An agent-based model for simulating the group dynamics involved in excluding a minority

Yoshinobu Maeda*, Kazuya Anezaki, and Yumi Takeuchi****

* Faculty of Engineering, Niigata University, Japan (maeda@bc.niigata-u.ac.jp)

** Graduate School of Science and Technology, Niigata University, Japan

1. Introduction

It is important for school students to make friends with those who have similar interests, hobbies and tastes. Thus, the social interaction of making friends generates homogenization of classmates. As homogenization progresses, the distinctive characteristics of students becomes apparent (refer to Figure 1) [1]. With this relationship between homogenization and distinctiveness, it often happens that those who are not interested in the hobbies and tastes of the majority of the class tend to become, unconsciously, candidates for victims of bullying. In general, bullying (or victimization) in schools means that the majority teases or treats the minority callously [2]. This is an example of one of the unpleasant relationships that can exist within a group or between individual students.

It has been said, from a psychological point of view, that students who bully others enjoy exercising power and status over their victims and fail to develop empathy for others. Physical or mental violence is usually a one way process from the bully to the victim. However, if the victim's behavior annoys and gives stimulation to the bullies, the bullying will evolve further into ill-treatment through a positive feedback loop (annoyance) caused by the victim's behavior. When petty bullying at an early stage evolves into cruelty, it can become a huge social problem because it is possible that the victim will attempt suicide. It is often difficult, however, for others, such as teachers, parents and other classmates, to detect bullying in its early stages. Therefore, a cooperative effort between the family and the school system may be the most effective means to intervene in bullying problems [3]. Prevention of bullying is important, as is the medical and psychological treatment given to victims of bullying. In dealing with the former case, the dynamic structure of bullying should be investigated. It is not sufficient for researchers to trace the origin of bullying in just individual personalities.

In this paper, we studied the group dynamics of peer to peer classmates by using multi-agent simulation [4-10], and observed that some agents were excluded from the groups. This group dynamics with exclusion suggests that these excluded agents become the victims. We identify these isolated agents, who do not have interests and hobbies in common with the others, as potential victims. In order to examine these phenomena and so prevent the evolution of a serious bullying problem, we proposed a formalized agent-based model; simulations using the model investigated schemes whereby evolution into serious bullying could be prevented.

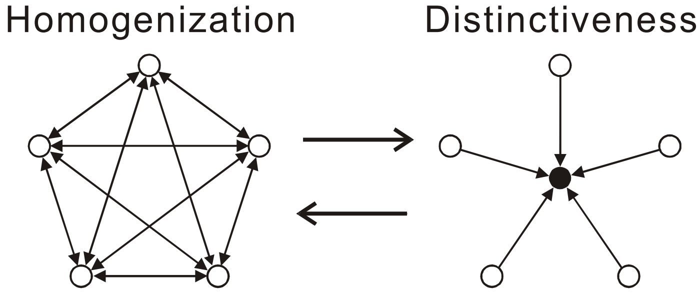


Figure 1: Akasaka's representation of students' interactions within a group transforming into school bullying [1]. Circles and arrows represent students and their interactions, respectively (the filled circle: the victim).

2. Fundamental model

2.1 Method

The main purpose of this study is to simulate the social interactions between students using a multi-agent system, and, as a result, to clarify the dynamics of the global grouping phenomenon. The local interaction consists of the following two actions; one is to homogenize oneself into a companion (homogenization), and the other is to be relatively distinctive by becoming estranged (distinctiveness).

Every agent is identified by a combination of *values*. A *value* is defined as a formalized term for the hobbies, tastes and interests preferred by the agents. We will distinguish the members of the two sets by using Greek indices φ, ψ, etc., which take values 1 through M, for the *value* set and Latin indices i, j, etc., taking values 1 through N, for the agent set. When an agent i is interested in, or has a preference for, a *value* φ, we describe it as $v_{i,\varphi} = 1$. Otherwise, $v_{i,\varphi} = 0$. In the initial stage, every agent is interested in m (=10) *values* randomly, that is,

$$\sum_{\varphi=1}^{M} v_{i,\varphi} = m \equiv m_i . \quad (i = 1, 2, \ldots , N) \tag{1}$$

If the relationship $v_{i,\varphi} = v_{j,\varphi} = 1$ $(i \neq j)$ is satisfied for *value* φ, then we define φ as a *mutual value*. The number of *mutual values* is represented by the following function:

$$c(i, j) = \sum_{\varphi=1}^{M} v_{i,\varphi} v_{j,\varphi} \leq m_i , \tag{2}$$

where the function c is commutative for i and j. If $c(i, j)$ is relatively large, we regard the two agents i and j as potential friends, or, agent i is likely to become a friend of agent j, and vice versa.

In executing the simulation, two agents are randomly selected; one is active, and the other passive. If an arbitrarily given random value $p \in [0, 1)$ is smaller than $p_{act} = c(act, pas)/m_{act}$, the active agent *act* homogenizes with the passive agent *pas*, by changing an arbitrary non-*mutual value* ψ =1 into zero, and simultaneously, an arbitrary *mutual value* $\varphi = 0$ into one. m_{act}, which is defined in equation (1), is preserved in the homogenization. We call p_{act} the homogenization probability, in the sense that the active agent easily homogenizes with the passive agent for large p_{act}. Furthermore, the agent *act* memorizes $c(act, pas)$, which is defined in equation (2), until the same agent *act* is randomly selected again.

On the other hand, if the given random value $p \in [0, 1)$ is greater than p_{act}, and simultaneously $c(act, pas)$ is smaller than the memorized $c'(act, pas')$, that is,

$$c'(act, pas') - c(act, pas) > 0 , \qquad (3)$$

then *act* becomes estranged from *pas*, or *pas* is regarded as strange by *act*. The passive agent *pas'* with whom the previous interaction took place may be different from *pas*. If the latter condition described by equation (3) is not satisfied, in other words, if the homogenization probability is only relatively small, the active agent hesitates about the distinctiveness, and, as such, does not act at all. In the model the exercise of distinctiveness is more restricted than that of homogenization, because distinctiveness is described in our model as *act* not changing its own preferred *value* but changing an arbitrary *mutual value* preferred by *pas*. In other words, *act* forces a certain *mutual value* $\varphi = 1$ of the other to zero. Therefore, the active agent takes a prudent attitude against the distinctiveness, by means of referring to the last information on *mutual values* in the memory.

m_{pas} is reduced by the distinctiveness, whereas it remains the same for homogenization. If m_{pas} becomes equal to zero, *pas* can never interact with any other agent, and, as a result, *pas* becomes a potential victim. The agent *pas* can increase the number of *values* again by means of homogenization, only if $0 < m_{pas} \leq m$ (m is the initial value and fixed to 10). In reality, people's *values* are never physically eliminated. The elimination is interpreted, in our model, as being not able to communicate with others using the *value*.

When either the homogenization or the distinctiveness (or no action if equation (3) is not satisfied) is finished, new active and passive agents are selected. We summarize this in a flow chart shown in Figure 2.

Next, using M as a control parameter, we observe the transformation of the number of potential victims and groups. When all the *values* preferred by agent i become the same as agent j, we define them as a group composed of agent i and j. The simulation is terminated when almost all the agents are grouped as a result of repetitive homogenization, and the remaining ones are isolated by the distinctiveness of the others. After terminating one simulation, we call the agent, which does not belong to any group, and, as such, must be isolated, the potential victim in the sense of becoming a victim someday. We represent the number of potential victims as n.

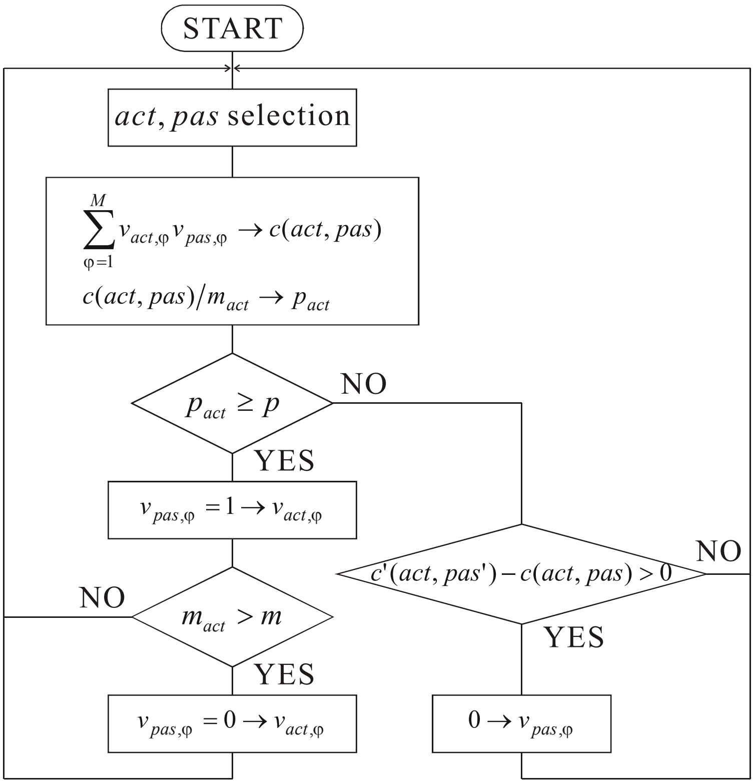


Figure 2: Flow chart of the agent-based model.

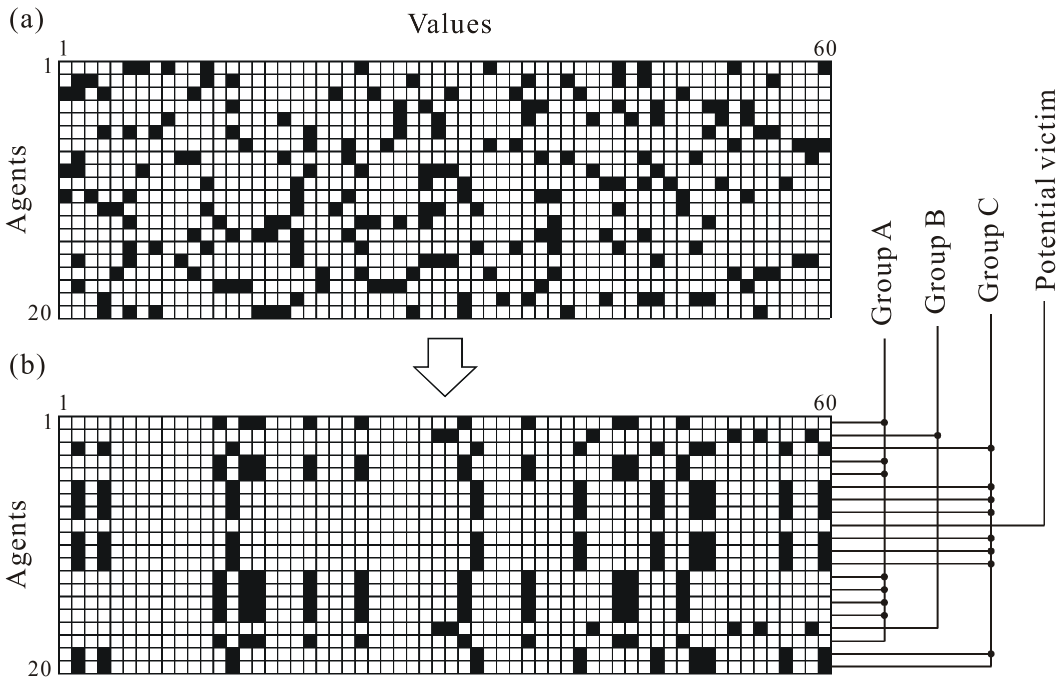


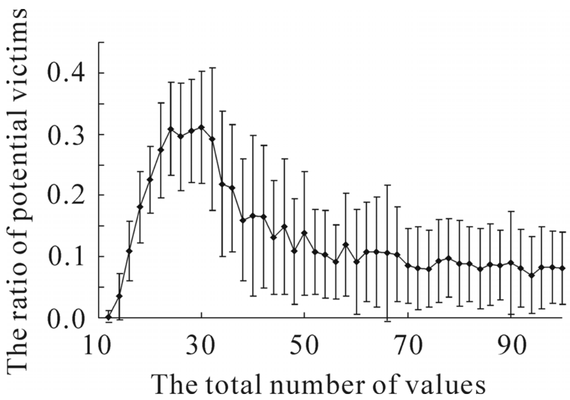
Figure 3: (a) Initial stage. (b) Final stage. Vertical and horizontal directions represent agents and *values*, respectively. Filled squares represent the preferred *value*. $N = 20$, $M = 60$, and $m = 10$.

2.2 Results

We set the number of agents $N = 20$ and the number of *values* $M = 60$, and every agent is given 10 randomly chosen preferred *values* in the initial stage, as shown in Figure 3(a). For example, for agent $i = 1$ the preferred *values* are $\varphi = 6, 7, 9, 12, 24, 34, 44, 46, 53$ and 60. When the simulation reached the final stage after the interaction of all the agents had terminated, we observed three groups, A ($i = 1, 4, 5, 13, 14, 15, 16, 18$), B ($i = 2, 17$) and C ($i = 3, 6, 7, 8, 10, 11, 12, 19, 20$), and one isolated agent ($i = 9$), the so-called potential victim, as shown in Figure 3(b). Groups A and C were large groups, in which the combination of *values* was completely identical. m_j ($j \neq 2, 9, 17$) was equal to m (=10) in the initial stage. In group B, we observed $m_2 = m_{17} = 6 < m_j$ ($j \neq 2, 9, 17$). In other words, the two agents, $i = 2$ and $i = 17$, who belong to group B, were grouped separately from the others by the elimination of their *values*. The potential victim ($i = 9$) was unable to form a group with any of the others and was therefore repeatedly eliminated from them. As a result, all the *values* of the potential victim were eliminated.

Next, we varied the total number of *values*, M, from 10 to 100 as shown in Figure 4. For a certain M, the model is simulated fifty times, beginning initially with random stages. Figure 4(a) shows the ratio of potential victims, n/N, versus M. Figure 4(b) shows the number of groups versus M. In these figures, the black points represent the mean and the bars represent the standard deviation when the simulation was repeated fifty times. The ratio of potential victims changes non-monotonously for increasing M, while the number of groups changes monotonously. The number of potential victims reaches a maximum, about 30%, in the range of M between 25 and 30. It was observed that there were at least 10% potential victims in the range of $M > 50$, in which there were at most three groups on average.

(a)



(b)

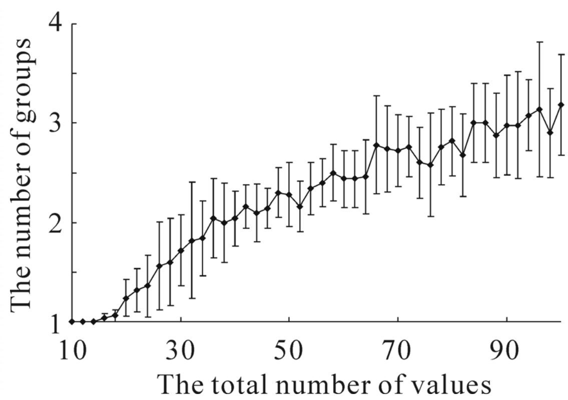


Figure 4: (a) The ratio of potential victims to all agents. (b) The number of groups composed of at least two agents. Abscissas represent the total number of *values*, M. $N = 20$, $m = 10$, and M : variable.

We see a similar non-monotonous change in the results from Axelrod's culture model [5].

In the culture model, which is composed only of homogenization of the agents, the number of cultures changes non-monotonously as the space which is modeled by the two-dimensional lattice is widened. Our model is composed of both homogenization and non-homogenization, the so-called distinctiveness. The non-monotonous feature in our work was found in the number of victims, which is generated by the anti-synergistic distinctiveness of the homogenization.

3. Improved model

3.1 Method

In the homogenization, the active agent homogenized by means of randomly paying attention to the *value* of the passive agent. However, the *values* are not equally popular for the agents. In this section, we attribute a variable of popularity, ρ_φ, to each *value* as follows:

$$\rho_\varphi = \exp\left(-\frac{a(\varphi-1)}{M}\right), \tag{4}$$

where a is constant and $0 < \rho_\varphi < 1$. ρ_φ monotonously decreases with increasing φ. Thus, the smaller φ is, the more popular the *value* is. We obtained an improved model reflecting the popularity of the *values*, by means of giving priority to the *values* of the passive agent in homogenization by the active agent. Note that Γ is the current *value* set preferred by the passive agent. Then, the active agent homogenizes one *value* of the passive agent depending on the following probability:

$$r_\varphi = \frac{\rho_\varphi}{\sum_{\psi\in\Gamma}\rho_\psi}, \tag{5}$$

where $0 < r_\varphi < 1$. If r_φ is relatively large, then *value* $\varphi \in \Gamma$ is popular with agents and tends to be homogenized by other agents.

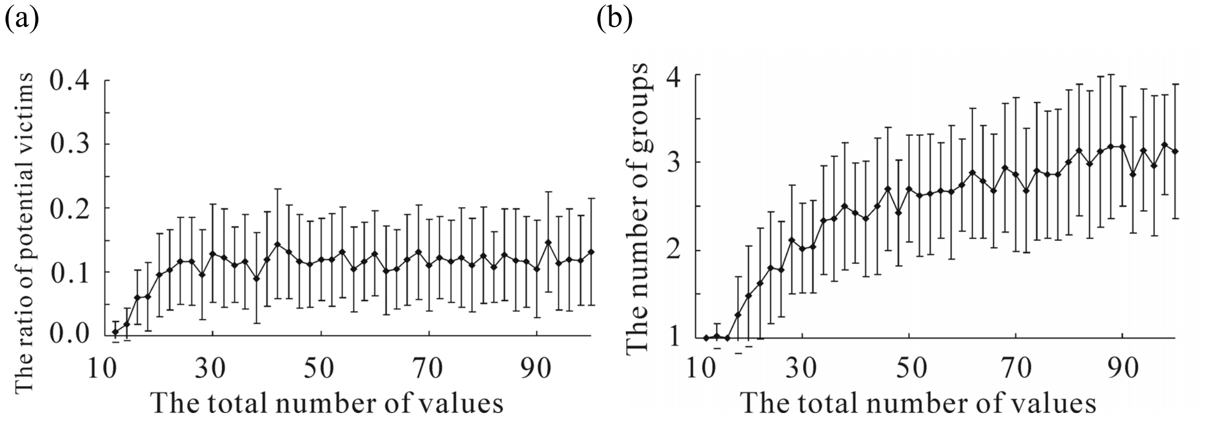


Figure 5: (a) The ratio of potential victims to all agents. (b) The number of groups composed of at least two agents. Abscissas represent the total number of *values*, M. $N = 20$, $m = 10$, $a = 50$ and M : variable.

3.2 Result

Figure 5(a) shows the ratio of potential victims, n/N, versus M. Figure 5(b) shows the number of groups versus M. Comparing Figure 4(a) with Figure 5(a), the ratio of potential victims is clearly changed, whereas the number of groups was not statistically significant (Figure 4(b) and 5(b)). However, in Figure 5(a), about 10% of potential victims remained over the whole range of M.

4. Discussion

We aimed to simulate global unpredictable phenomena by means of using the local interactions between agents. In this sense, we observed a non-monotonous phenomenon in the ratio of potential victims, by transforming the total number of *values*. When the total number of *values* was about three times larger than the maximum number of *values* one agent can prefer, the number of potential victims was a maximum (about 30%). However, when the act of homogenization by the agent was not random and the criteria for the actions depended on the popularity of the *values*, the curve showing the ratio of potential victims was no longer non-monotonous, as shown in Fig. 5(a). However, the number of groups was not changed by the popularity of *values*. For the bullying problem, it is important that the curve is non-monotonousness as this reduces the number of potential victims. Furthermore, a similar phenomenon was also observed when the total number of agents, N, was decreased with m constant [11]. According to our model, the existence of popular *values* or a relatively small class helps reduce school bullying. Actually, we know empirically that bullying problems are less likely to occur when students are positively engaged in some hobbies or have some interests. The bullying problem becomes a risk when the disposition of every agent is indifference.

On the other hand, the 10% value for the number of potential victims was observed over the whole range of M. This result was obtained from our model when carrying out repeated local interactions composed of the agent's homogenization and distinctiveness. We note that even the agent-based model composed of the formalized *value* gives rise to the emergence of 10% potential victims. There may be, therefore, at least 10% potential victims in any actual school or community.

5. Conclusion

We studied multi-agent simulation of group dynamics involving two actions of an agent; homogenization and distinctiveness. Almost all the agents were grouped with complete homogenization because of the somewhat strong desire to restrict distinctiveness. However, we also observed a few agents who were excluded because they were not interested in any *values* jointly with another, at least about 10% of the total number of agents. According to a Japanese national survey on bullying, the number of students who ‘currently are victims’ or ‘were victims in the year but are not now victims’ is as follows: elementary schools 21.9%; lower secondary schools 13.2%; upper secondary schools 3.9%; average 13% [2]. Similarly, we can confirm, the corresponding figure in Norway is 9.4% on average from second to ninth grades (maximum 17.5%; minimum 3.0%), and in Italy, 26.4% respond ‘sometimes or more’ and 9.5% as ‘once a week or more’ in middle school [2].

In future work, we introduce not only grouping but also ungrouping behavior (dispersion) into the model. We would like to clarify the effect of this on the transformation of potential victims, which has recently been observed in schools of Japan.

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