agent* exerts its own influence on the population through their escape in a somewhat selfish manner; however, could the notion of *leader* be introduced? In this paper most of our conclusions are based on numerical simulations, meanwhile we are also curious about whether the panic behavior can be interpreted in a more precise way, such as mathematical or physical principles and whether the 18:60 ration in our experiment can be strictly proved in the framework of mathematics. All these investigations are underway.

Acknowledgement

We are grateful to SFI and ITP for the complex system summer school and we shall thank the faculty of the summer school for the excellent lectures. Especially we appreciate the helpful discussion with Prof. John Holland, Dr. Van Savage, Dr. Jing Han and Dr. Ming Li.

References

[1] Saloma C., Perez G. J., Tapang G., Lim M., and Palmes-Saloma C. (2003). Self-organized queuing and scale-free behavior in real escape panic. *Proc Natl Acad Sci USA*, **100**, 11947–11952

[2] Helbing D., Farkas I. and Vicsek T. (2000).Simulating dynamical features of escape panic. *Nature*, **407**, 487-490

[3] Burstedde C, Klauck K. and Schadschneider A.(2001).Simulation of pedestrian dynamics using a two-dimensional cellular automaton. *Physica A*, **295**, 507-525

[4] Helbing D, Isobe M. and Nagatani T. (2003). Lattice gas simulation of experimentally studied evacuation dynamics. *Physical Review E*. **67**, 067101

[5] Mintz A.(1951). Non-adaptive group behavior. *J. Abnornal Normal Social Psychol*. **46**, 150-159

[6] Kelley H. H., Condry, J.C. Jr, Dahlke, A.E. & Hill, A. H.(1965). Collective behavior in a simulated panic situation. J. Exp. Social Psychol. 1, 20-54.

[7] Quarantelli, E.(1957). The behavior of panic participants. Social Social Res. 41, 187-194.

[8] Han J., Guo L. and Li M. (2005). Guiding a Group of Locally Interacting Autonomous Mobile Agents. *Proceedings of The 24th Chinese Control Conference.*