An Agent Model and its Gaming Simulation Reproducing the Emergence of a Minority

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***Abstract*— Bullying is a social problem that needs to be solved for happiness and well-being of the individuals. For junior high school students to make friends, it is very important that they find a common set of values, such as similar interests, the same hobbies, or some kind of common activity or striving. However, there is a minority of students who are unable to find a set of values in common with others, and these students are potential victims of bullying. To describe this phenomenon, we proposed a formalized agent-based model, both for the formation of a group and the exclusion of a minority, in order to clarify the mechanism by which a minority emerges. Secondly, in order to model real organizational and social phenomena, we upgraded the model to a hybrid multi-agent system consisting of both human and machine agents, in which a player could participate as in gaming. In this so-called multi-agent system model a player would be able to interact with the machine agents, which were controlled by the stochastic rules of the model. The game was made similar to amusement games by using interesting illustrations. We carried out a preliminary examination with a junior high school student playing the game and as a result, the appropriate number of parameters was determined.**

***Keywords*— school bullying, potential victim, group formation, homogenization, exclusion**

I. Introduction

It is important for school students to make friends with those who have similar interests, hobbies and tastes. This social interaction generates homogenization of classmates. As the homogenization progresses, the distinctive characteristics of each student becomes apparent and 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 [1-4]. 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 unidirectional process from the bully to the victim. However, if the victim's behavior annoys and gives stimulation to 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 [2]. Prevention of bullying is important, as is the medical and psychological treatment given to victims of bullying. In dealing with the former, the dynamic structure of bullying should be investigated. It is not sufficient for researchers to trace the origin of bullying in just individual personalities.

Firstly in this paper, we studied the group dynamics of peer to peer classmates by using multi-agent simulation [5-15], and observed that some agents were excluded from the group. This group dynamics with exclusion suggests that these excluded agents become victims. We identify these isolated agents, who do not have interests and hobbies in common with others, as potential victims [1]. In order to examine this phenomenon and so prevent the evolution of serious bullying problems, we propose a formalized agent-based model. Secondly, we improved the formalized agent-based model in order that a player might participate in the interactions between agents. Using this participation-type model, the so-called gaming simulation model, the player can sassily understand the mechanisms by which groups form and by which individuals are excluded. Such gaming simulation can investigate schemes whereby evolution into serious bullying can be prevented. We examined how the participation-type model performed when made available to a junior high school student, and improved the player interface by using interesting illustrations.

II. Formalized Agent-Based Model

The main purpose of the first 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

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phenomenon. The local interaction consists of the following two actions; one is homogenization of oneself into a companion (homogenization), and the other is to be relatively distinctive by becoming estranged (exclusion).

Every agent is identified by a combination of values (set of values). A value is defined as a formalized term for the hobbies, tastes and interests of the agents. We distinguish the members of the two sets (agents and values) by using Greek indices φ, ψ, etc., taking 1 through M, for the value set and Latin indices i, j, etc., taking 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, i.e.,

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

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:

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

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 from the same set composed of all agents; one is active, and the other passive. If an arbitrarily given random variable $p \in [0, 1)$ is smaller than $p_{act} = c(act, pas)/m_{act}$, the active agent, *act*, homogenizes with the passive agent, *pas*, by changing the arbitrary non-mutual value ψ =1 into zero, and simultaneously, the arbitrary mutual value φ = 0 into one. m_{act}, which is defined in (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 (2), until the same agent *act* is randomly selected again.

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

$$c'(act, pas') - c(act, pas) > 0 , \tag{3}$$

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 (3) is not satisfied, in other words, if the homogenization probability is only relatively small, the active agent hesitates about the exclusion (disregard), and, as such, does not act at all. In the model the exercise of exclusion is more restricted than that of homogenization, because exclusion 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 the specific mutual value φ =1 of the other to zero. Therefore, the active agent takes a prudent attitude against the exclusion, by means of referring to the last information on mutual values in the memory.

m_{pas} is reduced by exclusion, 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 number of values and is 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.

When either the homogenization or exclusion (or disregard if (3) is not satisfied) of the agents is finished at some simulation step, new active and passive agents of the next simulation step are selected. When all the values preferred by agent i become the same as agent j, we define them as a group composed of agents 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 exclusion. 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.

III. Result Of The Formalized Agent-Based Model

We set the number of agents N = 20 and the number of values M = 60, and every agent was given 10 randomly chosen preferred values in the initial stage, as shown in Fig. 1(a). For example, for agent i = 1 the preferred values are φ = 6, 7, 9, 12, 24, 34, 44, 46, 53 and 60. When the simulation reached the final stage after 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 Fig. 1(b). Groups A and C were large groups, in which the combination of *values* was completely identical. Except for j = 2, 9, and 17, the values of m_j were equal to those at the initial stage, m = 10. 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, belonging to group B, were grouped separately from the others by the exclusion of their values. The potential victim (i = 9) was unable to form a group with any of the others and was therefore repeatedly excluded from them. As a result, we observed that all the values of the potential victim were excluded.

Next, in order to investigate the fluctuation in the number of potential victims, we varied the total number of values, M, from 10 to 100 in step of 2, as shown in Fig. 2. For each M, the model was simulated fifty times, beginning initially with random stages. Figure 2 shows the ratio of potential victims,

n/N, versus M. In this figure, the black filled diamonds and crosses represent mean values and the bars represent the standard deviation when the simulation was repeated fifty times. As the total value, M, increases, the ratio of potential victims changes non-monotonously. The number of potential victims reaches a maximum, about 30% (ratio: 0.3), when M is around 26. In the analysis of variance (ANOVA), the null hypothesis, that all groups distinguished from the difference of the value of M are the same, was rejected ($p < 0.05$). Using multiple comparison (Scheffé's test) after ANOVA of all 45 sets from $M = 12$ to $M = 100$, the 11 sets illustrated by cross symbols, from $M = 18$ to $M = 38$, appear to be producing significantly differences in mean response ($p < 0.05$). It was also observed that there were at least 10% potential victims (ratio: 0.1) in the range of $M > 50$, in which there were at most three groups on average.

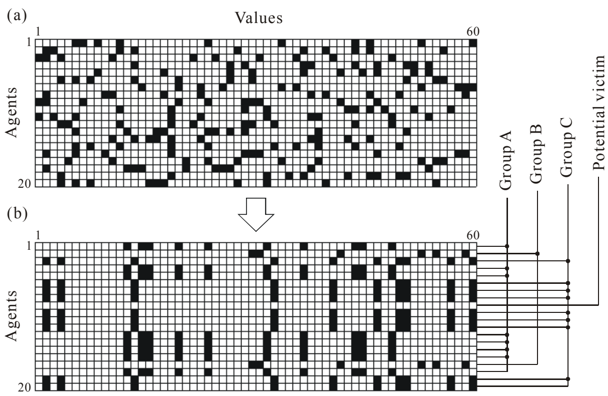


Figure 1. One example of the formalized multi-agent model of group formation and minority exclusion [14]. (a) Initial stage, and (b) Final stage. Vertical and horizontal directions represent agents and values, respectively. Filled squares represent the preferred value. $N = 20$, $M = 60$, and $m = 10$.

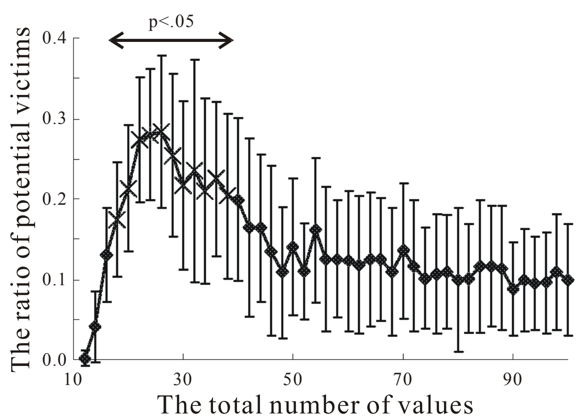


Figure 2. The ratio of potential victims to all agents. The abscissa represents the total number of values, M. $N = 20$, $m = 10$, and M : variable. the black filled diamonds and crosses ($p<0.05$) show mean values and the bars show the standard deviation when the simulation was repeated fifty times.

IV. Gaming Simulation Model

In this section, we upgrade the formalized agent-based model to a gaming simulation model (Fig. 3) advocated by the *Serious Games Initiative* [16]. Before playing the game, the player can refer to explanations of the game and the rules (refer to Fig. 4). In upgrading, formalized values were transformed into concrete values or hobbies (refer to Fig. 5). A player can freely select five ($m = 5$) from fifty given hobbies ($M = 50$) such as TV, dance, book reading, fishing and so on, since $m = 10$ used in the previous section is regarded as being too many hobbies for a junior high school student (Fig. 6). We found previously that the formalized model shows similar results if the ratio m/M is the same. Therefore, the case of $(m, M) = (5, 50)$ in the gaming simulation corresponds to that of $(m, M) = (10, 100)$ in the formalized model simulation. The maximum number of students per class in local public elementary and junior high schools is prescribed by law in Japan, and the present limit is 40 students per class [1]. Assuming that half of them are the same sex, we are able to set the number of agents $N = 20$. In this model, agent No. 1 represents the player. The player is selected as an active or passive agent based on the same rule for the other agents. When the player is an active agent, he determines his action (homogenization, exclusion, or disregard), and is permitted to refer to the others' situations for his determination.

Windows during the game playing are illustrated in Fig. 7 to Fig. 11. Figure 7 shows the initial window of the game. The center part composed of black and white squares represents the state of the artificial class. Each row represents the state of one of the agents, or the player in the case of No. 1. The hobbies are located in the horizontal direction, and each agent's five hobbies are shown in black. The player can freely choose his favorite hobbies in the interface window as shown in Fig. 5, whereas the hobbies of the other agents are determined at random. Figure 8 shows the behavior of agents at simulation step 975. In this case, the player is selected as the active agent, and the passive agent with whom the interaction occurs is No. 12 ('You met 12'). Figure 9 shows the behavior of agents at simulation step 1687. In this case, the player is selected as the passive agent and is excluded by agent No. 20 ('Mr.20 excluded you'). The case in which the player is homogenized appears at simulation step 1783 ('Mr.20 homogenized you' in Fig. 10). After repeating such interactions, the game finally reaches the goal shown in Fig. 11 when the simulation is terminated. In Fig. 11, the player obtains a school report on his behavior, i.e., either "*Pretty good*" or "*The best is yet to come.*" In the former case, it comments "Many homogenizations. Abstain homogenizations, and keep your hobbies," and the latter case, "Many exclusions. Abstain exclusions, and comply with the others." Simultaneously, it presents the initial and final hobbies to show how the player has been transformed, the number of actions taken by the player (homogenization, exclusion and disregard), and the number of members in the player's group.

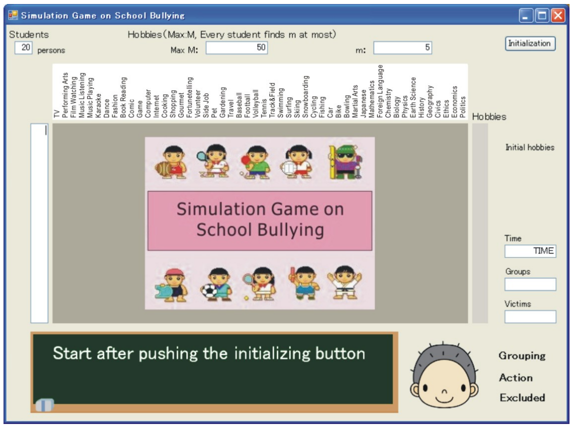
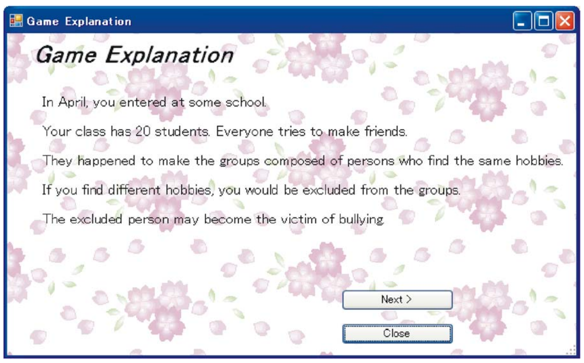


Figure 3. Start window of the game.

(a)



(b)

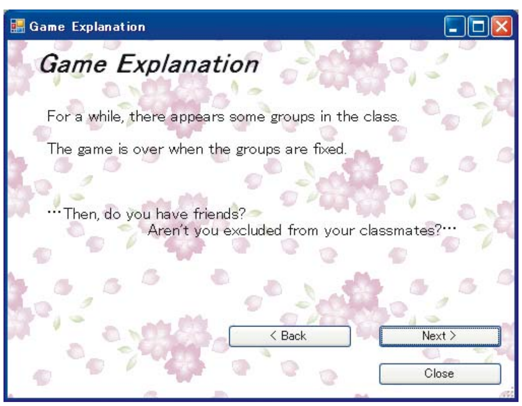


Figure 4. Game explanation window. On clicking "Next", window (a) changes to window (b), and vice versa on clicking "Back".

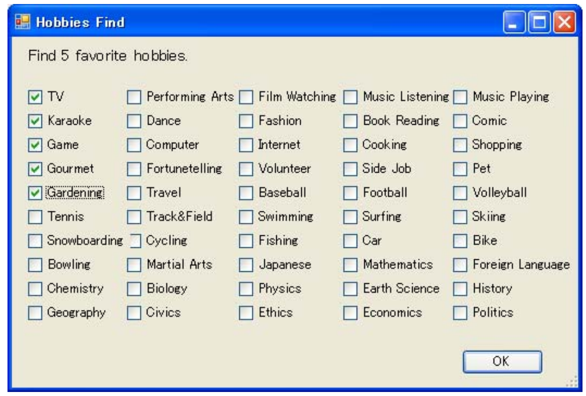


Figure 5. Interface window for selecting hobbies(*values*). Here, the hobbies TV, Karaoke, Game, Gourmet and Gardening are found and checked by the player.

Figure 6. Preliminary test of player-agent hybrid interaction at a junior high school in Niigata Prefecture to determine the parameters. It was clear from this preliminary test that m=10 is too many hobbies and m=5 is suitable for a junior high school student

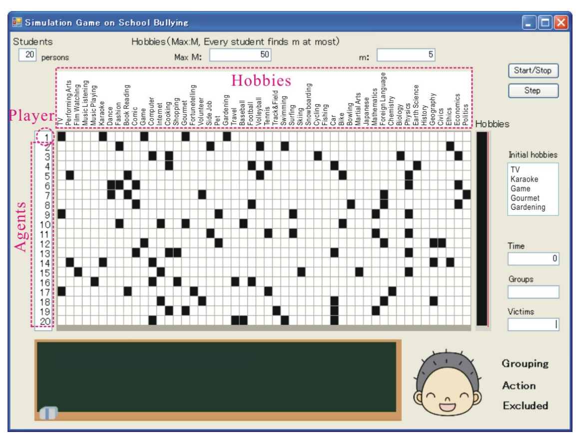


Figure 7. Initial window of the game.

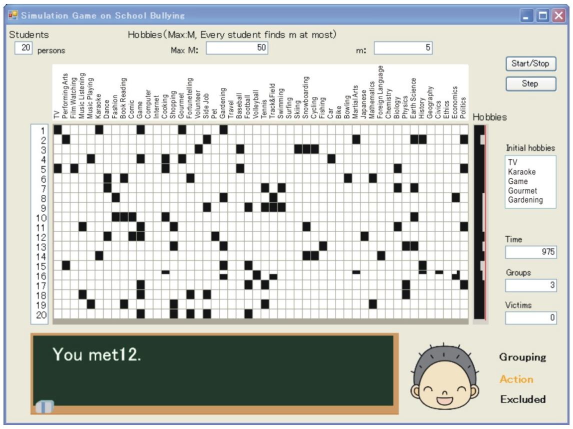


Figure 8. During the game when the player met Mr. 12.

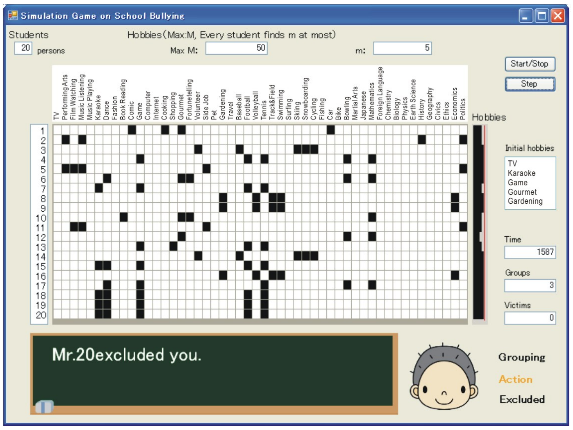


Figure 9. The player is excluded by Mr. 20.

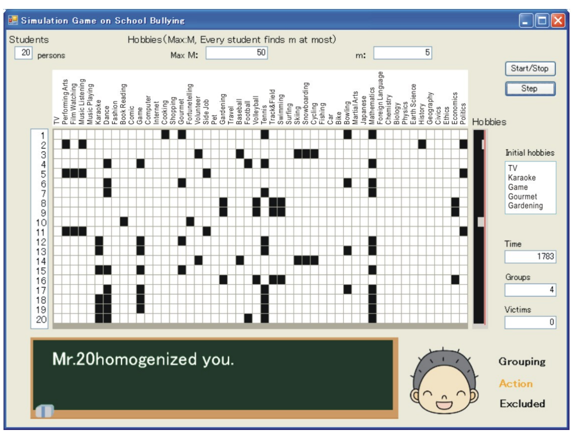


Figure 10. The player is homogenized by Mr. 20.

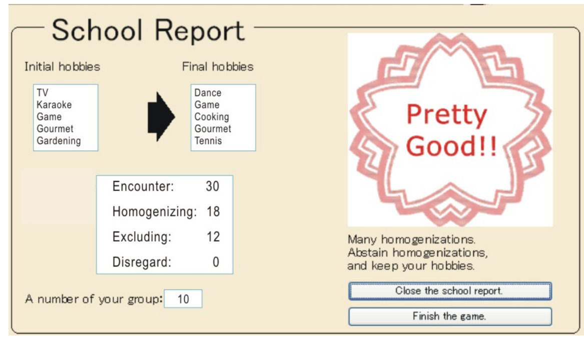


Figure 11. Final window of the game.

In order for the player to easily understand his current state, we use face illustrations corresponding to the number of the hobbies found by him, as shown in Fig. 12. If the player has all his hobbies (m=5), then the illustration shows a smiling face. As the player loses hobbies, the face changes in turns from straight (m=4), to long (m=3), to angry (m=2), to difficult (m=1), and then to sad (m=0).

Figure 12. Face illustrations corresponding to the player's hobby situation. Upper left: m=5. Upper middle: m=4. Upper right: m=3. Lower left: m=2. Lower middle: m=1. Lower right: m=0.

V. Conclusion

First, we proposed a formalized agent-based model to simulate the bullying phenomenon, composed of both homogenization and exclusion of classmates. In the simulation, we observed some groups in which the agents found a common set of values with complete homogenization because of the strong desire to prevent exclusion. However, we also observed a few agents who were excluded because they had no interests in common with others in the group. This was 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 middle school in Italy, 26.4% respond 'sometimes or more' and 9.5% as 'once a week or more' when questioned about bullying [2]. The number of potential victims, or isolated agents who are unable to make other friends, generated by our model simulation was similar to those given by the above data.

Second, we improved the model to a gaming simulation model so that students could participate in the simulation. Such combining of gaming with agent-based modeling is a new experimental trial designed to increase our understanding of complex and complicated problems [17]. We have attempted to apply this to the description and explain of the bullying phenomenon. Our trial using gaming simulation will help us solve serious bullying problems; however the work is not yet complete. Future work in this study will be as follows:

- We will add another algorithm to recover those agents that become potential victims.
- We will use CG images for each agent to enhance the interface with the player.
- We will use background music to give the player the feeling of being at a live performance.
- We will also enhance the model so that it can be used on a network to allow plural players into the gaming simulation.

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