Agent-Based Modeling and Simulation on the Crowd Formation Caused by Abrupt Social Grievance*

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Abstract: The fast changing Chinese society has accumulated a great pressure of social grievance. In recent years, many incidents happened from abrupt social grievance by attracting many common people to form a furious crowd. Such incidents pose a great threaten to social stability. Four types of agents and cops are designed in order to describe the interaction between different individuals. Simulations are also conducted to demonstrate the effect of various parameters of agents, and some interesting collective phenomena can be observed such as the furious crowd can always being formed and polarization among different agents. At last, simulated results suggest that raising the number and the abilities of cops are always of great benefit for taking the size of furious crowd under control.

Keywords: abrupt social grievance, collective behavior, ABMS, crowd formation, emotional transmission, communication, random walk.

1 Introduction

With the deepening of reform and opening policy, China has been entering the stage of comprehensive social reforming, and simultaneously there arise a large number of contradictions, such as, land expropriation, house relocation, medical dispute, arrangement for the unemployed, the official corruption etc. As a result, it always leads to abrupt social grievance if an emergency can't be solved properly by the local government. What's worse, the abrupt social grievance always turns into the gathering of a large number of furious people, which will trigger collective behavior, such as collective petitions, illegal demonstrations, blocking traffic, confrontation with the cops etc, and will pose a great threaten on the social stability (Yu, 2009). Take the 6.28 Incident in Weng'an (Guizhou) for example, more than 160 offices, 42 police cars and other vehicles of the county government and the county security bureau were burned, together with 150 people being injured [9].

As the collective behavior always causes tremendous damage on public properties and social order, the prevention and disposal of collective behaviors have been becoming an important routine and a difficult task for the local government. Therefore, it is of great practical meanings to look into the problem of the collective behavior. Some scholars have done a lot of researches on the causes, classifications and characters of the collective behaviors in China (Yu, 2009), which only consider the simple principles of the collective behaviors, but ignoring deeply discussion of the mechanism. Some other scholars focus on a special case of the collective behavior and do some in-depth qualitative analysis (Cai, 2009). All these researches have considered either the principles or qualitative analysis of the problem, from which we can have a profound understanding of the collective behavior. This article presents an agent-based computational model of the crowd formation in the collective behavior. To some certain extent, we can quantitatively look into the problem of collective behavior. Here, we show the evolution mechanisms for the crowd formation. We are interested in generating certain characteristic phenomena and core dynamics; we do not purport to reconstruct any particular case in detail which is an obvious long-term objective like the problem in (Epstein, 2002).

Briefly then, the outline of this paper is as follows. In Section 2, we discuss the benefits of agent-based modeling and simulation (ABMS) and introduce the ABMS software NetLogo. Section 3 discuses the detail and techniques of crowd formation modeling and simulation. Section 4 discuses the experiments and its results. Section 5 gives the conclusion and future work to do at last.

2 ABMS and NetLogo

* The research is supported by 973 program (2010CB731405).

Agent-Based Modeling and Simulation (ABMS) is a powerful simulation modeling technique. In ABMS, a system is modeled as a collection of autonomous decision-making entities called agents. Each agent individually apperceives the states of itself and environment, and interacts with other agents, then makes decisions on the basis of a set of given rules (Ren, 2009).There are many benefits of ABMS over other modeling techniques, such as flexible, capturing emergent phenomena, and providing a natural description of a system (Macal and North, 2007), therefore, ABMS is ideally suited to provide valuable insights into the mechanisms of the crowd formation in the collective behavior.

There have been great developments in both implications and the platforms for assisting multi-agent model designers thanking to lots of public research and development investments in the past 10 years. The celebrated open-source software environments include Swarm, Repast and NetLogo. These toolkits and frameworks all provide tools for designing agents as well as provide tools for developing an environment in which the agents interact.

NetLogo is a multi-agent programmable modeling environment. It is authored by Uri Wilensky and developed at the CCL of Northwest University. NetLogo is particularly well suited for modeling complex systems developing over time. Modelers can give instructions to hundreds or thousands of "agents" all operating independently. This makes it possible to explore the connection between the micro-level behavior of individuals and the macro-level patterns that emerge from the interaction of many individuals, and NetLogo's extensions facility allows NetLogo's capabilities to be extended from Java [8].

3 Crowd formation modeling and simulation

By browsing all the public information about collective behaviors in China, what can be known is that the majority of collective behaviors of large size are always initially caused by an emergency, such as a traffic accident, then as the news of the emergency spreads a large number of people join in for fun and the policemen come to investigate the case, eventually some of the onlookers become furious and support the victims in the emergency and begin to protest against the local government for the policemen’s improper enforcement.

In this paper, we focus on the process of the formation of human crowd in the spot who support the victims. In accordance with transmission of the virus, we call this the transmission process of the feeling of human. The whole process of the human crowd formation or the emotional transmission process can be described as follows. At first, there is a victim on a public place, the problem of whom is not solved or is solved unfairly by the policemen. The victim feels very angry and it is the source of emotional infection. The victim is called an emotionally infected person. And then the victim begins to ask the passer-bys for help in order to cause great social affection and to impact pressure on the local government. The angry feeling is transmitted from the victim to the passer-bys and onlookers who are called emotionally susceptible persons. Some of the emotionally susceptible persons become angry and become emotionally infected persons who have the ability to transmit the angry feeling like the victim. At last, the angry human crowd is formed.

The crowd formation model involves two categories of actors. ‘‘Agents’’ are members of the general population and may be emotionally infected or not. “Agents” are constituted by three different sorts of persons, including the emotionally infected agents, the emotionally susceptible agents and the emotionally immune agents. And the emotionally infected agents are subdivided into two categories, the weakly infected agents and the strongly infected agents. The weakly infected agents refer to the normal emotionally infected agents and the strongly infected agents refer to the emotionally infected agents who are persuaded by ‘‘Cops’’ and become angrier. ‘‘Cops’’ are the forces of the local government, who seek out to persuade the emotionally susceptible agents and the emotionally infected agents. Let us describe the agents first. As in all agent-based models, they are heterogeneous in a number of respects. The attributes and behavioral rules of the agents are as follows.

3.1 The agents specification

Like the transmission of the virus, we only consider the physically emotional transmission, which means that we only consider the communication between persons through the physical contact. Then if an emotionally infected person meets an emotionally susceptible person, the will communicate with each other and the susceptible person will become an infected person with some certain possibility. However, one can meet a person and communicate with each other if the person is in its vision. In order to model this problem, we give a useful definition of the agent’s vision (V_1) at first. This is the number of lattice positions (north, south, east, and west of the agent’s current position) that the agent is able to inspect (Epstein, 2002). It is exogenous and equal across agents. As in most agent-based models, vision is limited; information is local. In order to reduce the complexity of the problem, there come four assumptions.

1. There is only a victim at the initial state, who is of strong contagion. The victim is a special emotionally infected agent. It refers to that an emotionally susceptible agent near the victim is more likely to become an

emotionally infected agent than near another emotionally infected agent.

2. All the agents except the victim are all emotionally infected agents at the initial state. They can be infected by the victim and the other emotionally infected agents. They can also be persuaded by the cops and become emotionally immune agents. They can also be persuaded by the cops and become emotionally immune agents or weakly infected agents.

3. The emotionally infected agents, including both weakly infected agents and strongly infected agents, can infect the emotionally susceptible agents and have weak contagion compared with the victim. And the weakly infected agents can be persuaded by the cops and become emotionally susceptible agents or strongly infected agents.

4. The cops can communicate with the emotionally susceptible agents and the weakly infected agents. After the interaction with the cops, the emotionally susceptible agents have the possibility to become the emotionally immune agents, the weakly infected agents and to remain unchanged, and the weakly infected agents have the possibility to become the emotionally susceptible agents, the strongly infected agents and to remain unchanged. The cops don't interact with the victim and the strongly infected agents because the cops can't persuade them and likely intensify the contradiction.

With the above assumptions, we come to problem that how an emotionally susceptible agent become a weakly infected agent. There are two kinds of methods. One is that if an emotionally susceptible agent is within a cop's vision, then the cop maybe communicates with the agent and persuades the agent to keep calm, but the agent maybe has bias to the cop and doesn't believe the cop and then becomes a weakly infected agent. The other is that if there are some emotionally infected agents or the victim within the emotionally susceptible agent's vision, the agent maybe becomes to have the same feeling with the infected agents through the perception of their speeches and expressions and become a weakly infected agent. Whether an emotionally susceptible agent becomes a weakly infected in the second method depends on three factors, including the emotionally infected agents to all agents ratio (r_1) within the vision V_1 of the agent, the strongly infected agents to the emotionally infected agents ratio (r_2) within vision V_1 and whether there is the victim (r_3) in the vision V_1 of the agent or not. Then, the probability (p) of an emotionally susceptible agent becoming a weakly infected can be recognized as a function of the three factors, that is, $p = f(r_1, r_2, r_3)$. The specific function form of f needs more studies. In the paper, we use a piecewise function.

Then, we come to the problem how the cop communicates with the emotionally susceptible agents and the weakly infected agents. Firstly, we consider the interaction between the cops and the emotionally susceptible agents. As long as an emergency occurs, every member of the general population will become emotionally susceptible and have the possibility to become angry and support the victim. So, the cops are supposed to ease the mind of ordinary people, that is, to do some ideological work and to persuade the emotionally susceptible agents to become the emotionally immune agents. However, if the persuasion fails or the persuasion plays a counterproductive role, which indicates that the cops' involvement intensifies the contradiction between victim and the aggressor or the local government making the situation worse, the susceptible agents will also begin to support the victim and become weakly infected agents. After the interaction with the cops, the emotionally susceptible agents have the possibility to become the emotionally immune agents (p_1), the weakly infected agents (p_2) and to remain unchanged ($1 - p_1 - p_2$).Then, we consider the interaction between the cops and the weakly infected agents. In section 3.3, there is an assumption that the weakly infected agents are likely to come near to the victim to support him. So, in order to protect the social order, the cops are supposed to interact with them to keep calm and persuade them to become the emotionally susceptible agents. However, like the interaction between cops and the emotionally susceptible agents, the cops maybe make the weakly infected agents much angrier and become strongly infected agents. After the interaction with the cops, the weakly infected agents have the possibility to become the emotionally susceptible agents (p_3), the strongly infected agents (p_4) and to remain unchanged ($1 - p_3 - p_4$). In this paper, we regard the probabilities p_1, p_2, p_3 and p_4 as exogenous and equal across agents. Here, the four probabilities can be used to reflect the abilities of the cops. At last, we sum up the interaction and transformation among different agents using a simple chart.

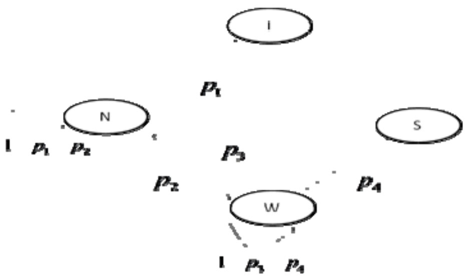

Fig. 1 The transformation among agents

Where the letter I is for the emotionally immune agent, W for the weakly infected agent, S for the strongly infected agent and N for the emotionally susceptible agent.

3.2 The cops' specification

The interaction between the cops and the agents has been given in the above subsection. In this subsection, we want to discuss how to choose an agent to communicate with for the cops. Here comes another definition of cop's interaction ability. It refers to the number of agents (n) that a cop can communicate with at the same time, which is different from the cop's role in (Epstein, 2002). As the number n increases, there arise a lot of problems. So, we only consider the simplest situation when n=1.

Here, we define cop's vision (V_2) like agent's vision in the subsection 3.1, and regard V_1 and V_2 as the same one V in this paper although they maybe have some difference. For each cop, if there is any the emotionally susceptible agent or the weakly infected agent within its vision V_2, the cop chooses one of these agents randomly and communicates with the agent. At last, we assume that the cops never defect to become emotionally infected in this model, which indicates that cops protect the local government's interests from beginning to end.

3.3 Movement

In the daily life, people always be in a mobile state. Here, we model the agent's movement using the movement ability (M). This is the furthest distance that an agent can travel in a given time interval. So, the agent can reach anywhere within the distance M at one time. The cop's movement ability can be defined similarly. Because of the cops' rules, they may have different movement ability from the agents. But, the movement abilities should not too far from each other at a short time interval. In this paper, we treat the two abilities as the same one. We assume that a cop will choose an agent within its vision V_2 to communicate with in section 3.2, and we know in this section that the cop can move to a random site with its movement ability M. So, it is necessary to assume that M is larger than V_2. We can obtain this by adjusting the time interval. Here, we give several assumptions about the movement of the cops and agents.

1. The victim doesn't move. In this paper, we put the victim on the center of the grid.

2. The emotionally immune agents and the emotionally susceptible agents move randomly within their movement ability M.

3. The emotionally infected agents are more likely to come near to the victim than to leave away from the victim.

4. The cops move randomly within their movement ability M until there is any emotionally susceptible agent or weakly infected agent within their vision V and each of the cops choose one of the agents within V to interact with and move to its site.

As assumptions 1, 2 and 4 can be easily implemented and understood, we need to look into the assumption 3 in detail. The assumption 3 shows that the infected agents move near to the victim with the probability larger than 0.5. We model this using the following chart.

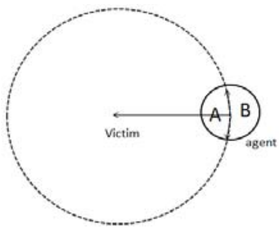

Fig. 2 The movement probability from agent to victim M

We can see from the chart that the centers of the two circles stand for the victim and the agent separately. The radius of the big circle is the distance between the victim and the agent, while the radius of the small circle is the agent's movement ability M .The intersection between the two circles is denoted A and the rest of the agent's movement range is denoted B. In order to describe the probability of the agent moving near to the victim, we will use the areas of A and B. If the agent moves into A, the distance between the victim and the agent will reduce. So, our aim is to make the agent move into A with a larger probability than move into B. In this paper, we denote the probability of the weakly infected agent moving into A as pr_1 probability of the strongly infected agent pr_2 .

4 Experimentation and Results

The scenario used in this paper is the real-world experiment. The external environment is a public place of 1 square kilometer with people and cops uniformly distributed. The shape of the place can be various, while we use square as in (Epstein, 2002). We can get an intuitive understanding of the experiment from the NetLogo interface, as shown in Fig. 3. The black circle is the victim in this model; the green "persons" are the agents; the blue "cops" are the cops. It is by changing the colors of the green agents that we can tell apart different sorts of agents in this model, including the weakly infected agents, the strongly infected agents, the emotionally susceptible agents and the emotionally immune agents.

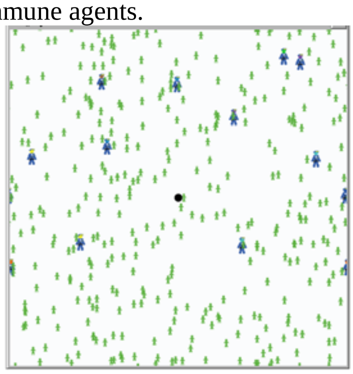

Fig. 3 The interface in NetLogo with agents and cops uniformly distributed

The attributes of people and the physical environment can be easily designed in NetLogo in which person is regarded as agent and the place as "Grid", as summarized in Fig. 4. We treat the agents and cops as particles of no size, which is different from the method used in (Epstein, 2002) and the treatment in (Georgoudas, 2007).

Attributes	Explanation
density of agents	>0
density of cops	>0
Vision V	(0,2]
movement ability M	(0,3]
pr_1 of the weakly infected agents	(0.5,1]
pr_2 of the strongly infected agents	(0.5,1]
p_1 of the emotionally susceptible agents	[0,1]
p_2 of the emotionally susceptible agents	[0,0.2]
p_3 of the weakly infected agents	[0,1]
p_4 of the weakly infected agents	[0,0.2]
p of the emotionally susceptible agents	[0,0.1]

Fig. 4 The attributes considered in this model

As our simulation region is of 1 square kilometer and the population density of the central area in China is about 250 persons per square kilometer, so the total number of agents is 250 in this model. In the interface of NetLogo, the length of the square is of 41 units, that is, one unit representing about 25meters, and then the density of agents is $250/41^2$. As the number of cops is much less than that of agents, so we can set the cops-to-agents ratio 1:100. The various probabilities are subject to the cop's ability and the agent's characteristics, and we use an average of all the agents in this paper. The base model is setup with the density of agents 0.2, the density of cops 0.002, the vision 2, the movement ability 2, pr_1=0.51, pr_2=0.55, p_1=0.35,

p_2=0.05, p_3=0.3, p_4=0.05. And, the probability p of the emotionally susceptible agents infected by the emotionally infected agents is subject to the factors r_1, r_2 and r_3. Here is a piecewise function used in this model.

$$p = \begin{cases} 0.05, if r_1 > 0.2, r_2 > 0.5, r_3 = 1 \\ 0.04, if r_1 > 0.2, r_2 \le 0.5, r_3 = 1 \\ 0.03, if r_1 \le 0.2, r_2 > 0.5, r_3 = 1 \\ 0.02, if r_1 \le 0.2, r_2 > 0.5, r_3 = 1 \\ 0.02, if r_1 + r_2 > 0.2, r_3 = 0 \\ 0.01, if\, 0.001 < r_1 + r_2 \le 0.2, r_3 = 0 \\ 0, others \end{cases}$$

With different parameters (Attributes in Fig.4), such as, the density of cops, the movement ability M, the probabilities p_1, p_2, p_3 and p_4, this experiment was run several times. Fig. 5, Fig. 6 and Fig. 7 as follows are parts of our simulation results which demonstrate the base model and the effect of the density of cops and the abilities of cops.

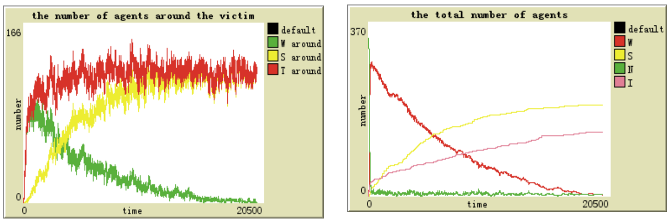

Fig. 5 The result of the base mode

As can be seen from the left chart of Fig. 5, the number of the weakly infected agents around the victim (the green line), which indicates that the distance from the agents to the victim is less than a given number, such as 8 units in this paper, rises sharply at the beginning, and reaches the summit after a few iterations. From then on, the number falls slowly and reduces to zero after more than 20,000 iterations. However, the number of the strongly infected agents around the victim (the yellow line) rises slowly from beginning to end, with some small fluctuations. The total number of the emotionally infected agents (the red line) rises sharply, which is the same as the number of weakly infected agents for there are only few strongly infected agents after some iterations, and the number reaches stability quickly. This result of the base model is consistent with the phenomena of the formation of the “furious crowd” observed in reality. Because of the curiosity for fun and the sympathy for the weak, there arise, in a short time, a large number of onlookers who will develop the same feelings with the victim and onlookers who have developed some similar feelings as the victim. With the communication among these angry onlookers and the improper enforcement or the inappropriate involvement of cops, the angry onlookers become much angrier as time goes on, and these angrier onlookers are becoming the strongly infected agents. After a large number of iterations, the three numbers all stay stability with Slight fluctuations. There are only the strongly infected agents and immune agents left. These strongly infected agents can’t be persuaded except for the problems of the victim being solved and their requirements being met. So, what the local government should do most urgently is try its best to control the number of the strongly infected agents.

As can be seen from the right chart of Fig. 5, there come two extremes that the number of the weakly infected agents and the number of the emotionally susceptible agents reduce to zero and that the number of the strongly infected agents and the number of the emotionally immune agents rise and stay stability after some iterations. This is because that those who support the victim are going to take actions to fight for the interests and that those who are indifferent with the victim are only onlookers for fun or don’t take part in this incident at all, that is, the strongly infected agents taking actions while the others being onlookers.

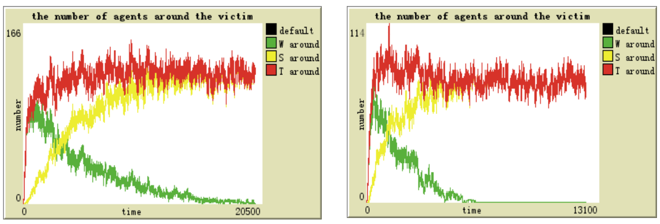

Fig. 6 The effect of doubling the density of cops

As can be seen from Fig. 6, the effect is very significant when we raise the density of cops from 0.002 to 0.004 (the left chart is the base model with the density of cops 0.002). The summit number and the stability number of the new model are much less than those of the base model. The stability number of the strongly infected agents in the new model reduces so sharply that increasing the number of cops can be very useful. However, this can also be harmful if the cops can't perform their duties appropriately, as the number of the strongly infected agents rises much faster in the new model than in the base model.

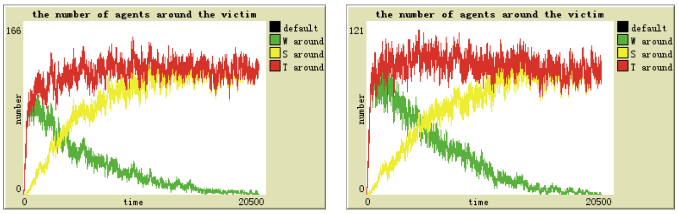

Fig. 7 The effect of raising the abilities of cops

As can be seen from Fig.7, the effect is also very significant when we raise the abilities of cops by increasing p_1 from 0.35 to 0.4, p_3 from 0.2 to 0.25, and decreasing both p_2 and p_4 from 0.05 to 0.04. The summit number and the stability number of the new model are much less than those of the base model. The stability number of the strongly infected agents in the new model reduces so sharply that raising the abilities of cops can be very helpful. We can safely come to a conclusion from the above analysis that raising the number and the abilities of cops always are of great benefit for controlling the number of the strongly infected agents. But, as every coin has two sides, these methods will inevitably increase the government's running costs.

5 Conclusion and Future Work

There have been more and more collective events recently in China, among which several large ones have caused great social uneasiness and broken the normal social order. Therefore, the prevention and disposal of collective evenyts are becoming an important routine and a difficult task for the local government. Instead of looking into the collective behaviors from the qualitative point of view and only discussing the principles of collective behaviors, we show the evolution mechanisms for the crowd formation of the collective behaviors using ABMS. We are interested in generating certain characteristic phenomena and core dynamics.

ABMS can easily define the attributes and behaviors of the individuals in contrast to conditional simulation methods. This paper presents an ABMS method using NetLogo to construct crowd formation model triggered by an emergency and has been of interest to many researchers such as psychologists, sociologists, management scientist, especially the government officials. Four types of agents (i.e., N, W, S, I) and cops are designed in order to describe the interaction between different individuals. The attributes that govern the characteristics of the people are studied and tested by iterative simulations. Simulations are also conducted to demonstrate the effect of various parameters of agents, and some interesting results were observed.

Our future work involves making the agents' movement purposeful, for people always have their own specific purposes in daily life. The second one is to endow agents more autonomy, i.e., agents can make decisions like human being. Another important aspect is to enrich the theoretical foundation for the parameters of this model. At last, we will validate the models we have designed.

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