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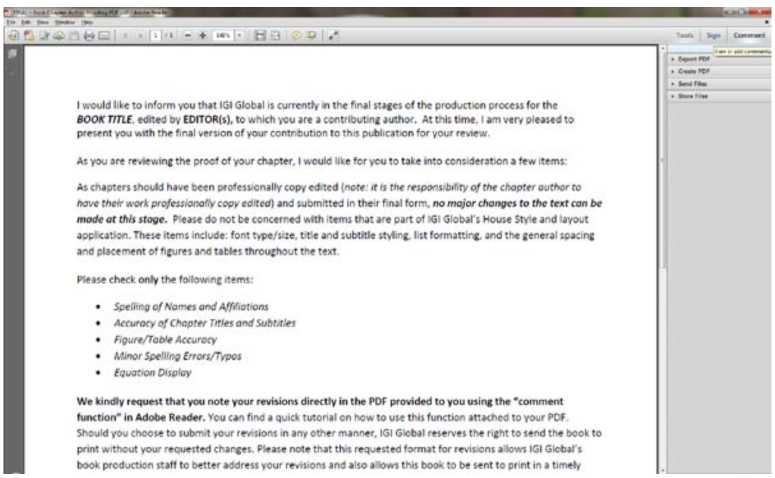

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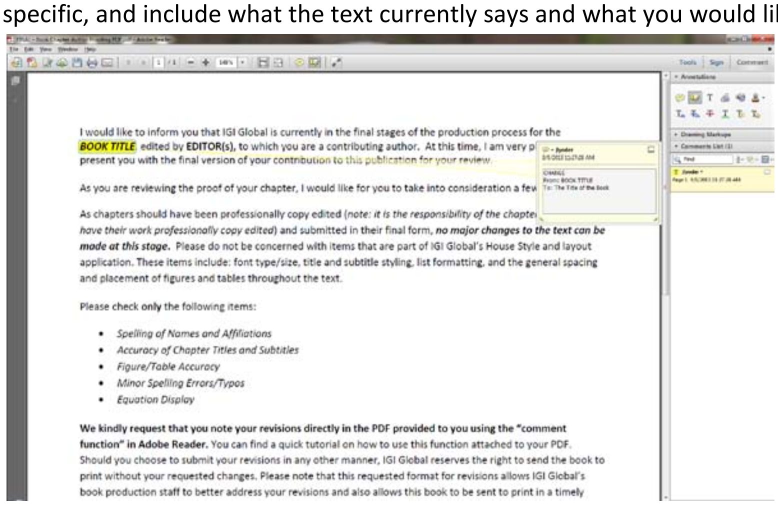

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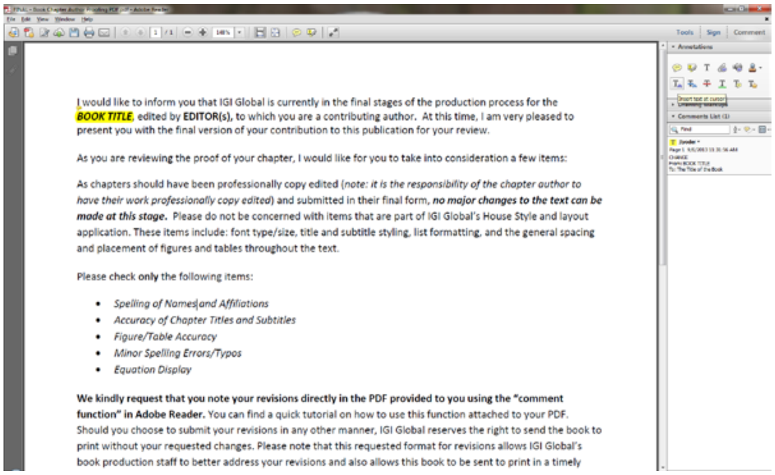

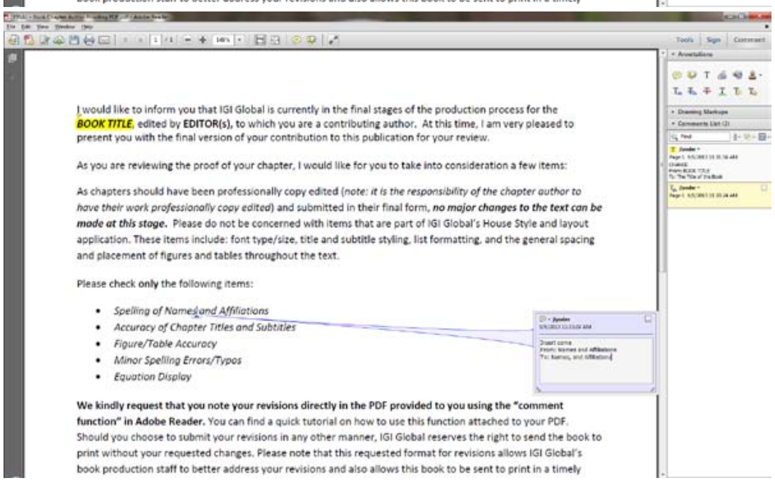

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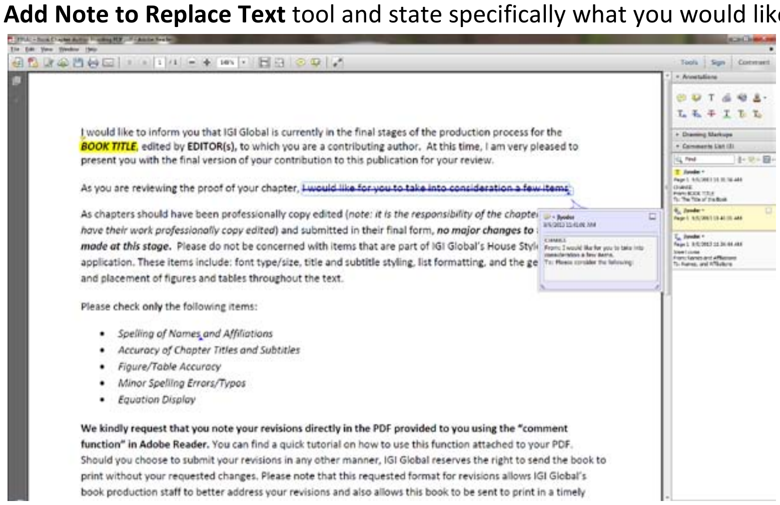

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Collective Threshold Model Based on Utility and Psychological Theories

Zhenpeng Li, Dali University, Dali, China

Xijin Tang, CAS Academy of Mathematics and Systems Science, Beijing, China

ABSTRACT

In this paper the authors investigate critical phase transition characteristic of collective action by considering the mechanisms of both rational utility and psychological threshold based on the Granovetter (1978)'s threshold model. Numeric simulation is used to observe the collective dynamics with consideration of both spatial factor and social network friendship density. The authors observe that activation threshold model with both utility and psychological thresholds included shows more stable in phase transition than that in the classic model. The authors also find that spatial factor and friendship network density have trivial impact on final equilibrium of collective behavior.

Keywords: *Collective Action, Numeric Simulation, Psychological Threshold, Threshold Model, Utility*

1. INTRODUCTION

Collective action models seek to explain how group behaviors diffuse among actors in a collective context, and emphasize on how the individual decides to participate. The individual decision making processes involve the rational choices of interdependent decision-makers together with social network structure influence. The eruption and spread of collective behavior depends on relations within a group and on the imitators' identification with the instigators.

For quantitative modeling, threshold model is used to distinguish levels of individuals active thresholds, i.e. above one critical level individual may enter into the collective action, below the value results on the contrary. Classic threshold models were developed by Schelling (1971) and Granovetter (1978) to model collective behaviors. Thomas Schelling attempted to model the dynamics of segregation motivated by individual interactions in America by constructing two simulation models. He demonstrated that "there is no simple correspondence of

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individual incentive to collective results," and that the dynamics of movement influenced patterns of segregation. The significance of a general theory of tipping point is highlighted in that research.

Mark Granovetter, following Thomas Schelling, proposed the threshold model (Granovetter, 1978; Granovetter & Soong, 1983; Granovetter & Soong, 1986), which assumed that individuals' behavior depended on the number of the other individuals who already had engaged in that behavior (both Schelling and Granovetter classified that their "threshold" referred to the behavioral threshold). He used the threshold model to explain the riot, residential segregation, and the spiral of silence. The main advantage of threshold model is concise and feasible, however the lack of psychological or economic implications hinder its wide applications. The counterpart of the threshold model is utility model, which is based on individual rational decision-making processes. Although the parameters of utility model have explicit psychological and economic implications, the complicated model design and absence of unified forms inhibit its further development (Lopez-Pintado & Watts, 2008).

Inspired by the normal active threshold model provided by Granovetter (1978), we incorporate insights from psychological threshold and utility principles and observe more results by considering more factors. Numeric simulation is used to investigate the collective action equilibrium and critical phase (which refers to one tipping point), the spatial factor and friendship influence are also considered.

2. GRANOVETTER'S THRESHOLD MODEL

Granovetter (1978)'s threshold model is one of the classic models which are used to describe collective action, such as riots and strikes. The model assumes that the possibility of each actor would join the collective action depends on the proportion of actors who have been participated in the action. In one social group, each member has his/her specific activation threshold for one specific action, and the group threshold belongs to certain probability distribution. The threshold for the instigator is zero, the radical has lower threshold and the conservative has higher threshold. The strict mathematic form of threshold model is as following:

$$F(x) = \int_0^x f(u)du \qquad (1)$$

where $f(u)$ is the probability mass distribution of group threshold, and $F(x)$ is the corresponding cumulative distribution function and stands for the proportion of actors whose threshold is equal or less than x. We assume at the certain discrete time step t the ratio of actors who have been entered into collective action is $r(t)$, then at step $t + 1$ the proportion of actors who join in the action is $r(t + 1) = F(r(t))$:

Proposition: When r (t + 1) = r (t), the equilibrium state of one collective action is reached. The final equilibrium number of actors joining the collective action is denoted by r^*_{final}.

In next section, we analyze mechanism of collective action from economic and psychological aspects and simulate the collective action equilibrium state by adding both spatial and friendship factors.

3. THE THRESHOLD MODEL EXTENSION

In the collective action, each individual's decision to join the collective action depends on the tradeoff between his/her benefit and cost. For example, the reason that a radical instigator has lower activation threshold is that his/her active action could bring him/her more economic or political benefits than others, e.g. the participation to the action may bring more benefit than cost for that action. For this reason a jobless actor may join the strike with higher probability than those actors with stable social status. In other words, the threshold of each is different; actors are heterogeneous, i.e. the intention, background, benefit and cost of each actor for one collective action is different. Then we differentiate actors abstractly from economic utility point of view. Formally actor i has benefit b_i and cost c_i for certain collective action, and his corresponding utility is u_i, we have the following relation:

$$u_i = b_i - c_i \tag{2}$$

Except the tradeoff between benefit and cost, Lopez-Pintado and Watts (2008) suggested there was another factor, i.e. local social network information or local social signal. For example, the friendship network of one actor may have higher impact than others; provided that actor i has a neighborhood with a size of N, $w_{ij} = 2$ stands for the influence strength between friends i and j, and $w_{ij} = 1$ stands for the influence strength between ordinary actors i and j, $a_j = 1$ represents actor j enter into certain collective action, $a_j = 0$ for the opposite, we have local social signal or local social pressure as described by Macy et al (2003) as follows:

$$k_i = \frac{\sum_{j \in N_i} w_{ij} a_j}{N - 1} \tag{3}$$

Equation 3 also denotes the local information that actor i could access to. In economics, value function of local social signal is named the network effect, which is applied to describe products value or utility are increased or decreased with the number of consumers who have adopted the same products (March & Simon, 1958). The analogy is that actor's utility will increase if he/she observes more and more people participating into the action, while the possible punishment or cost will decrease.

In this paper, the value function form is $v(x) = 1 - e^{-\gamma x}, x \geq 0$, where the parameter γ denotes risk aversion. According to the above analysis, when considering benefit, cost and corresponding network effect of actor i, we acquire the modified utility measure for actor i by Equation 4:

$$u_i = b_i - c_i + v(k_i) \tag{4}$$

Here based on classic Granovetter's threshold model, we introduce an important psychological definition, *psychological threshold*, one of the basic concepts in psychological measurement field to measure the critical point of some psychological stimulation. This experimentally verified concept illustrates that human psychological feeling keeps a general stable state until some stimulation reaches the critical level. We use psychological threshold to describe an actor who would not take part in the collective action if his/her utility value is less than his/her psychological acceptable critical level. Through this principle we inject economic and psychological meanings into the classic Granovetter's model, and our primary assumption is that collective action is rooted from human psychological acceptable basis with utility connotation. It is difficult to quantify human complicated and varying decision-making processes; however threshold mechanism is one comparably simple and effective method, whatever the stimulating responses are from learning, group pressure, utility motivation or other psychological, physiological and social factors generated in the group environment. In this paper, we assume that each actor has each different psychological acceptable threshold p_i. To measure the individual difference between the practical utility and the acceptable threshold p_i, we adopt a satisfying level e_i - a behavioral tendency provided by March and Simon (1958). Even satisfying is suboptimal when judged by forward-looking game-theoretic criterion, it may be more effective in leading agents out of social traps than the sophisticated decision rules (Macy & Flache, 2002). Here we define the actor i 's satisfying level e_i as the following concise form:

$$e_i = u_i - p_i \tag{5}$$

Obviously, if $e_i \geq 0$ means that the utility of actor who join the action is large than or equal to the corresponding psychological acceptable threshold, else $e_i < 0$ represents the opposite. If we assume p_i follow uniform distribution $m(x)$ in the interval $[a, b]$, the actor i 's expected satisfying level is defined as:

$$E_i = \int_a^b e_i m(x)dx \tag{6}$$

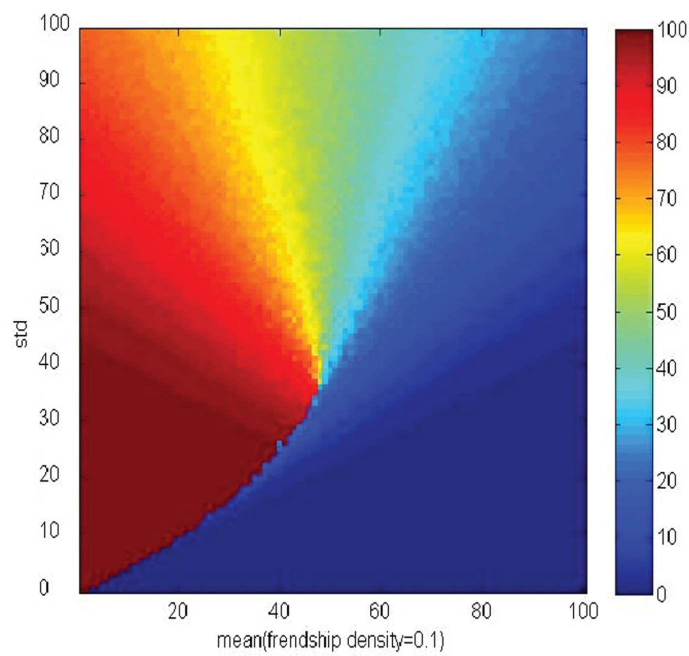
Provided that group utility threshold T_i subject to normal distribution $f(x)$, when the individual expected satisfying level $E_i \geq T_i$, actor i would like to participate the action, conversely actor i would not join the action.

Next section, we conduct simulations on the presented model by considering spatial and friendship influence. We suppose group utility follows normal distribution (the reason is that normal distribution can best describe group average characteristics, e.g. central limit theory), and put N actors on periodic boundary regular lattice with local eight neighbors.

4. SIMULATION AND RESULTS ANALYSIS

In the simulation, we choose N=100 and put actors on periodic lattice with friend influence strength equal to 2 and ordinary impact is 1. The benefit, cost and psychological threshold of actor i, b_i, c_i and p_i follow $U(0,1)$ and $\gamma = 1.5$. Figure 1 shows the equilibrium state of collective action with friendship density=0.1 and without considering utility and psycho-

Figure 1. Collective action equilibrium state vs. activation mean and stand deviation, by considering both utility and psychological thresholds with friendship density 0.1



logical threshold, where x-axis stands for group average activation threshold and y-axis donates for the standard deviation of group activation threshold; the pixels represent the number of actors who enter into the action when collective action reach equilibrium state. We observe a critical line from activation thresholds mean 2 to 50. When the activation thresholds mean reaches 50, the collective action is in a very unstable state, any small perturbation might lead to some unexpected group dynamics.

Another interesting result illustrated in Figure 2 is there are two critical points around 12 and 33 of activation standard deviations. When the standard deviation reaches 12, the involved actors increase from less than 10 to the total abruptly. This equilibrium state remains unchanged until the standard deviation is close to 33. We also find that the friendship density or friend influence strength seems of no evident impact on the final equilibrium of collective action (in Figure 2 we vary the density of friendship from 0 to 1; different color represents different friend density).

We conduct simulation by considering both utility and psychological threshold and the results are as shown in Figure 3. The simulation condition is the same as the simulations as shown in Figure 1. Since the friendship density does not affect final equilibrium result, we fix it at 0.1. Figure 3 shows that within a wide range of the activation mean, the fluctuation of activation standard deviation results in unstable collective equilibrium. We only observe a vague critical line between standard deviation and mean. Neither a distinctive critical line nor the critical phenomena appear as the activation mean equals to 50 as illustrated in Figure 1.

In order to investigate the equilibrium dynamics of collective action with and without utility and psychological threshold implication further, we conduct simulations of both cases and results are given in Figure 4 and Figure 5 respectively. As the friends' density does not significantly affect the collective action equilibrium, we again fix it at 0.1 during simulations. For the threshold model of collective action without introducing utility and psychological

Figure 2. Collective action equilibrium state vs. activation standard deviation and friendship density (activation mean is fixed at 25)

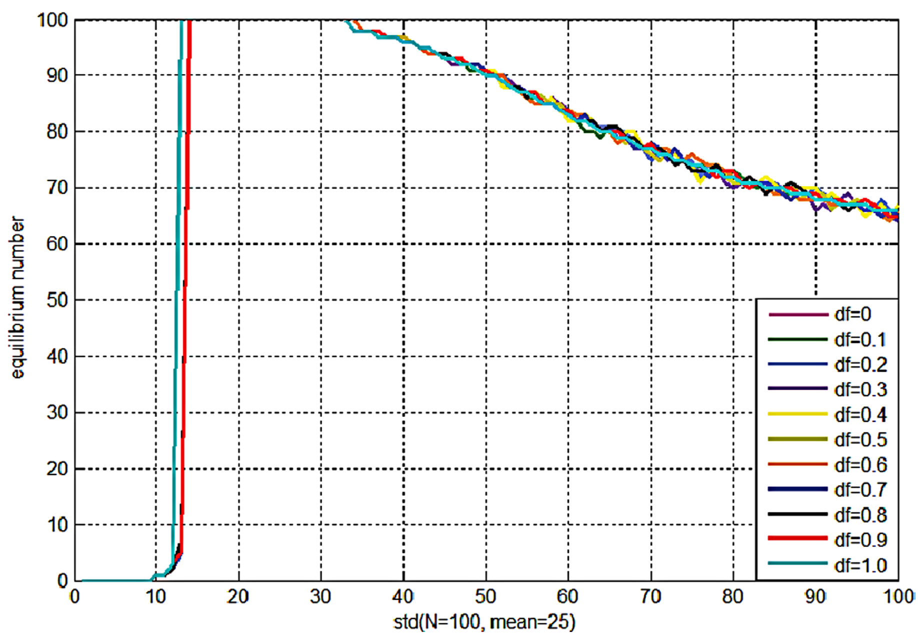


Figure 3. Collective action equilibrium state vs. activation mean and stand deviation, under the condition of considering utility and psychological theories, and with friendship density 0.1

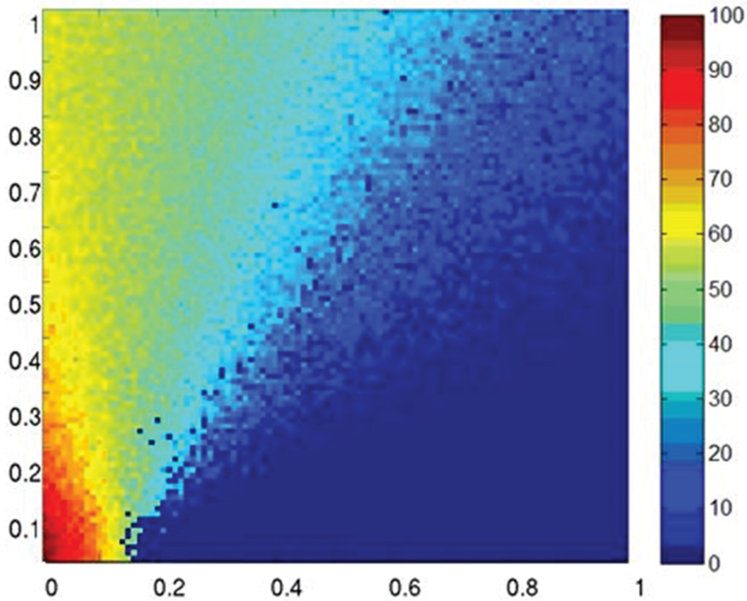


Figure 4. Given average activation threshold, the impact on equilibrium state as a result of the variation of threshold standard deviation without considering utility and psychological thresholds

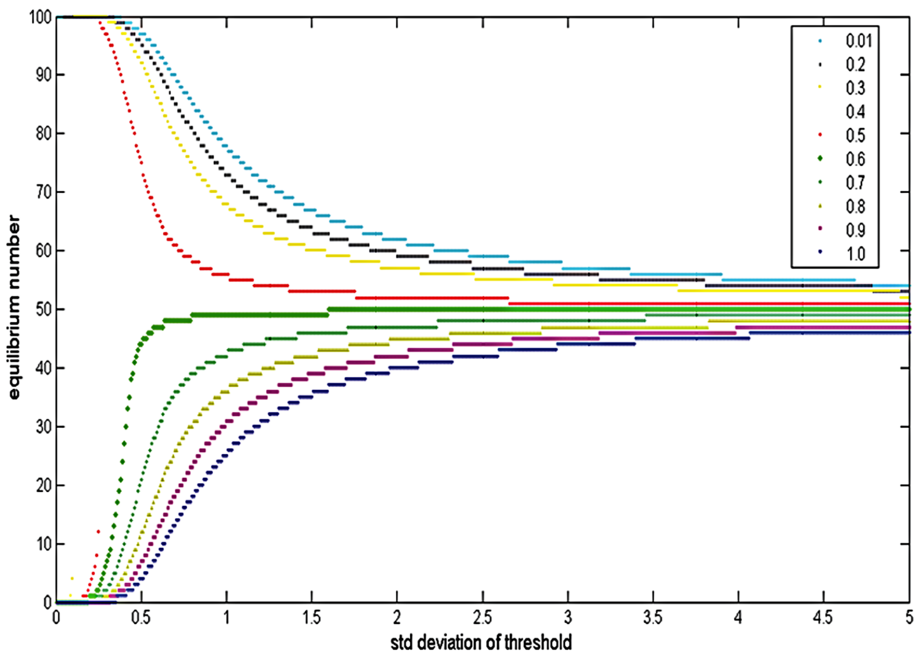
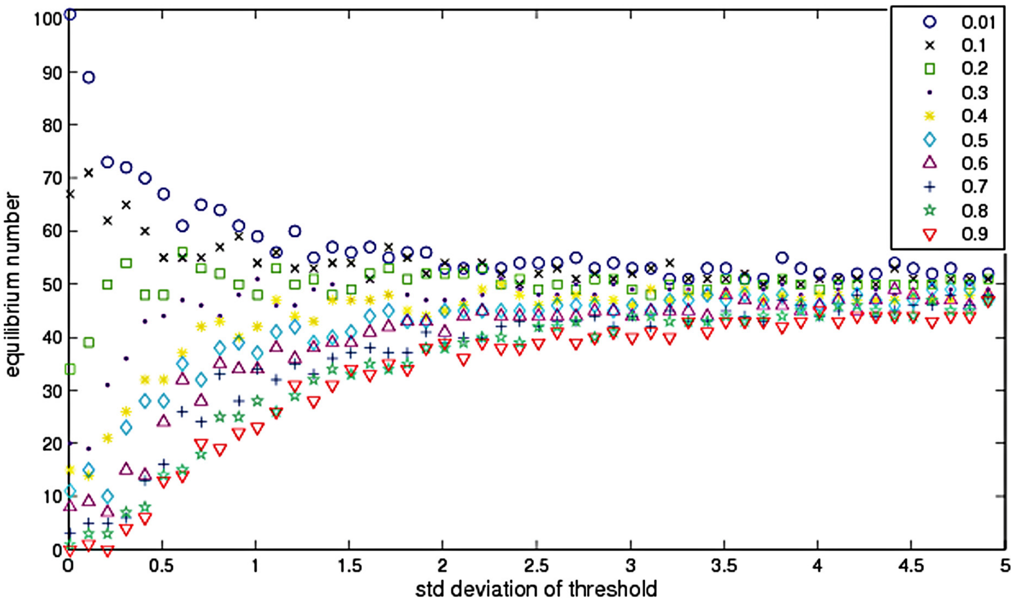


Figure 5. Given average activation threshold, the impact on equilibrium state as a result of the variation of threshold standard deviation under the condition of considering utility and psychological theories



threshold, the simulation results demonstrate that the group unstable critical feature appears as the average activation threshold is less than 0.5 (in proportion) and the standard deviation is close to 0.25 (in proportion). For example, when the activation mean is 0.5 and the standard deviation is 0.25, the equilibrium number of actors involved into the collective action suddenly jumps from 12 to 100, e.g. all actors participate in the action.

In distinct contrast to the results shown in Figure 4, with the involvement of both utility and psychological threshold, the simulation results indicate that collective action equilibrium reveals a stable transitional state, i.e. no critical feature displays, as shown in Figure 5.

The most important and interesting unexpected result in our simulation shows a common trend in both cases (either considering both utility and psychological thresholds or not), the collective action displays bi-polarization pattern (the ratio between involved actors and the not involved approximates to 50%:50%) with the increase of standard deviation, even with different means.

5. CONCLUSION

In this paper, we present a new model by adopting both utility and psychological thresholds on the basis of Granovetter's threshold model. We investigate the collective action equilibrium through numeric simulations. Our numeric simulation finds that the normal threshold model with incorporation of utility and psychological threshold does not exhibit a radical phase transition characteristic. This result also applies to the case as we adopt a spatial lattice structure and social network friendship influence into the model. The simulations show that the final equilibrium number r^*_{final} is not closely related to friendship impact and spatial lattice structure. However when not considering utility and psychological threshold, the final equilibrium number r^*_{final} is sensitive to the distribution of group threshold and displays critical phase transition feature. Comparing to the classic Granovetter's model, r^*_{final} is comparably robust to threshold distribution when we introduce utility and psychological thresholds into the classic model.

Another main result is that both cases demonstrate group bi-polarization pattern with the increase of threshold standard deviation. This interesting phenomenon is another evidence of group behavior bi-polarization feature, which is consistent with our former studies (Li &Tang, 2012a; Li & Tang, 2012b).

Our preliminary conclusion in this study is that the classic model is more appropriate to depict riot, strike and similar unexpected outbreak of social events while the model with utility and psychological threshold is suitable to depict human economic behaviors, e.g. innovation and technological spreading. Next more experimental and empirical evidences are needed to verify the effectiveness of the proposed model. We also intend to consider some meaningful active threshold distributions which are closer to the real world.

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Zhenpeng Li is now an assistant professor in the Department of Statistics of Dali University. His research interests cover agents-based modeling and statistic data analysis. He got his Ph.D from CAS Academy of Mathematics and Systems Science in 2012, M.S from Northern Polytechnic University in 2006 and B.S from Bohai University (China) in 2000, respectively.

Xijin Tang is a full professor in the Academy of Mathematics and Systems Science, Chinese Academy of Sciences. She received her BEng (1989) on computer science and engineering from Zhejiang University, MEng (1992) on management science and engineering from University of Science and Technology of China and PhD (1995) from CAS Institute of Systems Science. She had developed several decision support systems for water resources management, weapon system evaluation, e-business evaluation, etc. during her early system research and practice. Her recent interests are meta-synthesis and advanced modeling, opinion dynamics, knowledge creation and creativity support systems. She co-authored and published two influential books on meta-synthesis system approach and an oriental system approach in Chinese. She is the general secretary of International Society for Knowledge and Systems Sciences. She was one of 99 who won the 10th National Award for Youth in Science and Technology in China in 2007.