Toward Quantitative Assessment of the Effect of Social Education
- A Multi-agent Model Applicable to Jordanian Society -

Teruaki Ohnishi, Abdelaziz L. Khlaifat, Mahmoud Abu-Zaid
Al-Hussein Bin Talal University

ABSTRACT

A multi-agent model applicable to the Jordanian society was developed for assessing the effect of social education. Each agent has two variables representing the knowledge and the attitude to a certain issue; those are continuous variables quantified between 0 and 1 and assumed to change their values with time due to the interaction with other agents, the restriction by social norms, and to the recovery of their original values by oblivion. The communicator, the person who undertakes the responsibility of the social education, was modeled as a similar agent to the general public but with different characteristics from the public. Moreover, the effectiveness of the public relations activity by the mass media was also prepared to be assessed in this model.

Example calculations by this model have revealed that the public knowledge and attitude become to be in collectively unified states depending on the values of constants, the communicator can be an effective attractor which has a decisive influence on the public knowledge and attitude, and that the communicator induces quite an effective change of the public knowledge and attitude when it is overlapped on the effects of the spatial movement of the public and the smooth communication among them. Some examples are shown by animations along with figures. To make such a type of model usable as a tool of assessment, it is necessarily required the fixation of values, which are specific to Jordan, for the various constants in this model, so that the work for quantifying the Jordanian society will be required hereafter.

KEY WORDS: Jordanian society, multi-agent model, social education, public relations, communicator, mass media, social norm, mutual interaction, knowledge, attitude

1. INTRODUCTION

The social education has, in this paper, the same meaning as the so-called public relations (PRs) activity, which is defined as the one to inform the public about some specific subject directly by personal communication or indirectly via the mass media to make them in a state of deep understanding and to stimulate them toward the change of attitude to the subject (We use the term PRs activity hereafter). Such types of activities have been widely executed in developing countries as well as in developed countries by the so-called communicator (or the facilitator) in many fields; for instance, such as the health and environmental protection campaigns (McDivitt, Zimicki and Hornick 1997; Valente and Saba 1998; Korhonen et al. 1998), and the activities to increase the awareness of some risky life style (for instance, Perloff 2001). In this paper, considered are only the social, health or moral campaigns which have such non-profit purposes as to change public's values (as seen in Photos 1, 2 and 3), excluding the advertisements aiming at the commercial purchase or the support of a certain candidate in the election, although all these issues may essentially results in the same type of problem. The problem in this paper is that, when the communicator intends to send non-profit information to the public, to what extent is it effective in enhancing the state of public's understanding and in changing their attitudes to the issue ? In this case, if the communicator's effort is quantified by some means, is it possible to quantitatively assess the results of the activity ?

When the information is send to the public, aiming at the change of their attitudes to a certain subject, its effect can not be estimated, in general, without taking into account the mutual interaction of the public within their society. This means that the public understanding and attitude are forced to be subject to the influence of social environment and to the mutual communication among the people, in other words to the collective dynamics of the public or the opinion dynamics in the society. Although many theoretical researches on this subject have been made in the field of mathematical sociology (Weidlich 1991; Helbing 1992; Holyst, Kacperski and Schweitzer 2000; Laguna et al. 2005), the approach by using simulation models has also grown popular from about a decade ago, visually showing its dynamics and fundamental behaviors with computers (Axelrod 1997). One of such simulation models is the cellular automaton (Ohnishi 1991; Hegselmann and Flache 1998; Stocker, Green and Newth 2001) where an individual is assumed to correspond to one cell on the cellular field regularly arranged in lengthwise or crosswise, purchasing the internal state, for instance the attitude, of the cell changing with time by the interaction with surrounding cells. Another model, the multi-agent model (Epstein 1999; Weisbuch et al. 2001; Mitrovic and Dautenhahn 2003; Urbig 2003; Salzarulo 2006; Lorenz 2006; McKeown and Sheehy 2006) also becomes notable as a promising technique for the simulation during the last decade.

In the multi-agent model, a particle called an agent is introduced corresponding to each individual in the real society. Each agent has variables quantified by some means corresponding to the individual's feelings or senses, such as the attitude and/or opinion to some issue. A multi-agent system, a collective set of agents, is, therefore, considered to be able to simulate the real society, if the interaction among the agents is appropriately modeled as to mimic the real interaction among the people. In this case, the essence of the problem lies in the methodology of modeling of the mutual interactions among the people and between an individual and social environment, which exert an influence on the individual's variable such as the attitude. The communicator can also be modeled as a specific agent in this model together with the general public, which has characteristics somewhat different from the ones of the general agents, such as a stiff attitude and/or the high activity in the system. A schematic diagram of the multi-agent system is depicted in Figure 1.

Since the multi-agent model, as is the case of the multi-particle model in the field of natural sciences (Ohnishi 1994, 1997; Greenspan 1997; Helbing, Farkas and Vicsek 2000), thus makes correspondence the real group of the public to the virtual system of interacting particles, each variable appeared in the model must correspond to a certain variable or statistical value in the real world. In so far as there does not exist quantitative and strict correspondence between those two sets of variables, the interpretations are forced to be qualitative even if the results deduced from the model are given by quantitative values. In spite of such limitation, it is still aimed here to develop an assessment model for estimating in advance the effect of the PRs activity and for making policy for the activity, since the authors are convinced that, by refining its quality hereafter, it can become one of the practical and significant tools in the case when the government, NGOs and other organizations intend to exert some PRs activities on the Jordanian society.

In the next section, the characteristics of the Jordanians and of the Jordanian society to be modeled in this paper are briefly described. The methodology of our multi-agent model is described in Section 3. Example calculations are made and behavioral features of the public's knowledge and attitude are shown in Section 4. In Section 5, conclusions are made, where some remarks are also given in case of the application to this model to the real society.

2. GENERAL CHARACTERISTICS OF JORDANIAN SOCIETY

Although the characteristics of the Jordanians and Jordanian society are as follows, they are more or less common to all nations and societies: Namely, the values of constants or parameters for Jordan merely differs somewhat from the values of other society.

(1) Existing the social pressure or the strong social norm: The public tend to be subject to the social environment or the way of thinking of others surrounding them. This may be able to interpret as the public's following after the religious culture of Islam where the manifestation of individuality is not welcomed. There scarcely exist the cases where the individual characteristics are manifested. The public have a strong tendency to hold traditional states even to the future, this indicating a large social inertia.

(2) A high frequency of oral communication: The rate of the expansion and propagation of information by the mutual communication among the public is quite high. The high penetration rate of mobile phone in recent years has spurred on this trend.

(3) A low frequency of communication among the people with different attributes: The frequency of communication is low between the different gender, the different tribes, the different religious sects, and the different professions, this indicating high in-homogeneity in information propagation.

(4) High imitativeness or a high rate of becoming a follower of a person with high trustworthiness: It is not neglected the trend for the Jordanians to follow without any consideration the way of thinking or the attitude of the

person who is in a high social standing, his or her superior or the tribal leader. In this case, the trustworthiness of the person who is followed is regarded as quite high.

(5) Low imitativeness or a low rate of becoming a follower of a person with different attributes: Such a characteristic may seem stubborn in a third person's eyes. The success or the failure of the activity by the communicator who is a third person in the Jordanian society is only dependent on whether he or she is regarded as a trustworthy person or the person with the same attributes as theirs.

(6) A finite frequency of spatial movement within the tribal territory or over the territory: The movement may be due to one's business, the pasturage of cattle, or to the rearrangement of various subsidies for one's rural tribe, which are determined at some governmental offices in the capital. Considering the high frequencies of spatial movement and mutual communication among the pubic, it is highly probable for the information to propagate and to diffuse throughout the society in a relatively short time. It should be noticed, however, that such movement is also highly dependent on the attributes of the public; for instance, the movement of women is quite scarce comparing to that of men so that it makes the society in-homogenous also from this point.

A model will be developed in the next section by taking such characteristics into account.

3. A MULTI-AGENT MODEL

3.1. General

The model society is virtually set as a regular square plane with each side of unit length, the number of inhabitants, that is the number of agents being set as n_a. Each agent is assumed to have an attribute vector of k components, $\vec{a}_i = \{a_{i\ell}\}, \ell = 1,...k,$ where the suffix i indicates the ith agent and ℓ represents, for instance, the tribe to which the agent belongs, the gender, the occupation, the educational history and so on.

Such a virtual society is, in turn, assumed to be a collective body composed of n_{trb} different tribes, each of which has an equal area of territory to each other in the society. The agents belonging to a certain tribe are randomly distributed on their tribal territory, occupying respective original positions. In the following example calculation, we consider the cases of n_{trb}=1 and 9. In the latter case, the territory of each tribe is assumed to be a regular square of the area of 1/9 neighboring to each other.

The values of constants and constant parameters for the agents are all assumed to randomly distribute within certain ranges of values. For instance, a certain constant X_i of the agent i is given by

$$X_i = X_{\min} + \varsigma_i (X_{\max} - X_{\min}), \tag{1}$$

where $\varsigma_i \in [0,1]$ is a random number and X_{min} and X_{max} are respectively the minimum and the maximum values of a set of $\{X_i\}$. In what follows the X_{min} is taken to be null in general, and the X_{max} is represented as X without the subscript max for simplicity.

The extent of knowledge K_i and the attitude A_i with regard to the issue considering are treated as two variables for each agent. These variables are continuously quantified within the range [0, 1], the numerals 0 and 1 corresponding to the worst and the best states of the variables, respectively. All agents are assumed to be innocent at an initial time so that the quantities K_i and A_i are set null at t =0.

At the time t =1, the PRs activity using some types of mass media is impulsively put in the virtual society in such a manner as the set of knowledge $\{K_i\}$ satisfies either of the following two distributions.

(1) The knowledge is randomly distributed so that

$$K_i = D_k \varsigma_{i,} \tag{2}$$

where ζ_i is a random number as before and D_k (≤1) is a constant parameter.

(2) The knowledge follows the beta distribution with a probability $P(K_i)$ of the form

$$P(K_i) = CK_i^{\alpha-1} \exp(-K_i / \beta), \tag{3}$$

where $K_i \in [0,1]$, and C , α and β are constants. By choosing appropriate values for α and β, we can give an initial distribution of K_i leaned to one side of 0 or 1.

The attitude A_i can not be independent, in general, on the knowledge K_i irrespective to the cases (1) and (2). We assume here that, the more grows the extent of the public's knowledge of an issue, the better becomes the attitude to the issue. The distribution of the attitude at t =1 is, therefore, assumed so that the probability $P(A_i)$ has the form

$$P(A_i) = C_i \exp\left\{-\left((A_i - K_i)/\sigma_i\right)^2 / 2\right\}, \quad (4)$$

where $A_i \in [0,1]$, and C_i is a normalization constant. The quantity σ_i is the standard deviation which is also assumed to be dependent on K_i as

$$\sigma_i = \sigma_0 K_i, \quad (5)$$

σ_0 being a constant.

The agent i changes the values of K_i and A_i in $t > 1$ according to the rules which will be described in the following subsections. In this case, some prerequisites as followings are further introduced.

(1) The knowledge and the attitude are both consisted of two components of temporary and eternal parts. The temporary component exponentially disappears with time by oblivion, whereas the eternal one remains in the public. This means that the agent gradually recovers its original values of knowledge and attitude in the case when the eternal components do not change.

(2) The extent of social sensation with regard to the issue considering, or the public's enthusiasm of the issue, also exponentially decreases with time from the instant of PRs activity by the mass media. The frequency of mutual communication among the public with regard to the issue, f_c, therefore, decreases with time in such a manner as

$$f_c = C \exp\{-(t-1)/\tau_s\}, \quad (6)$$

where C and τ_s is constants. The period when there exists high sensation on the issue is called the stage of high social temperature.

(3) Each agent tacitly senses the average attitude of the agents surrounding oneself by mutually communicating with them, which acts as a social norm.

In what follows we describe the modeling techniques in further details.

3.2. Spatial movement of agent

The agent is assumed to move around the virtual society according to the following rules.

(1) The agent i at its original position has a finite probability P_1 to move to another position. This corresponds to the trip of the individual for the usual business or some other tasks.

(2) The direction of the movement is random, which is given by

$\exp(2\pi\varsigma_i \cdot \vec{j})$, where $\vec{j}$ is an imaginary unit and $\varsigma_i \in [0,1]$ is a random number as before.

(3) The length of the movement λ at one time has the following probability P_2(λ).

$$P_2(\lambda) = C_2 \lambda, \qquad \text{if } \lambda_0 \le \lambda \le R_0, \tag{7}$$

$$= C_2 R_0^{1-\gamma} \lambda^{-\gamma}, \quad \text{if } R_0 < \lambda \le R_{\max}, \tag{8}$$

where $C_2 (= 2(1-\gamma)/\{(1-\gamma)(R_0^2 - \lambda_0^2) + 2R_0^{1+\gamma}(R_{\max}^{1-\gamma} - R_0^{1-\gamma})\})$ is a normalization factor and γ is a constant, which is estimated as 1.6 according to the human traveling behavior (Brockmann, Hufnagel and Geisel 2006). The R_0 and R_{max} are also constants. They are regarded as the effective radius of the territory to which the agent belongs, and the effective radius of the virtual society as a whole, respectively;

$$R_0 = (\pi n_{trb})^{-1/2} \quad \text{and} \quad R_{\max} = \pi^{-1/2}. \tag{9}$$

On the other hand, the quantity λ_0 is the minimum length over which the movement is regarded as a trip, which is given by

$$\lambda_0 = (\pi n_a)^{-1/2}. \tag{10}$$

(4) The agent which is not at its original position at a given time has the probability P_1 to further remove to another position, the probability of P_3 to return to its original position, and the probability (1-P_1-P_3) to stay there as it is.

(5) At the following discrete time which proceeds by a finite time step Δt, each agent repeats the above processes from (1) to (4).

3.3. Knowledge and attitude of agent

The knowledge and the attitude are assumed to change according to the following rules.

(1) The agent *i* has a finite probability P_4^{ij} at a given time to contact with another agent *j* which exist within the interaction lengths r_{int}^{00} or r_{int}^{01}, the r_{int}^{00} and r_{int}^{01} being for the two agents belonging to the same tribes and to

the different tribes, respectively. These are assumed to be given by

$$r_{\text{int}}^{00} = MIN(R_{\text{int}}^{00}, \chi R_0), \tag{11}$$

$$r_{\text{int}}^{01} = MIN(R_{\text{int}}^{01}, r_{\text{int}}^{00}/2), \tag{12}$$

where R_0 is the length given by Eq.(9), χ is a constant, and R_{int}^{00} and R_{int}^{01} are constant parameters.

After the contact, the communication on the issue considering is assumed to take place between the agents with a probability P_5^{ij}. These probabilities are dependent on the attributes of the interactive agents *i* and *j*.

(2) In case of the realization of communication between two agents, the knowledge is transferred one-directionally from the agent with a large value of knowledge to the one with a small knowledge as

$$K_m = K_m^{(0)} + \vartheta_m \{K_n^{(0)} - K_m^{(0)}\}, \tag{13}$$

$$K_n = K_n^{(0)}, \tag{14}$$

where the subscripts *n* and *m* represent the agents with a large and a small values of knowledge in *i* and *j*, respectively, whereas the superscript (0) represents the value in a previous time, and θ_m is a constant depending on the attribute of *m*, $\vec{a}_m$.

The quantity K_m can be decomposed into the temporary part K_m^t which is oblivious afterward and the eternal part K_m^e which remains in the agent even after a long time as the fundamental knowledge of the issue:

$$K_m^t = \vartheta_m \xi_m \{K_n^{(0)} - K_m^{(0)}\}, \tag{15}$$

$$K_m^e = K_m - K_m^t, \tag{16}$$

where ξ_m (<1) is a constant parameter depending on $\vec{a}_m$.

When the communication takes place between the agents, their attitudes are also changed according to the following rules.

(3) If the difference of the attitudes of interactive agents is greater than

some value, namely $|A_i\text{-}A_j|\geq\delta_{ij}$, both of these attitudes do not change their values. Here δ_{ij} is a threshold depending on $\vec{a}_i$ and $\vec{a}_j$. This condition is owed to the fact that they can not accept each other when there exists too large a gap of values between them (Hegselmann and Krause 2002). The δ_{ij} is a factor representing the softness of the agent in changing its attitudes in case of the encounter with another agent so that it is called the *receptivity* of others, hereafter.

(4) When the difference does not exceed the threshold, the agent's attitudes are changed after the communication as (Deffuant et al. 2000)

$$A_i = A_i^{(0)} + \omega_i\{A_j^{(0)} - A_i^{(0)}\}, \tag{17}$$

where the ω_i is a constant depending on $\vec{a}_i$.

(5) Two components of temporary and eternal parts of the attitude, A_i^t and A_i^e, are also given by

$$A_i^t = \omega_i\eta_i\{A_j^{(0)} - A_i^{(0)}\}, \tag{18}$$

$$A_i^e = A_i - A_i^t. \tag{19}$$

where η_i is a constant depending on $\vec{a}_i$.

(6) In general, the more stands the attitude on the right knowledge, the stronger it becomes without blindly following others. This means that the extent of the change of attitude, which arises from the influence of others, decreases with the increase of knowledge of the agent. To take such an effect into account, the above constant ω_i is assumed to be given by the following logistic function with respect to *K.*

$$\omega_i = c_\omega\{1 + \exp(a_\omega + b_\omega K_i)\}^{-1}, \tag{20}$$

where a_ω, b_ω and c_ω are constants. When the value of b_ω is given by the form

$$b_\omega = \varphi\ln(\Phi), \tag{21}$$

then, the a_ω and c_ω are respectively given in terms of φ *and* Φ by

$$a_\omega = \ln\{(1-\Phi)/(\Phi-\Phi^\varphi)\}, \tag{22}$$

$$c_\omega = \omega_0\{1 + (1-\Phi)/(\Phi-\Phi^\varphi)\}, \tag{23}$$

where φ, Φ and ω_0 are constant parameters. Since the quantity ω_0 is a factor representing the extent of following others' opinion, it is called the *adaptability* to others, hereafter.

(7) The attitude can also be changed by the social environment since it is influenced by the social norm of the society to which the agent belongs. Such an extent increases with increasing the extent of the commitment of agent to the society. The social norm can act as a social pressure on the agent, so that the agent changes its attitude during the successive times, tacitly sensing the social environment surrounding oneself, by the amount

$$\Delta A_i = \varepsilon_i \{\langle A \rangle_i - A_i^{(0)}\}, \tag{24}$$

$$\langle A \rangle \equiv \sum_k{}' A_k^{(0)} / \sum_k{}' 1, \tag{25}$$

where ε_i (≤ 1) is a constant parameter. Since the influence from the social norm increases with the increase of ε_i, this is called the *assimilability* hereafter. The expression Σ' means the sum with respect to all agents within the radii $r_{\rm int}^{00}$ or $r_{\rm int}^{01}$ of the agent *i*. Here the $r_{\rm int}^{00}$ and $r_{\rm int}^{01}$ are the interaction lengths given by Equations (11) and (12), respectively.

(8) At the same time of the manifestation of mutual communication and social norm, but apart from them, the temporary parts of the knowledge and attitude decrease exponentially with time. The quantities $K_i^{(0)}$ and $A_i^{(0)}$ must, therefore, be replaced at the final stage of the procedures by

$$K_i^{(0)} \Leftarrow K_i^e + K_i^t \exp(-\Delta t / \tau_i^K), \tag{26}$$

$$A_i^{(0)} \Leftarrow A_i^e + A_i^t \exp(-\Delta t / \tau_i^A) + \Delta A_i. \tag{27}$$

Here τ_i^K and τ_i^A are constants.

(9) The calculation repeats the above processes (1)~(8) in the next time step.

3.4. Communicator agents

To investigate the effect of communicator, we introduce n_c communicator agents (referred to as the C-agents, hereafter) into our virtual society, each of which has the moving probability $P_1^C (\equiv \mu_1 P_1)$ and the probability of return to its original position $P_3^C (\equiv \mu_2 P_3)$, where μ_1 (≥1) and μ_2 (≥1) are constants and the superscript (or the subscript) C indicates the C-agent. The original position of the C-agent is randomly set in a territory of a given tribe. The knowledge, together with the trustworthy, of the C-agent is complete for the issue considering and its attitude is also sufficiently stiff (Ohnishi 2004) so that

$$K_C = 1.0, \delta_{Cj} = 1.0 \text{ and } A_C = 1.0, \tag{28}$$

for all times without being changed with time. Here δ_{Cj} is the receptivity of the C-agent by the other agent *j*.

3.5. PRs activities by using the mass media

The mass media are used in many cases in the PRs activity. The information offered by the activity reaches to the public with a probability Λ_i which depends on the attributes of the public, or the agent *i*. The extent of public understanding for the offered information, that is the easiness of information for the public to understand is also dependent on the public attributes. As for a parameter representing such an extent, we have already introduced the quantity D_k (or $D_k\zeta_i$) in Equation (2). Without describing the details of mass media, we investigate, in our model, the effect of PRs activity by using the mass media with a pair of parameters $(\Lambda_i, D_k) \equiv (\Lambda, D_k)$, neglecting for simplicity the dependency of the reach on agents.

When we intend to change the public's thought and/or the attitude to some issue, the activities for it are, in general, executed repeatedly in several times by using the same measures or different measures in each time. If, in the *m*'th trial of such activities, the knowledge of the agent *i* which accept the information message increases by $\Delta K_i^{(m)}$, the attitude of the *i* must also increase by $\Delta A_i^{(m)}$ (≥0), because it is connected with $\Delta K_i^{(m)}$ in our model. Here we assume the probability for the $\Delta A_i^{(m)}$, $P(\Delta A_i^{(m)})$, as

$$P(\Delta A_i^{(m)}) = C \exp\left\{-[(\Delta A_i^{(m)} - \Delta K_i^{(m)}) / \sigma_i^{(m)}]^2 / 2\right\} \tag{29}$$

where $\sigma_i^{(m)} = \sigma_{00} \Delta K_i^{(m)}$, and C and σ_{00} are constant. The increment $\Delta K_i^{(m)}$ can be determined by the similar manner as Equations (2) and (3). Considering the range of $\Delta A_i^{(m)}$ which is equal to or less than unity, the attitude after the m'th trial of the activity is given by

$$A_i = A_i^{(0)} + \Delta A_i^{(m)} \tag{30}$$

where

$$\Delta A_i^{(m)} = MIN(\Delta A_i^{(m)} \textit{ given by the distribution Eq.}(29)\,, 1 - A_i^{(0)}). \tag{31}$$

When there exist communicators in this society, the effect can be surmounted on such activities.

3.6. Time evolution of the agent system

We can see the evolutional feature of the system under a given initial condition by repeating the above procedures at every discrete time. To what real time the discrete time interval Δt corresponds must be determined by taking into account the real frequency of trip, the frequency of mutual communication, and all other probabilities and frequencies in real society for which we have no information at present. The non-dimensional *time* in our model is, therefore, merely an independent variable representing the evolutional speed of the virtual society, at this time.

At a given time t, the following procedures are executed for all agents in random order.

(1) The positions are determined for all agents at a time t according to whether they move or not.

(2) The possibility for all agent to interact with the other are investigated. If they interact, then, its new values of K and A are calculated.

(3) The relaxation processes, which include the effects of oblivion (or the recovery of each original value) and restriction by the social norm during the time interval Δt to the next discrete time, are considered for all agent.

(4) The time is proceeded by Δt, and the procedure is returned back to (1). The procedures (1)~(4) are repeated up to the time t_{max} .

A FORTRAN program named SEasses (Social Education assessment) of about 1200 lines, which was developed for this model, is given in the Appendix 1.

4. EXAMPLE CALCULATION

The values given in Table 1 are used for constants and constant parameters in our calculation. Qualitative results do not essentially depend on those values. Control parameters in what follows are the quantities $R_{\rm int}^{00}$ (interaction length), P_1 (moving probability), δ (receptivity), ω_0 (adaptability), ε (assimilability), n_{trb} (number of tribe), and n_c (number of C-agents), together with the PRs conditions of Λ (reach) and D_k (understandability); these are all treated as independent on the agents' attributes, for simplicity, except for ω_0 and ε which follow Equation (1). After the first execution of PRs activity by using the mass media at t =1, the knowledge of the agents is assumed to distribute randomly within the range [0, D_k] according to Equation (2), unless otherwise noticed. The word *the agents* is used as the same meaning as the public in the virtual society. In what follows, we briefly investigate the meaning or the role of the parameters in our model, that is, how our virtual society responds to the change of the parameters.

4.1. Fundamental response of the virtual society

In the first place the investigation is made by what extent we can finally expect the effect of PRs activity by using the mass media which is input at t =1 under the condition of, for instance, $(R_{\rm int}^{00}, P_1, \delta, \omega_0, \varepsilon)$ =(0.04, 0.0, 1.0, 0.08, 0.0) with n_{trb} =1 and n_c =0.

Figure 2 shows the values of knowledge and attitude at t =400 averaged over all agents, $\langle K\rangle$ and $\langle A\rangle$, as functions of Λ and D_k. The quantities $\langle K\rangle$ and $\langle A\rangle$ purely represent the resultant effects of PRs activity as we assume the innocent conditions at t =0, that is, K_i = A_i =0 for all i. The extent of these effects is roughly proportional to the input efforts, Λ and D_k. When we use a certain type of mass media in the activity, the magnitude of the reach Λ is dependent on what popular media among the public we use in the activity. On the other hand the magnitude of the understandability D_k

realized in practice is owed to the degree by what extent the offered information fits the cultural level of the public, and by what extent the information attracts the public's interest, namely, to the extent of an appealing force to the public. The fact that the effect is roughly linear to the efforts made on Λ and D_k means that it makes easier to estimate the effect in the case of repeated activities on the same society and of the activities using several measures at one time. In what follows in this section, we fix the values of parameters as Λ =1.0, D_k =1.0.

Figures 3 and 4 respectively show the time behaviors of knowledge and attitude for randomly chosen 30 agents under the condition of $(R_{\text{int}}^{00}, P_1, \delta, \omega_0, \varepsilon)$ =(0.04, 0.0, 1.0, 0.08, 0.0). Since the area occupied by one agent, S_a, is $S_a \approx (n_a)^{-1}$ = 0.001, the value of 0.04 for the R_{int}^{00}, hence for the r_{int}^{00} according to Equation (11), roughly corresponds to the existence of four agents in average $(\approx \pi\left((r_{\text{int}}^{00})^2 / S_a\right) - 1)$ with which the agent considering has a probability to interact. The mean knowledge of agents just after the PRs activity at t =1 is about 0.5. The information transfer between the agents makes the distribution of knowledge collectively unified with time, elevating the state of the agent with a low level of knowledge whereas the knowledge of high level agent gradually decreasing due to oblivion, so that the mean knowledge over the society decreases to 0.319 at t =400.

The mean attitude $<A>$ is also about 0.5 at first. Since, under such a condition of receptivity as δ=1.0, every agent changes its attitude, being influenced from all other agents with which the interaction takes place, the agents' attitudes gradually become resemble to each other with the elapse of time, as seen in Figure 4. Although we consider the recovery of attitude to its original state, that is null in this case, the mean attitude becomes $<A>$ =0.559 at t =400 due to a relatively long time scale (τ^A =8000) assumed for its recovery.

When we enlarge the range of interaction as $R_{\text{int}}^{00} = \chi R_0 = \chi \pi^{-1/2} = 0.187$, (according to Equation (9), where χ =1/3), without changing other parameters, the situations change as seen in Figures 5 and 6. The value

$r_{\rm int}^{00}(=R_{\rm int}^{00}$, according to Equation (11)) corresponds to the possible interaction of an agent with about one nineth the agents in the whole society. The quantity *<K>* shows a maximum at an early time ($<K>_{max}$=0.765 at *t* =71), being influenced by the agents with high values of knowledge, but decreases exponentially with time due to the oblivion to *<K>* =0.556 at *t* =400. The distribution of knowledge in the society becomes sharp at *t* =400. On the other hand, the attitudes in the society are collectively unified within a very early time (t<50), slowly recovering their original attitudes to become *<A>* =0.591 at *t* =400. These figures indicate that the expansion of interactive region leads the promotion of unification of knowledge and attitude between the public.

The behaviors of <K> and <A> under the condition of a small value of $r_{\rm int}^{00}$, but with a non-zero, finite value of P_1, are essentially similar to the ones of a large value of $r_{\rm int}^{00}$ with a zero P_1. This is simply because the effect of agent with a small interaction length but with the freedom of movement throughout the society is seemingly the same as the effect of static agent with a large interaction length over the whole society. The individual behavior of K_i and A_i under a non-zero vale of P_1, however, quite differ from the previous cases with P_1 =0, considerably fluctuating with time. An example for the attitude in case of $R_{\rm int}^{00}$=0.04 and P_1 =0.01 is shown in Figure 7.

Figure 8 shows the attitudes for the case of small δ, with $(R_{\rm int}^{00}, P_1, \delta, \omega_0, \varepsilon)$ =(0.187, 0.01, 0.1, 0.08, 0.0). The knowledge distribution is not shown here as it scarcely depends on δ. The attitudes, however, split into five collectively unified attitudes with roughly the same distances between them. This is the manifestation of the so-called 1/2δ-rule (Weisbuch et al. 2001). Since the agents with those unified attitudes distribute randomly but almost uniformly on the plane of virtual society without forming any lumps of agents with the same attitude, as seen in Figure 9, this mimics the society intermingled by the people with a few discrete but different attitudes from each other.

Figure 10 shows the attitude behavior under the condition of a much smaller value of ω_0 than that used heretofore; $(R_{\text{int}}^{00}, P_1, \delta, \omega_0, \varepsilon)$ =(0.187, 0.0, 1.0, 0.005, 0.0). Since the value of ω_0 (=0.005) is the same in its magnitude as the θ which determines the extent of the change of knowledge, the extent of the unification of attitude with time is almost similar to that of knowledge given in Figure 5. Although the attitudes of almost all agents are changed toward a collectively unified value by the time t =100, such a unified attitude does not grow to a so sharp distribution as in Figure 6 at least up to t =400 with that value of ω_0.

Figure 11 shows the attitudes under the existence of social norm (:ε>0) with $(R_{\text{int}}^{00}, P_1, \delta, \omega_0, \varepsilon)$ =(0.187, 0.01, 0.1, 0.08, 0.01). The knowledge scarcely depends on ε. For the attitude, however, the social norm clearly has a force to make them approach toward the average value of the whole or local society, depending on the value of R_{int}^{00}. The effect of such unification by the social norm further exerts on the collectively unified attitudes so that the society becomes to be finally subject to one unified attitude.

The rate of unification or the state of aggregation of attitude, thus, depend on the large and small values of R_{int}^{00}, P_1, δ, ω_0, and ε ; namely, the swift unification of attitudes can be realized by making large for one or more than one of the values of variables R_{int}^{00}, P_1, δ, ω_0, and ε.

4.2. The effect of communicator

Investigated in this subsection is the influential effect of the communicators when they are input in the society at t =1 instead of or in addition to the PRs activity by using the mass media. We fix the values of parameters as $(R_{\text{int}}^{00}, \delta, \omega_0, \varepsilon)$ =(0.187, 0.2, 0.08, 0.0), and Λ =1.0, D_K =1.0 and n_{trb} =1, leaving the moving probability of agent P_1 and the number of communicators n_c as control parameters. As stated earlier, the moving probability of C-agent, P_1^C, is given by $\mu_1 P_1$, where μ_1 being a constant.

According to the 1/2δ-rule (Weisbuch et al. 2001), there appear two collectively unified attitudes intermingled in the society when δ=0.2. The effects of the communicator on the knowledge, ΔK^C, is defined here as

ΔK^C =(average knowledge of the society at t=400 under the existence of communicators, $<K^C>$) -

- (average knowledge of the society at t=400 without any communicators, $<K^0>$) (32)

The similar definition as this is also made for the attitude ΔA^C. When P_1 =0.01, those values, $<K^0>$ and $<A^0>$, of the ensemble mean of ten cases are $<K^0>$ =0.519 and $<A^0>$ =0.487, respectively, so that the effects of one C-agent which is put in the society but does not interact with its surroundings are (ΔK^C *without interaction*) $\equiv \Delta K_0^C$ = (1.0-$<K^0>$)/n_a ≈ 0.0005 and ΔA_0^C = (1.0-$<A^0>$)/n_a ≈ 0.0005. Table 2 gives the effect of interacting C-agent which is input at t =1 in an initially innocent society. Although the introduction of the communicator obviously has a positive influence on the public's knowledge and attitude, the extent of its effect per one communicator, $e_K \, (\equiv \Delta K^C / \Delta K_0^C / n_C)$ and $e_A \, (\equiv \Delta A^C / \Delta A_0^C / n_C)$, decreases with increasing the number of communicators input in the society.

Figures 12 and 13 show the features of time variation of the public's knowledge and attitude, respectively, when the twenty communicators (: n_c=20) are introduced at t =1 in an innocent society under the static condition (:P_1 =0.0). These figures, especially Figure 13, indicate that the communicator's activity can effectively influence on the public when the public within the interaction range evolve with almost the same pace as each other, since the agent's attitude scarcely decreases by interacting the other agent with a much lower attitude than it has.

Hereafter the cases are considered where the communicators are introduced in the society at the same initial time t =1 as the execution of PRs activity by using the mass media, whose effect is given randomly according to Equation (2). Under our condition of parameters, firstly formed two unified attitudes are further collectively unified finally to become a thought common to all social members as shown in the previous subsection. How the final attitude thus formed behaves afterward depends on the number of C-agents, since the final attitude is attracted toward the C-agents' attitude, A_C =1.0, with time. The rate of attraction, in this case, depends on the number of C-agents. The behaviors of public's knowledge for the case without any C-agents, (n_c, P_1)=(0, 0.0), and the case of twenty C-agent, (n_c, P_1)=(20, 0.0), are respectively shown in Figures 14 and 15. for comparison, whereas in Figures 16 and 17 for the attitude. We can see in these figures the distinct nature of communicators as an attractor of the knowledge and attitude.

Figure 18 shows the spatial distribution of attitude on the plane of virtual society corresponding to the time t =400 in Figure 17. There appear two distinct regions with different values of attitude. In case of a static society with P_1 =0, the change of the attitude spatially propagates throughout the society. The state shown in Figure 18 is just of a transient one of such propagation, whose feature up to t =400 can clearly be seen in Animation 1.

Such a type of attitude propagation is scarcely realized in a dynamical society with $P_1 > 0$. In this case, however, under the existence of strong social norm, there temporarily appears spatial in-homogeneity in the public attitude. An example for this is shown in Figure 19, which is the social state at t =200 under the conditions of $(R_{\text{int}}^{00}, \delta, \omega_0, \varepsilon) = (0.04, 0.2, 0.08, 0.01)$ with (n_c, P_1)=(20, 0.01), whereas Figure 20 shows the feature of attitude evolution in this case. Figure 19 clearly indicates the appearance of the in-homogeneity of an order of r_{int}^{00} (=0.04, according to Equation (11)) in scale. Such a social tendency, however, is also transient and the in-homogeneity in space gradually disappears with time. We can see such a situation of social evolution up t =400 in Animation 2. The evolutional feature of the knowledge is not necessarily so spectacular as the attitude.

The spatial in-homogeneity as seen in Figures 18 and 19, even if they are temporary, never appear in our virtual society when there exist no C-agents. This indicates that the introduction of communicators brings the society perturbed, making spatial distribution of knowledge and attitude inhomogeneous, along with the enhancement of knowledge and attitude of the public.

4.3. Society composed of many tribes

The society considered here is of composite of nine different tribes where square territories with a side length of 1/3 are regularly neighboring to each other as seen in Figure 21. We call this as the multi-tribe model instead of the one-tribe model heretofore. We investigate in what follows the influential effect of communicators introduced in the central tribe 1 on its surrounding tribes 2~9. The total number of agents assumed in the tribes 1~9 is 1000 so that about one C-agent in the tribe 1 corresponds, in its surface density, to nine C-agents in the one-tribe model of 1000 agents.

In the first place, studied is the case where the initial condition for the tribes except for the tribe 1 is assumed innocent on the issue considering, whereas the PRs activity given by Eq.(2) with Λ=D_k=1.0 is assumed to exert on the 1 along with the introduction of C-agents. In this case, so far as the society is static (;P_1 =0), the situation in the surrounding tribes can not be changed fundamentally even when the C-agents are input in the tribe 1 by more than 100. This is mainly due to the model assumption that the influential effect by the agents in the different tribe is much weaker than the agents in the same tribe; that is $r_{\rm int}^{01} = r_{\rm int}^{00}/2$ according to Equations (11) and (12).

The society becomes perturbed once P_1 has a finite value. In the case when P_1=0.01, the C-agents can move almost freely throughout the whole society, irrespectively to the tribe borders. The time behavior of knowledge and attitude in the tribe 1, therefore, approaches to the case of one-tribe model with the number of nine times the C-agents input in the tribe 1. The enhancements of knowledge in the tribe 1 and, for instance the tribe 5, are 0.165 and 0.010 in average at t =400, respectively, whereas those of the attitude are 0.407 and 0.176, respectively, when twenty C-agents are input in the region 1. Figure 22 shows the attitude in the tribe 1, which should be compared to Figure 15 in one-tribe model, whereas Figures 23 and 24 respectively show the time behaviors of the knowledge and the attitude in the tribe 5. All these figures are under the conditions of $(R_{\rm int}^{00}, P_1, \delta, \omega_0, \varepsilon) = (0.187, 0.01, 0.2, 0.08, 0.0)$. The abrupt and discontinuous increases of knowledge and attitude in the tribe 5 are the resultant effect of the temporary visit of communicators to this tribe.

In the next place, the cases are considered where the PRs activity is executed throughout the whole society at t =1 by using the mass media, but the C-agents are input only in the tribe 1 by the number n_c. When the society is static (P_1=0) and the conditions of (R_{int}^{00}, δ, ω_0, ε)=(R_0/3(=0.062), 0.2, 0.08, 0.01) hold along with n_c =20, the attitudes in every tribe can be collectively unified into two branches according to the 1/2δ-rule (Weisbuch et al. 2001). Here $R_0 = (\pi n_{trb})^{-1/2} = 0.187$ is an effective radius corresponding to the territory of one tribe. Figures 25 and 26 show the distributions of the knowledge and the attitude on the social plane at t =400, respectively. The effect of the C-agents in the tribe 1 on the knowledge seems to be restricted almost to the 1, only giving a limited influence on the agents in the neighboring tribes, which exist near the border with the 1.

Studied in the next place is the case when the interaction becomes uniform among tribes; $r_{\mathrm{int}}^{01} = r_{\mathrm{int}}^{00}$, not restricted by the conditions Equations (11) and (12).

Figures 27 and 28 respectively show the distributions of the knowledge and the attitude at t =400 under the conditions of $(R_{\mathrm{int}}^{00}, P_1, \delta, \omega_0, \varepsilon) = (0.062,$ 0.0, 1.0, 0.08, 0.01) with $r_{\mathrm{int}}^{01} = r_{\mathrm{int}}^{00}$ and n_c =20. These figures show a tendency of outward propagation of knowledge and attitude, although their state of propagation is slightly non-uniform in direction due to the fluctuation in calculation. Figures 27 and 28 show the situation of knowledge and attitude in the surrounding tribes clearly improved comparing to the previous Figures 25 and 26, indicating that the smoothed communication between the tribes by making $r_{\mathrm{int}}^{01} = r_{\mathrm{int}}^{00}$ and δ =1 leads the effective transport of knowledge and attitude from the C-agents. Animation 3 shows the evolutional feature of the public attitude on the social plane.

On the other hand, Figures 29 and 30 respectively shows the same distributions as Figures 27 and 28, but for the dynamic society with P_1 =0.01. The evolutional features of the public attitude on the virtual plane can be seen in Animation 4. From these figures and animation, we can notice that the spatial movement of people is one of the most important factors which bring the spatial homogenization of attitude as well as the knowledge enhancement in the society as a whole. This indicates that the communicators' effort can manifest their influence on the public's knowledge and attitude if they are synchronized with the dynamics of the society, that is the spatial movement of and the smooth communication among the public.

5. CONCLUDING REMARKS

When we notice the correspondence between the real society where the public are in the state of psychological interaction and the physical system composed of many particles interacting among them, we can easily accept the multi-agent model as an effective measure to simulate the collective social system. By applying such a model, although it may be qualitative, we can obtain the information on the time behaviors of public psychology and/or attitude to some specific issue which have been understood only phenomenally. Thus, the followings have become clear by our multi-agent model.

(1) The public's knowledge and attitude have a tendency to be pulled in some specific values with time finally to form collectively unified values.

(2) The expansion of the spatial extent of interaction among the public further promotes the unification of the knowledge and attitude.

(3) The social norm also promotes the unification, gathering some collectively unified values into a single unified value.

(4) The PRs activity by using the mass media exerted on the society initially innocent on the issue has an effect roughly proportional to its effort. The effort in this case is related to the reach of the information into the society and to the understandability of the offered information.

(5) The introduction of communicators in the society is clearly effective in that they enhance the extent of knowledge and attitude of the public in average.

(6) The communicator can be a social attractor for the change of public's knowledge and attitude, whose effect appearing non-linearly with respect to the input human resources.

(7) In a static society without any movement of agents, the change of knowledge and attitude propagate through the space of society.

(8) In the society of strong social norm, there appears the spatial in-homogeneity in the knowledge and attitude, whose scale length being of

the order of effective interaction length.

(9) In the society composed of many different tribes, the extent of the dynamics of the society is one of the important factors which promote the homogenization of knowledge and attitude among tribes.

(10) In this case, the activity by the communicator can be quite effectively manifested in the public's knowledge and attitude when the introduction of the communicator in the society is just synchronized with the dynamism of the society, that is the movement of the public and the effective communication among the public.

In the meantime, the most difficult problem which arises in any simulation model in social sciences, irrespective of the kind of model, is that there scarcely exists the clear correspondence between the constants and/or the coefficients in the model and the concrete variables and/or the statistical quantities really observed in the real society. For this reason, we have been forced to discuss only qualitatively the results of social phenomena derived by using simulation models. To approach the quantitative discussion, therefore, we must first define precisely the constants and parameters used in the model and then derive the values of corresponding quantities from the subject society through the observation or the on-site social survey, that is the fixation of the values of constants and parameters. For instance, in our case, they may be obtained from the observation on the public's contact and communication frequency with others and the frequency for the movement, together with the extent of the change of one's opinion under the influence of the conversation with others. Without any quantification to break through the limit over an academic interest, such a simulation model can not become an effective tool for the practical use of estimation and of policy making. To be asked in Jordan now is the swift determination of the values for such constants and parameters via the social survey.

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Table 1 Values of constants and constant parameters*)

n_a =1000, n_{trb} =1 or 9, Δt =1, t_{max} =400,
α =1.2, β =0.2, γ =1.6, η =0.9, θ =0.005, $\mu_1 = \mu_2$ =10,
ξ =0.9, φ =2.0, Φ =10.0, χ =1/3, $\sigma_0 = \sigma_{00}$ =0.1,
τ_s =400.0, τ^K=400.0, τ^A=8000.0,

$P_3 = P_1$ =0 or 0.001, P_4 =0.5, P_5 =1.0, $R_{\text{int}}^{01} = R_{\text{int}}^{00}$

*) all assumed independent on agent's attributes

Table 2 The effect of C-agents under the conditions of, for instance,

$$(R_{\text{int}}^{00}, P_1, \delta, \omega_0, \varepsilon) = (0.0187, 0.01, 0.2, 0.08, 0.01)$$

n_c	ΔK^{C} †)	ΔA^{C} †)	e_K *)	e_A *)
1	8.08-3	3.84-2	16.2	76.8
5	3.80-2	1.53-1	15.2	61.2
10	7.29-2	2.44-1	14.6	48.8
50	2.12-1	4.26-1	8.5	17.0

†) a-b denotes $a \times 10^{-b}$.

*) $e_K \equiv \Delta K^C / \Delta K_0^C / n_C$ and $e_A \equiv \Delta A^C / \Delta A_0^C / n_C$,

where the quantities with the subscript 0 indicate the cases of the C-agents without any activity.

Photo 1: A scene of toothbrush lesson exerting in Syria. Such an activity is a typical one of the public relations activities claimed in this paper. (photo by K.Ebisu from JICA 2006 Calendar *Dear World,* May).

Photo 2: Improving campaign of sanitary environment exerting in a village of Northern India. The left hand-side person in this photo is the communicator in this activity. (photo by M.Tanimoto from *Monthly Jica* , April 2006, pp.6-9).

Photo 3: An example of PRs activity by using the mass media. One of the UNICEF's activities in 2006 is to widely inform the public about the present status of *'excluded and invisible'* children, aiming at the change of public recognition and attitude to this issue. Young boys and girls from refugee camps in Jordan produced a documentary film on this subject under the guidance of UNICEF and UNRWA, whose presentation caused a great sensation in a UNICEF meeting. This article reports about it. Although the produced film and printed matters, for instance, posters as shown by the photo in this article are important measures for the PRs activity, the fact that UNICEF released the news related to its campaign into the society via the mass media, the newspaper in this case, should be noted just to be one of the meaningful PRs activity. (from *The Jordan Times*, December 15, 2005)

Animation 1: Time evolution of the spatial distribution of attitude from t =1 to 400 on a plane of static society (P_1 =0.0). The conditions are $(R_{\text{int}}^{00}, \delta, \omega_0, \varepsilon, n_c) = (0.187, 0.2, 0.08, 0.01, 20)$. The agents are represented by small circles and their attitudes in the ranges [0, 0.2], (0.2, 0.4], (0.4, 0.6], (0.6, 0.8], and (0.8, 1.0] are respectively given by blue, green, red, yellow and white in color.

Animation 2: Time evolution of the spatial distribution of attitude on a plane of dynamic society under the constraint of social norm. The conditions are $(R_{\text{int}}^{00}, \delta, \omega_0, \varepsilon, n_c) = (0.04, 0.2, 0.08, 0.01, 20)$.

Animation 3: Time evolution of the spatial distribution of attitude on the plane of multi-tribe society under the stationary condition (:P_1 =0.0) without any restriction of information transfer among the tribes. The conditions are $(R_{\text{int}}^{00}, \delta, \omega_0, \varepsilon, n_c) = (0.062, 1.0, 0.08, 0.01, 20)$.

Animation 4: The same as Animation 3 but under the dynamical condition of P_1 =0.01.

Figure 1: Schematic diagram of multi-agent model. This is an example of the system composed of five agents A_1~A_5 with respective interaction lengths $r_1^{\text{int}} \sim r_5^{\text{int}}$. Since each agent can interact with the other agents situated within the length, the agent A4 interacts with A_2, A_3, A_5 and A_6, and the A_3 interacts with A_4. The agent A_1, however, can not interact with any agent at this position. On the other hand, although the A_2 has an influence from the A_4, it can not influence on any other agents.

Figure 2: Increments of knowledge and attitude, <ΔK> and <ΔA>, as functions of reach Λ and understandability D_k.

Figure 3: Time evolution of knowledge of randomly chosen 30 agents under the conditions $(R_{\text{int}}^{00}, P_1, \delta, \omega_0, \varepsilon) = (0.04, 0.0, 1.0, 0.08, 0.0)$.

Figure 4: Time evolution of attitudes of randomly chosen 30 agents under the same conditions $(R_{\text{int}}^{00}, P_1, \delta, \omega_0, \varepsilon) = (0.04, 0.0, 1.0, 0.08, 0.0)$ as in Figure 3

Figure 5: The same as Figure 3 but under a longer interaction length R_{int}^{00} =0.187

Figure 6: The same as Figure 4 but under a longer interaction length R_{int}^{00} =0.187

Figure 7: The same as Figure 4 but under the moving probability P_1 =0.01

Figure 8: Time evolution of attitudes under the conditions $(R_{\text{int}}^{00}, P_1, \delta, \omega_0, \varepsilon) = (0.187, 0.01, 0.1, 0.08, 0.0)$. The splitting of collectively unified attitudes is mainly owed to the small value of the receptivity δ.

Figure 9: Spatial distribution of attitude on the plane of visual society at t =400. The agents are randomly distributed on the plane and their attitudes are distinguished with every 0.2 interval by different colors, as given in the legend.

Figure 10: Time evolution of attitudes under the same condition as in Figure 6 except for the adaptability ω_0 =0.005

Figure 11: Time evolution of attitudes under the same condition as in Figure 8 except for the assimilability ε =0.01

Figure 12: Time evolution of knowledge when the C-agents are introduced by

the number n_c =20 in the society where D_k =0. The conditions are $(R_{\rm int}^{00}, P_1, \delta, \omega_0, \varepsilon) = (0.187, 0.0, 0.2, 0.08, 0.0)$.

Figure 13: Time evolution of attitudes under the same condition as in Figure 12

Figure 14: The same as Figure 12 but under the conditions of n_c =0 and D_k =1.0

Figure 15: Time evolution of knowledge under the same condition as in Figure 14 except for n_c =20

Figure 16: Time evolution of attitudes under the same condition as in Figure 14

Figure 17: Time evolution of attitudes under the same condition as in Figure 15

Figure 18: Spatial distribution of attitudes at the time t =400 in Figure 17

Figure 19: Spatial distribution of attitudes at t =200 under the conditions of $(R_{\rm int}^{00}, P_1, \delta, \omega_0, \varepsilon) = (0.04, 0.01, 0.2, 0.08, 0.01)$ and n_c =20

Figure 20: Time evolution of attitudes under the same conditions as in Figure 19

Figure 21: Territories of the tribes 1~9. The introduction of C-agents is assumed only in the tribe 1.

Figure 22: Time evolution of attitudes in the tribe 1 where D_k =1.0 at t =1. The conditions are $(R_{\rm int}^{00}, P_1, \delta, \omega_0, \varepsilon) = (0.187, 0.01, 0.2, 0.08, 0.0)$ and n_c =20.

Figure 23: Time evolution of the knowledge in the tribe 5 where D_k =0.0 at t =1, under the same conditions as in Figure 22

Figure 24: The same as Figure 23 but of the attitudes

Figure 25: Spatial distribution of knowledge at t =400 under the conditions of $(R_{\rm int}^{00}, P_1, \delta, \omega_0, \varepsilon) = (0.062, 0.0, 0.2, 0.08, 0.01)$ and n_c =20.

Figure 26: The same as Figure 25 but of the attitudes

Figure 27: Spatial distribution of knowledge under the same condition as in Figure 25 except for δ =1.0

Figure 28: The same as Figure 27 but of the attitudes

Figure 29: Spatial distribution of knowledge at t =400 under the conditions of

$(R_{\text{int}}^{00}, P_1, \delta, \omega_0, \varepsilon) = (0.062, 0.01, 1.0, 0.08, 0.01)$ and n_c =20.

Figure 30: The same as Figure 29 but of the attitudes

APPENDIX 1

Computer Program *SEasses* in FORTRAN

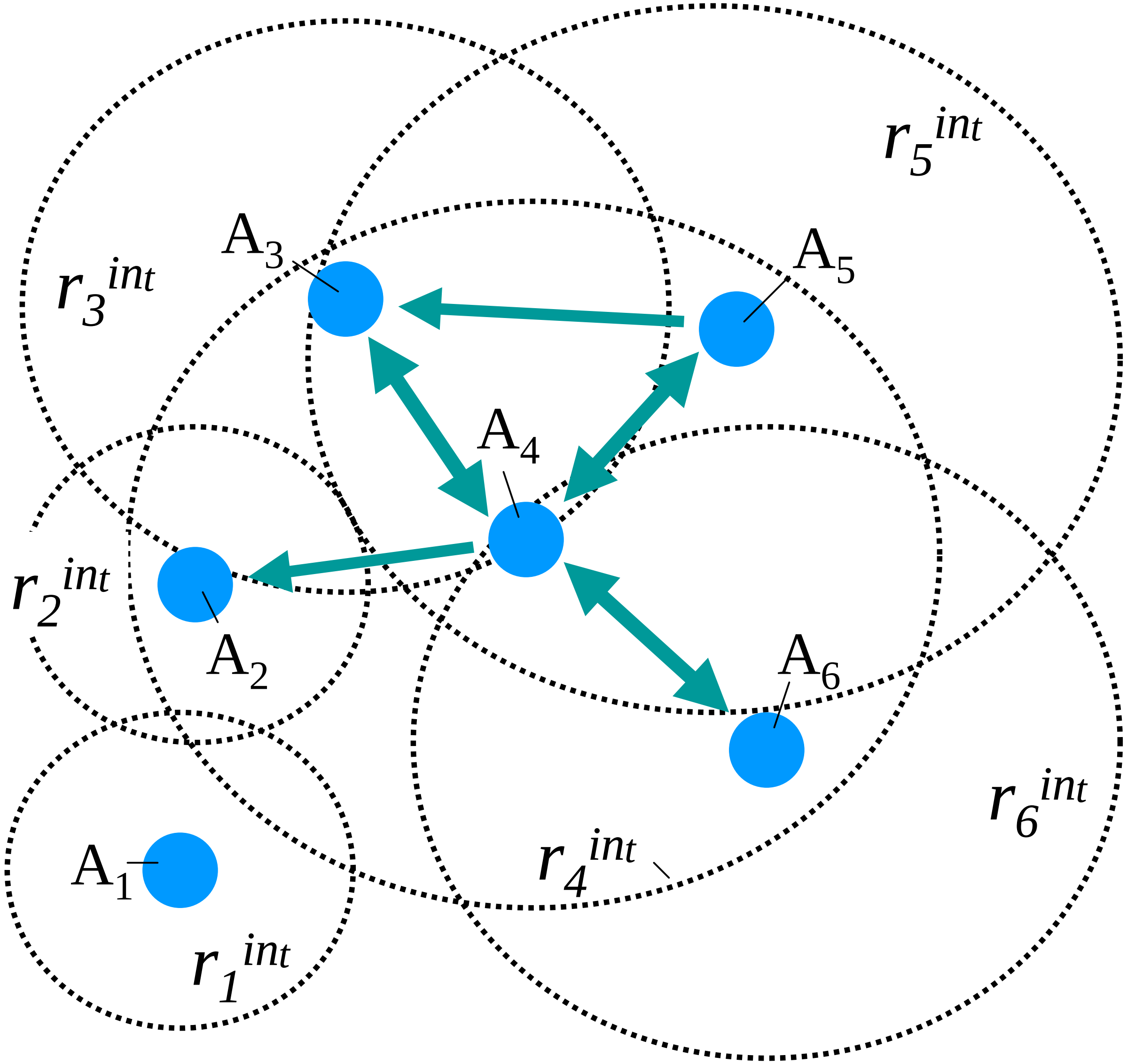
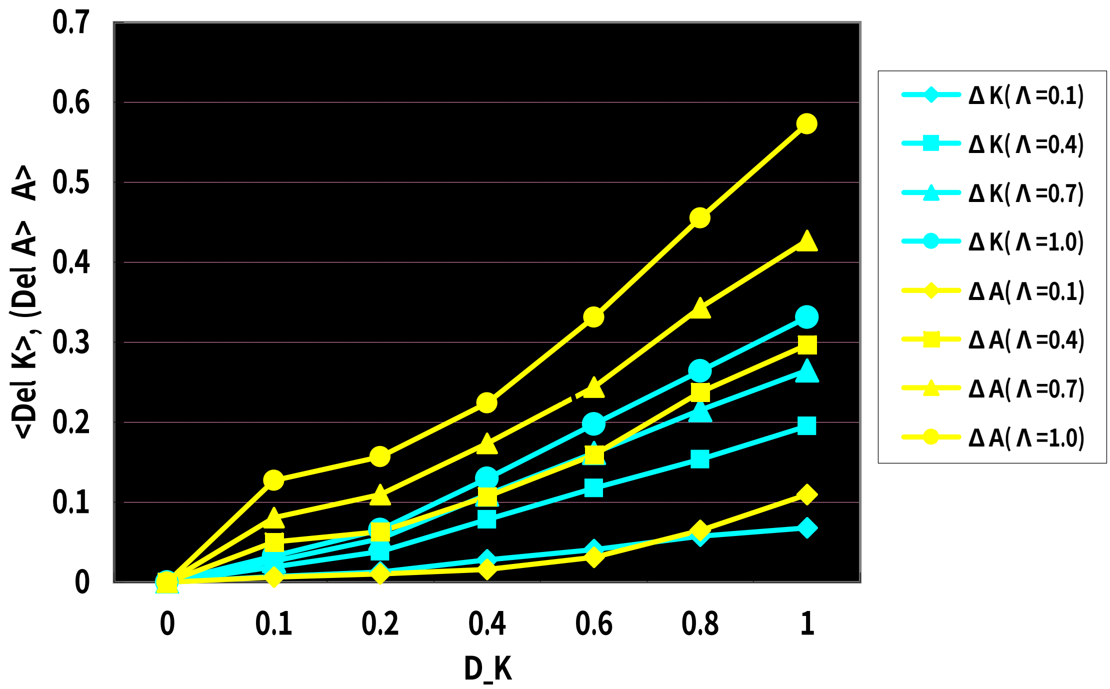


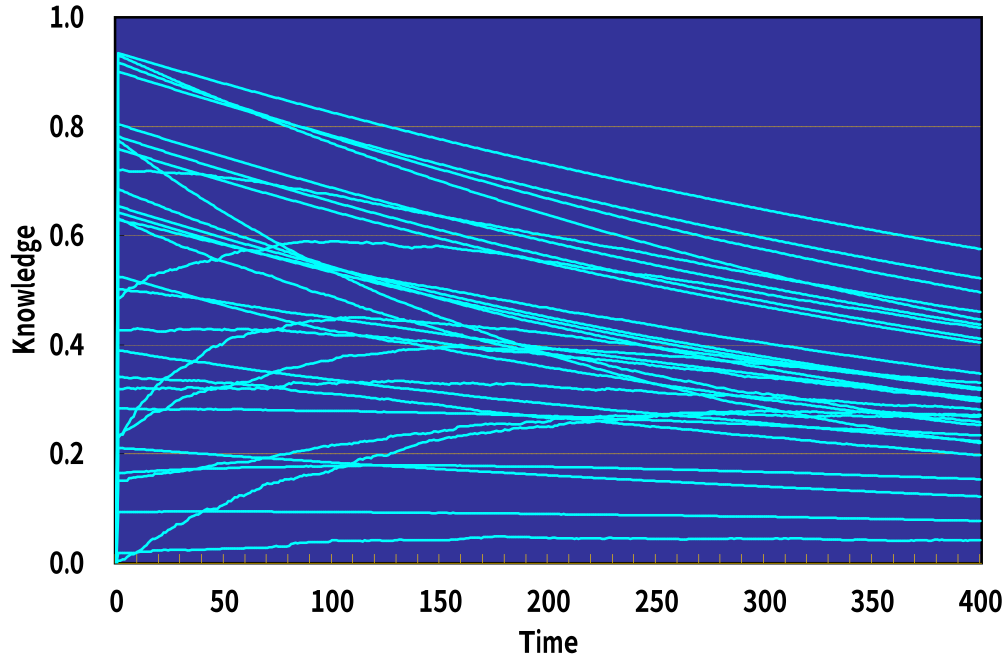
Fig.1

Fig.2



0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
<Del K>, (Del A> A>
0
0.1
0.2
0.4
0.6
0.8
1
D_K
ΔK(Λ=0.1)
ΔK(Λ=0.4)
ΔK(Λ=0.7)
ΔK(Λ=1.0)
ΔA(Λ=0.1)
ΔA(Λ=0.4)
ΔA(Λ=0.7)
ΔA(Λ=1.0)

Fig.3



1.0
0.8
0.6
0.4
0.2
0.0
Knowledge
0
50
100
150
200
250
300
350
400
Time

Fig.4

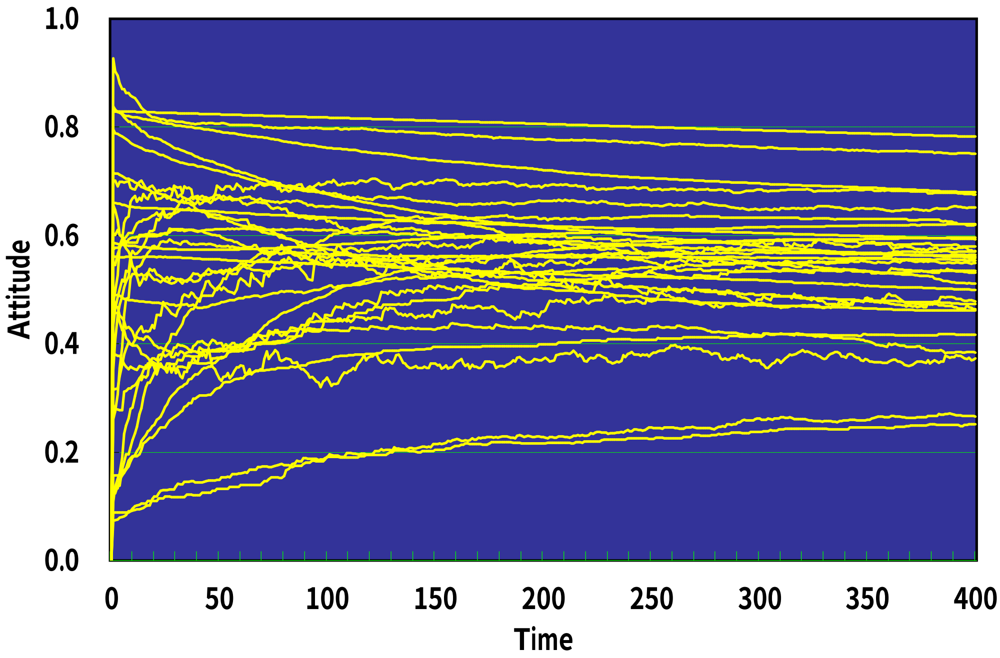

1.0
0.8
0.6
0.4
0.2
0.0
Attitude
0
50
100
150
200
250
300
350
400
Time

Fig.5

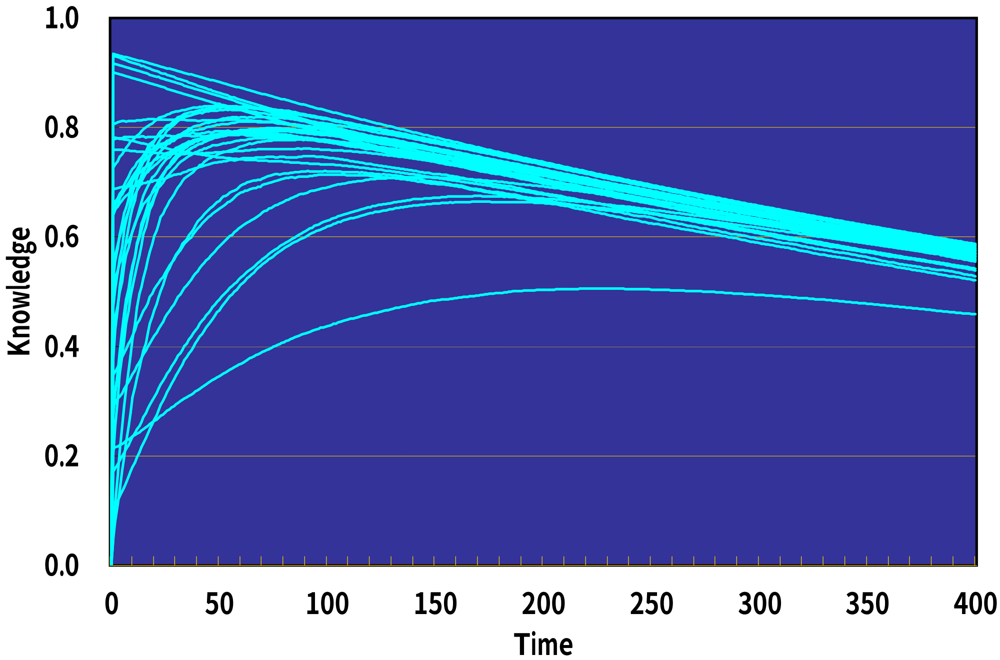
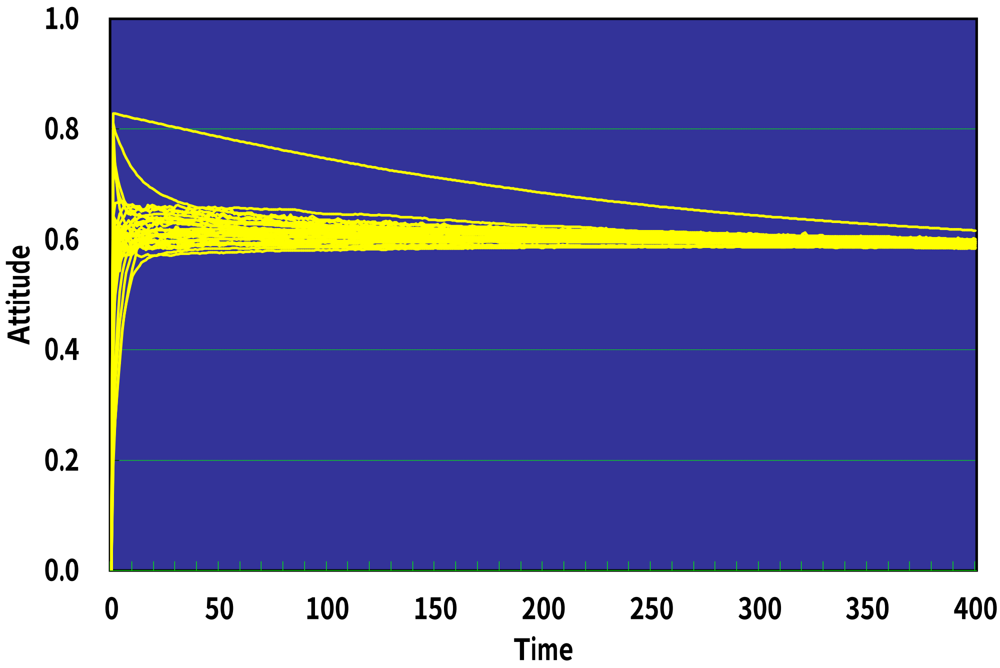
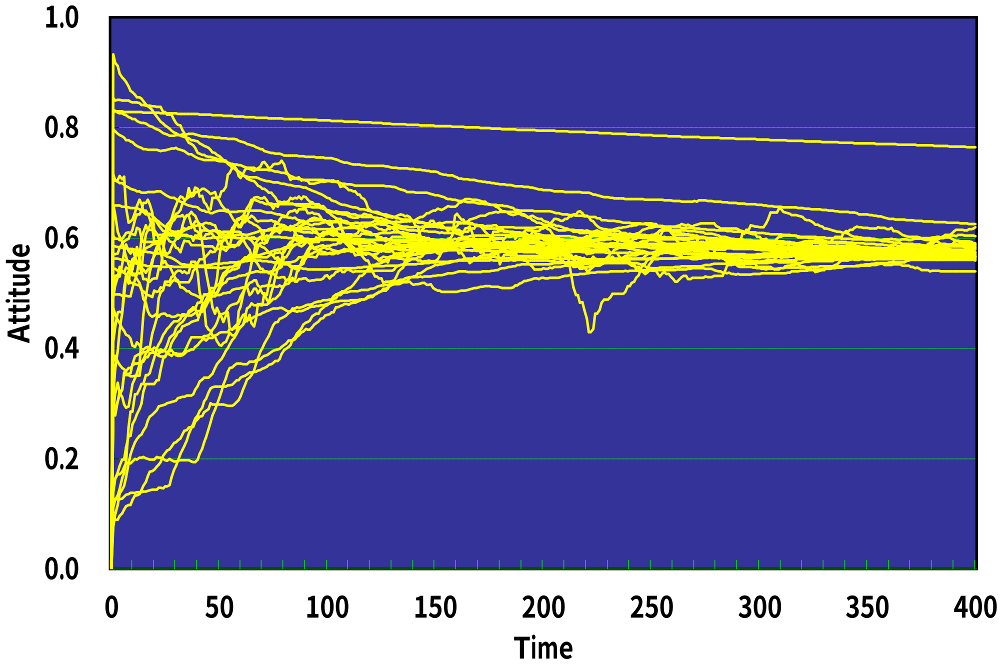

1.0
0.8
0.6
0.4
0.2
0.0
Knowledge
0
50
100
150
200
250
300
350
400
Time

Fig.6



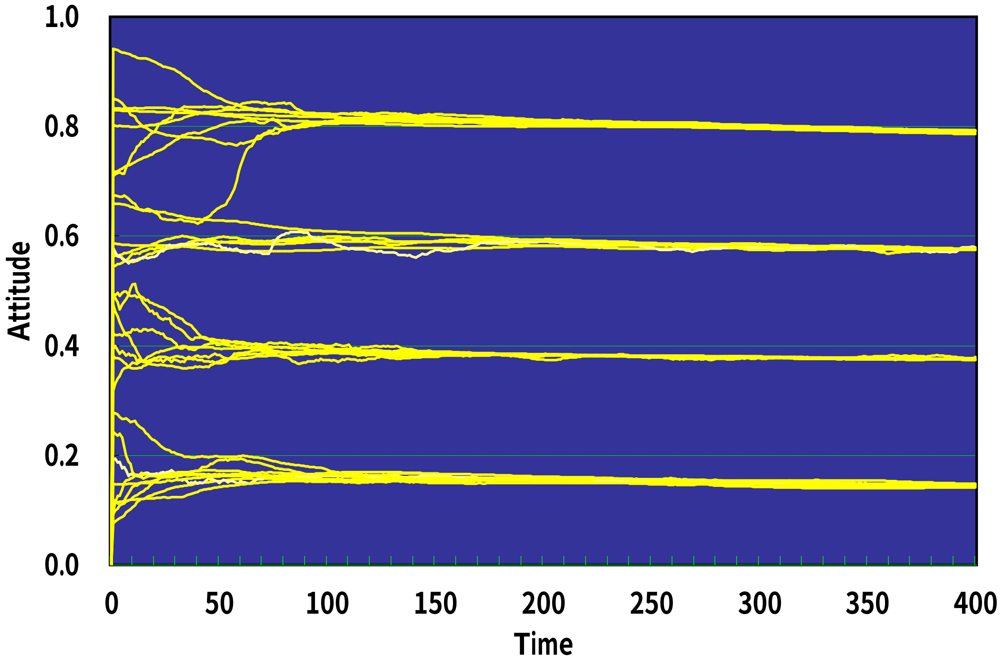
1.0
0.8
0.6
0.4
0.2
0.0
Attitude
0
50
100
150
200
250
300
350
400
Time

Fig.7



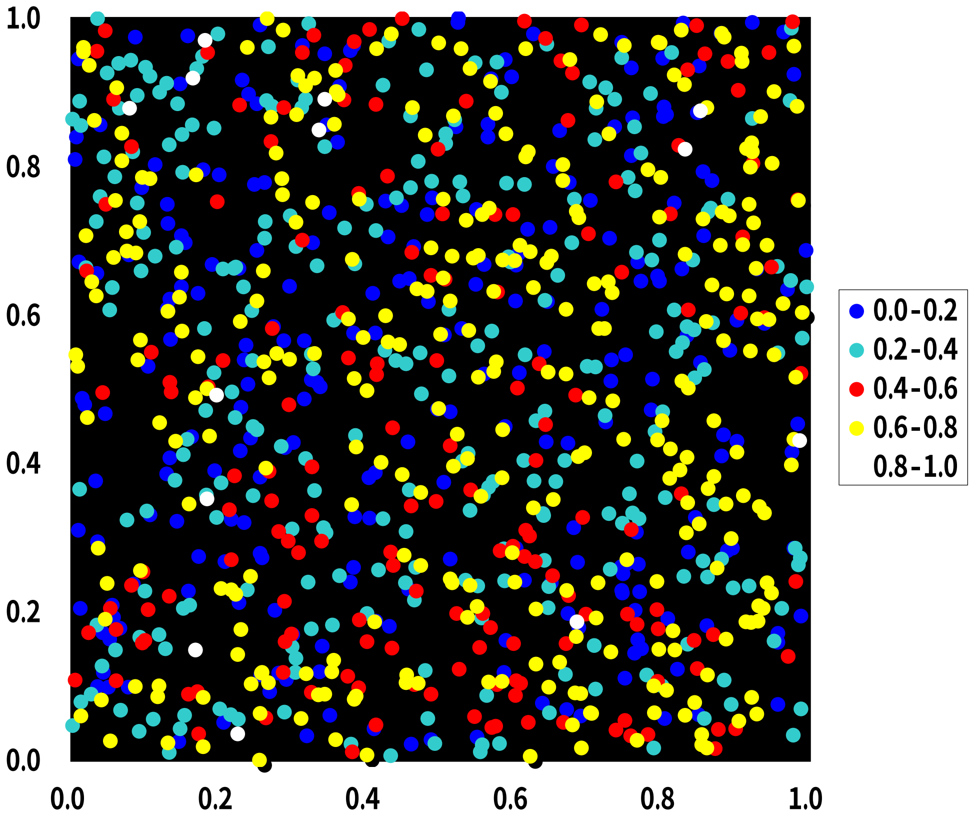
1.0
0.8
0.6
0.4
0.2
0.0
Attitude
0
50
100
150
200
250
300
350
400
Time

Fig.8



1.0
0.8
0.6
0.4
0.2
0.0
Attitude
0
50
100
150
200
250
300
350
400
Time

Fig.9



1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
0.0-0.2
0.2-0.4
0.4-0.6
0.6-0.8
0.8-1.0

Fig.10

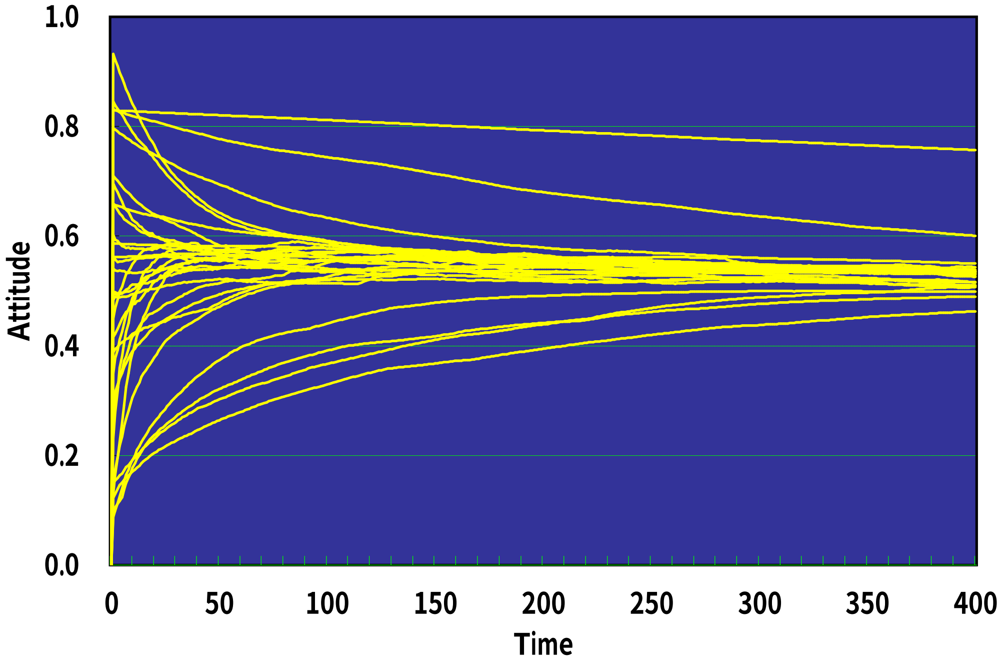
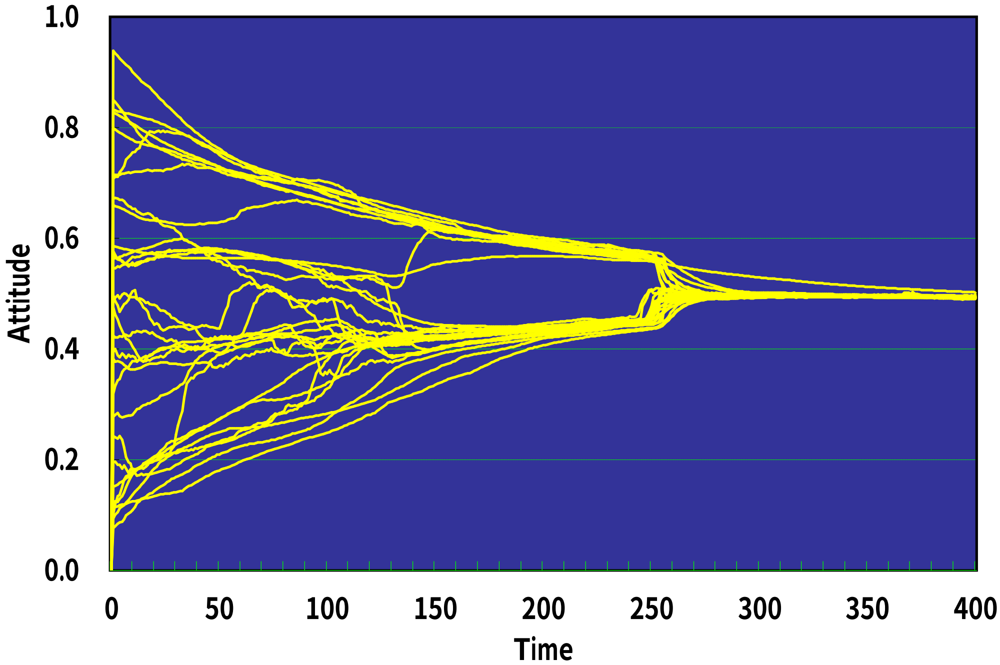

1.0
0.8
0.6
0.4
0.2
0.0
Attitude
0
50
100
150
200
250
300
350
400
Time

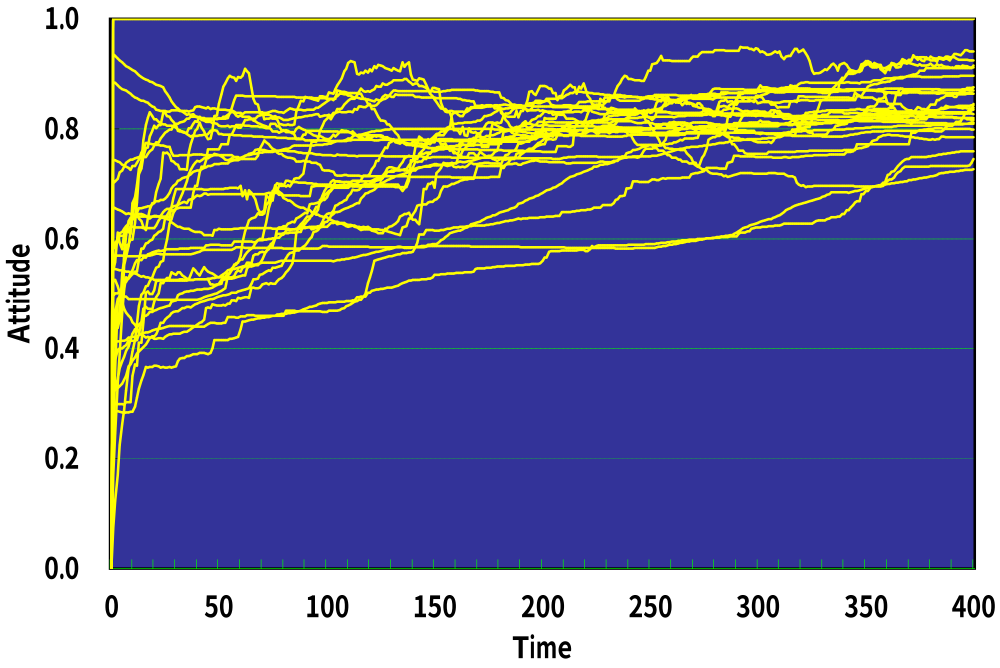
Fig.11


1.0
0.8
0.6
0.4
0.2
0.0
Attitude
0
50
100
150
200
250
300
350
400
Time

2	3	4
9	Tribe 1	5
8	7	6

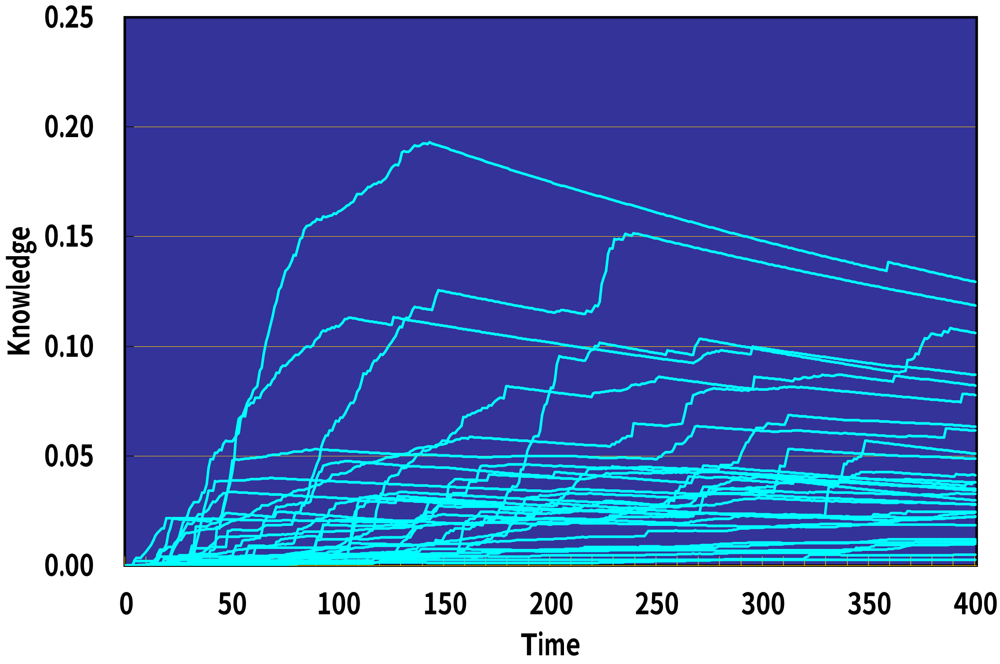
Fig.21

Fig.22



1.0
0.8
0.6
0.4
0.2
0.0
Attitude
0
50
100
150
200
250
300
350
400
Time

Fig.23



0.25
0.20
0.15
0.10
0.05
0.00
Knowledge
0
50
100
150
200
250
300
350
400
Time

Fig.24

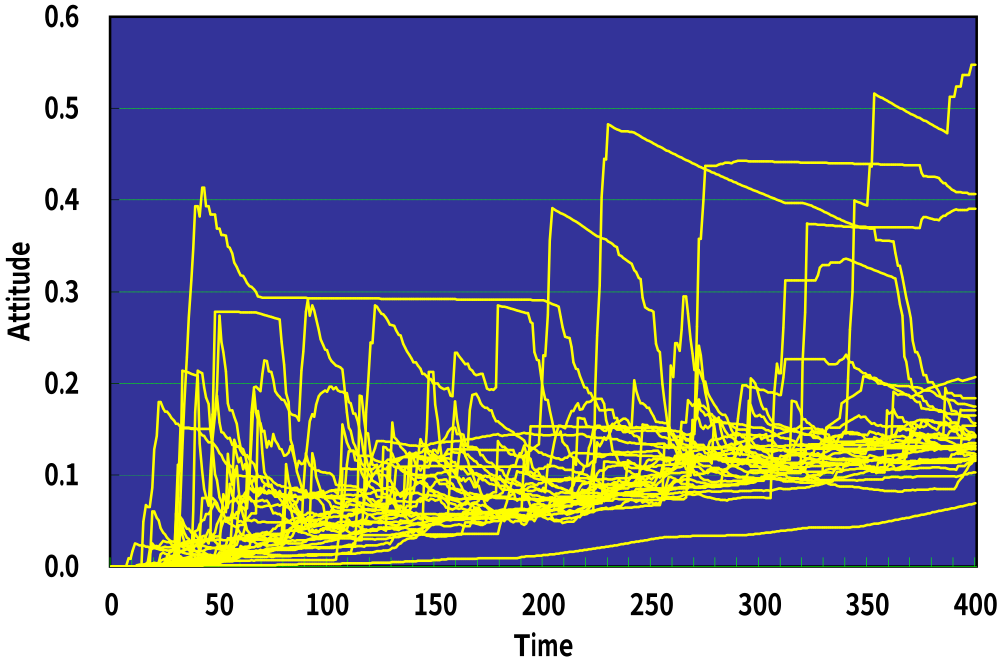

0.6
0.5
0.4
0.3
0.2
0.1
0.0
Attitude
0
50
100
150
200
250
300
350
400
Time

Fig.25

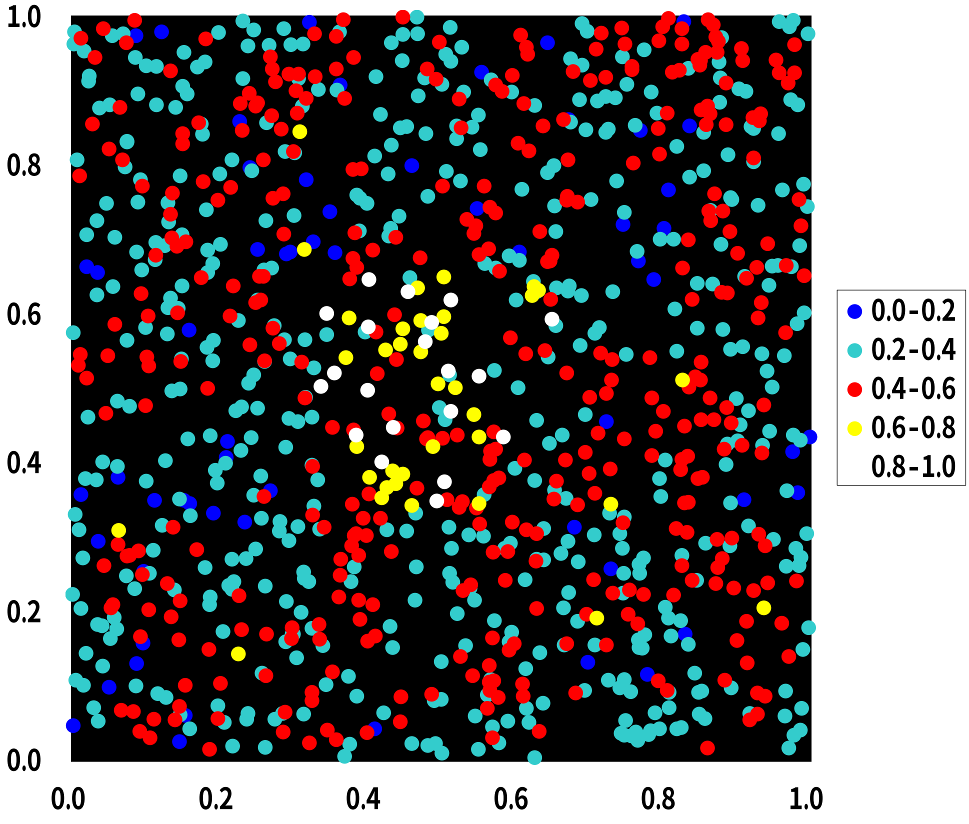

1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
0.0-0.2
0.2-0.4
0.4-0.6
0.6-0.8
0.8-1.0

Fig.26

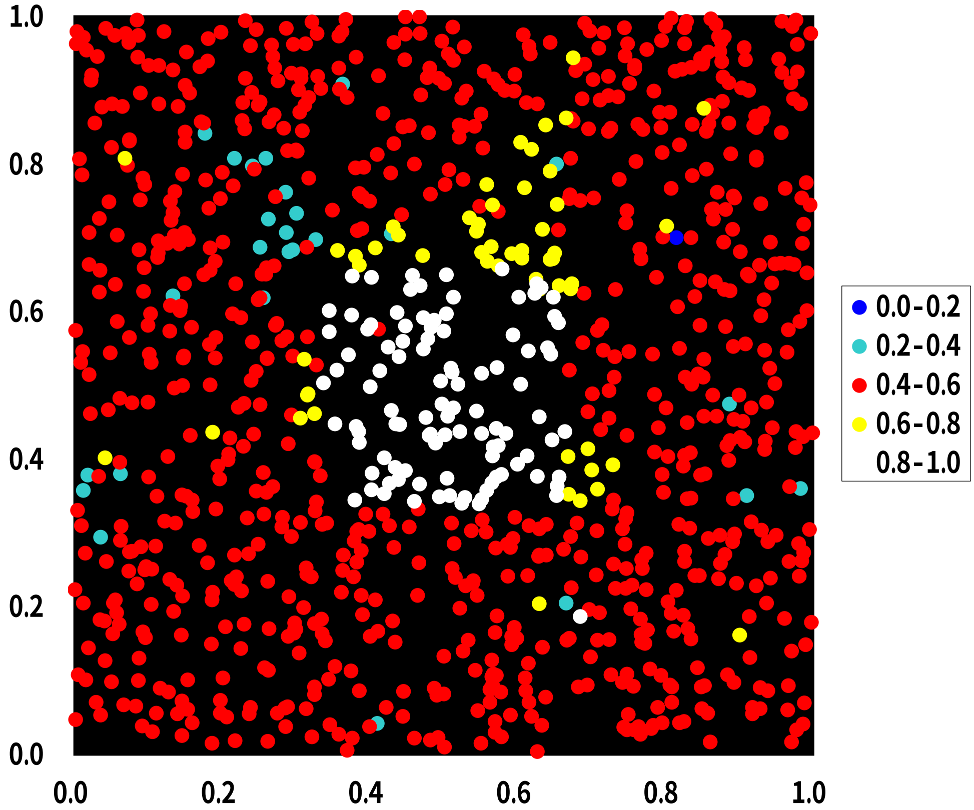

1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
0.0-0.2
0.2-0.4
0.4-0.6
0.6-0.8
0.8-1.0

Fig.27

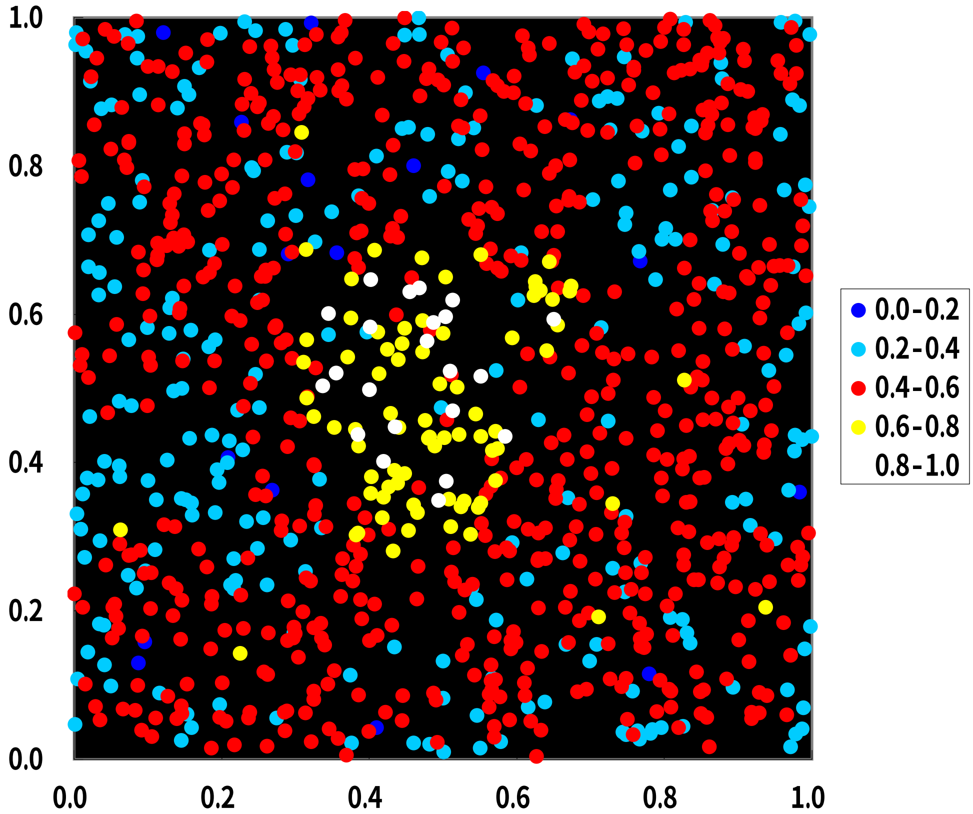

1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
0.0-0.2
0.2-0.4
0.4-0.6
0.6-0.8
0.8-1.0

Fig.28

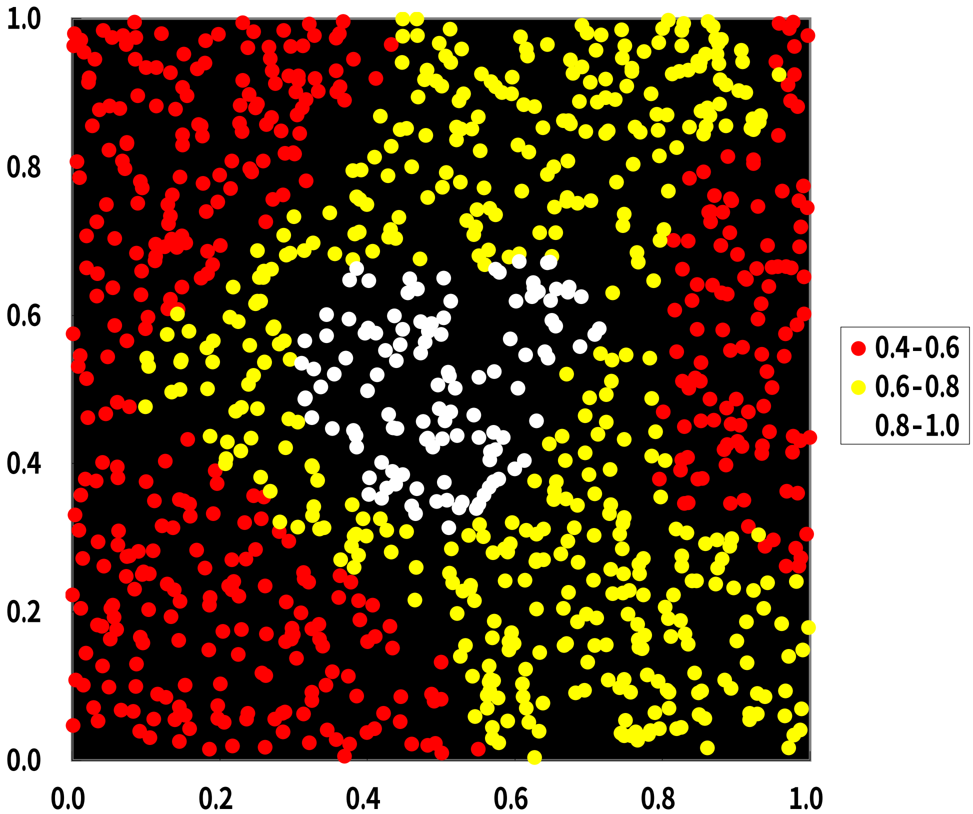

1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
0.4-0.6
0.6-0.8
0.8-1.0

Fig.29

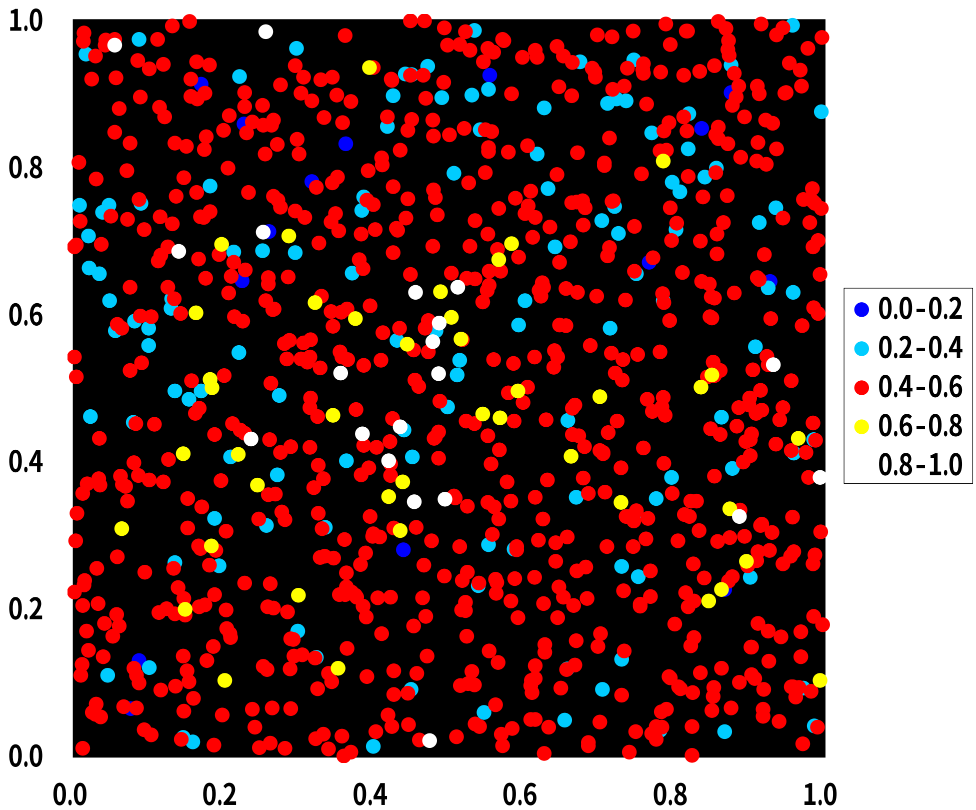
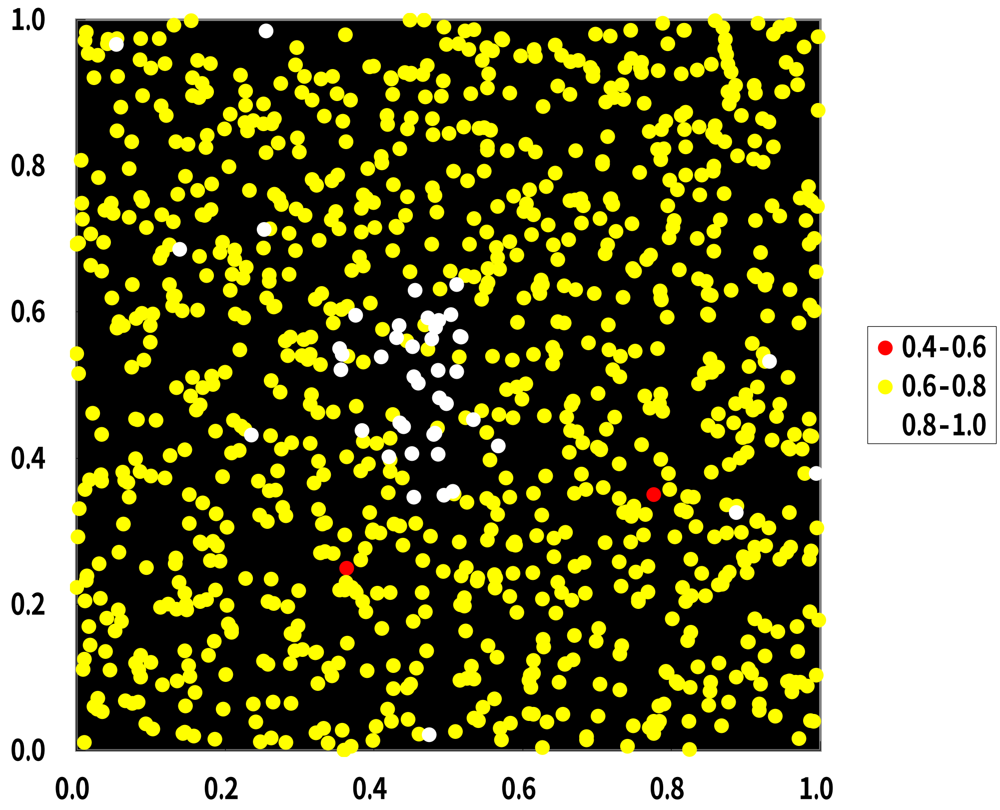

1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
0.0-0.2
0.2-0.4
0.4-0.6
0.6-0.8
0.8-1.0

Fig.30




"व्यक्तिगत सफाई"
माँ का दूध

```
c
c     SEasses.f
c     Simulation for Assessing the effect of Social Education or
c     the Public Relations executing on the Jordanian Society
c     March 20th 2006 at Al Hussein Bin Talal University
c     revised version #3 May 27 2006
c
c
c     ----------------------------------------------------------------------
c
      blockdata PRMTR
        parameter (nP=1000,nAtrbt=2,nknwlg=1)
        common /PRM/nInt,L1,L0,ntribe,Lt,Ltmax,nt0,pInt,Pcom,Mm,iOPL,
     1        nOPL(nP),nmbOPL,jOPL,iAnime,intDep,iRepet,iTmInt,rcrit,
        2          rmale(25),female(25)
        common /Var/Ax(nP),Ay(nP),Ax0(nP),Ay0(nP),iAt(nP,nAtrbt),
     1        Aknow(nP,nknwlg),Atitud(nP,nknwlg),Dknow(25),Move(nP),
        2        Dattd(25),AK0(nP,nknwlg),At0(nP,nknwlg),ntimep(6),
        3        AAknow(nknwlg,25,3,400,2),AAtitd(nknwlg,25,3,400,2),
        4        nPSeq(30,3),OutK(nknwlg,30,3,400),OutA(nknwlg,30,3,400),
        5        ktribe(25),kCtr
        common /CNST/gamma,aguzai,bguzai,tauK,tauA,Pturn,Rint00,Rint01,
     1        tau,MNnInt,DeltaK(25),DeltaA(25),AK0(25),AA0(25),
     2        sigma,width
        common /COEF/PR(25,2),alp(25,2),bet(25,2),del(25,2,25,2),
     1        eps(25,2),GalpK,GalpA,GbetaK,GbetaA,alpha(nP),beta(nP),
        2        epsrn(nP),aTauK(nP),aTauA(nP)
       data L0/ 123457 /
        data Ltmax/ 400 /
c       data pInt,PR,Pturn,Pcom/ 0.5, 50*0.01, 0.01, 1.0 /
        data pInt,PR,Pturn,Pcom/ 0.5, 50*0.0, 0.0, 1.0 /
c       data nInt,gamma,Rint00,Rint01,rcrit/ 1, 1.6, 0.04, 0.04, 0.1 /
c       data GalpK,GbetaK,GalpA,GbetaA/ 1.2, 1.0, 1.2, 1.0 /
        data del/ 2500*0.2 /
c       data ((eps(i1,i2),i1=1,25),i2=1,2)/ 50*0.01 /
        data intDep/ 9999 /
c
        data nInt,gamma,Rint00,Rint01,rcrit/ 1, 1.6, 0.56, 0.56, 0.1 /
        data GalpK,GbetaK,GalpA,GbetaA/ 2*0.0, 1.2, 1.0 /
        data ((alp(i1,i2),i1=1,25),i2=1,2)/ 50*0.005 /
c       data ((bet(i1,i2),i1=1,25),i2=1,2)/ 50*0.005 /
        data ((bet(i1,i2),i1=1,25),i2=1,2)/ 50*0.08 /
c       data del/ 2500*1.0 /
        data ((eps(i1,i2),i1=1,25),i2=1,2)/ 50*0.0 /
c
        data aguzai,bguzai/ 0.1, 0.1 /
        data tauK,tauA,tau/ 400.0, 8000.0, 400.0 /
        data iOPL,nmbOPL,iAnime/ 9999, 20, 2 /
        data iRepet,iTmInt/    0, 1000 /
c       data iRepet,iTmInt/ 9999, 1000 /
c       data iRepet,iTmInt/ 9999, 100 /
c       data (Dknow(i),i=1,25)/ 25*1.0 /
        data (Dknow(i),i=1,25)/ 25*0.0 /
c       data iOPL,nmbOPL,iAnime/ 0, 1, 2 /
        data (rmale(i),i=1,25)/ 25*1.0 /
        data (female(i),i=1,25)/ 25*1.0 /
c       data (rmale(i),i=1,25)/ 25*0.4 /
c       data (female(i),i=1,25)/ 25*0.4 /
c
c     L1 : parameter set for the random number generator RAN
c     Ltmax : maximu number of iteration time
c     pInt : interaction probability of an agent with the other agent at t
c     PR : probability to move an agent from a point to another point
c     Pcom : probability to communicate with a neighbouring agent at Lt
c     nInt : square root of the number of tribe, ntribe=nInt**2: nInt must be
c            an odd number
c     gamma : the exponent of probability for the agent in moving the outer
c             region of r > R0, ie, prob =: r**(-gamma)
c     Pturn : returning probability of removed agent to the original position
c     Rint00: threshold length of interaction between two agents similar in
c             their tribes
c     Rint01: the same as Rint00 but different in their tribes
c     rcrit : maximum radius for an agent within which region smoothing of the
c             attitude occurs with surrounding attitudes
c     GalpK, GalpA : constants alpha's in gamma distribution functions for
c            the initial K and A distributions
```

```
c     GbetaK, GbetaA : constants beta's in gamma distribution functions for
c            the initial K and A distributions
c     intDep : interdependency parameter (with (9999, i.e., ne.0), and
c            without 0) between Aknow and Atitud
c     alp  : coefficient for enhancing the state of knowledge in interaction
c     bet  : coefficient for enhancing the state of attitude in interaction
c     del  : threshold of attitude difference between two agents in
c            interaction
c     eps  : coefficient for the relaxation of attitude in blind-following
c     aguzai : fraction of eternal change in knowledge communication
c     bguzai : the same as above but in attitude
c     tauK, tauA : time constants for oblivion
c     tau  : time constant for the enthusiasm of the issue
c     iOPL : C-agent setting parameter : iOPL=0 without C-agent, whereas
c            iOPL.ne.0 with the effect of C-agent
c     nmbOPL : number of C-agent set at an initial time (whereas jOPL the number
c            really determined in the program)
c     iAnime : data aquisition for the animation of knowledge (iAnime=1) or
c            attitude (=2)
c     iRepet : conditional parameter for the repeated offer of information
c             with offer (=/0, =9999) or without offer (=0)
c     Dknow : maximum fraction of knowledge enhanced by the information
c             offered
c     iTmInt : its time interval which is costant within tE(0,Lt)
c     rmale : the extent of reach of the information to the male in the tribe
c     female : the same as the above but to the female
c
        end
c
c     ------------------------------------------------------------------
c     Determination of information-offering mode, that is the manner how
c     the public relations is made on the knowledge and attitude with
c     regard to a certain subject, for instance on the environment
c
      subroutine OfferI
        parameter (nP=1000,nAtrbt=2,nknwlg=1)
        common /PRM/nInt,L1,L0,ntribe,Lt,Ltmax,nt0,pInt,Pcom,Mm,iOPL,
     1        nOPL(nP),nmbOPL,jOPL,iAnime,intDep,iRepet,iTmInt,rcrit,
        2          rmale(25),female(25)
        common /Var/Ax(nP),Ay(nP),Ax0(nP),Ay0(nP),iAt(nP,nAtrbt),
     1        Aknow(nP,nknwlg),Atitud(nP,nknwlg),Dknow(25),Move(nP),
        2        Dattd(25),AK0(nP,nknwlg),At0(nP,nknwlg),ntimep(6),
        3        AAknow(nknwlg,25,3,400,2),AAtitd(nknwlg,25,3,400,2),
        4        nPSeq(30,3),OutK(nknwlg,30,3,400),OutA(nknwlg,30,3,400),
        5        ktribe(25),kCtr
        common /CNST/gamma,aguzai,bguzai,tauK,tauA,Pturn,Rint00,Rint01,
        1        tau,MNnInt,DeltaK(25),DeltaA(25),AK0(25),AA0(25),
     2        sigma,width
        common /COEF/PR(25,2),alp(25,2),bet(25,2),del(25,2,25,2),
     1        eps(25,2),GalpK,GalpA,GbetaK,GbetaA,alpha(nP),beta(nP),
        2        epsrn(nP),aTauK(nP),aTauA(nP)
        data kknwlg/ 1 /
        data (Dattd(i),i=1,25)/ 25*1.0 /
        data sigma,width / 0.1, 3.0 /
c
c     Aknow,Atitud : states of vector knowledge and attitude with regard
c                    to the issues "nknwlg" after the offer of information
c     ktribe : the tribe number to which information is given,
c              only when ktribe.ne.0
c     kknwlg : knowledge number for which information is offered
c              kknwlg =< nknwlg
c     Dattd : the same as the above but of attitude
c
        cG=0.39894/sigma
        Xmax=(GalpK-1.0)*GbetaK
        cK=Xmax**(1.0-GalpK)*exp(GalpK-1.0)
        width0=width*sigma
      if(kknwlg.gt.nknwlg)kknwlg=nknwlg
        do 12 kk=1,kknwlg
      do 10 n=1,nP
        OAk=Aknow(n,kk)
        OAt=Atitud(n,kk)
        if(Dknow(kCtr).eq.0.0)go to 10
c
c       if(iAt(n,1).ne.ktribe(kCtr))go to 10
c
```

```
        reach=female(kCtr)
        if(iAt(n,2).eq.1)reach=rmale(kCtr)
        if(Ran(L1).gt.reach)go to 10
      if(GalpK.eq.0.0.and.GbetaK.eq.0.0)go to 18
c
c     gamma distributions of the effect of information offer
c
   15   dummyX=Ran(L1)
        dummyY=cK*dummyX**(GalpK-1.0)*exp(-dummyX/GbetaK)
        if(dummyY.le.Ran(L1))go to 15
        dummyX=Dknow(kCtr)*dummyX
        Aknow(n,kk)=amin1(1.0,dummyX+OAk)
        Akdum=Aknow(n,kk)-OAk
   17 dummyX=2.0*(Ran(L1)-0.5)*width0+Akdum
      if(dummyX.lt.0.0.or.dummyX.gt.1.0)go to 17
      dummyY=cG*exp(-0.5*((dummyX-Akdum)/sigma)**2)
        if(dummyY.le.Ran(L1))go to 17
        Atitud(n,kk)=amin1(1.0,dummyX+OAt)
        if(Mm.eq.2)go to 20
      go to 19
c
c     uniform distribution of the effect of information offer
c
   18   Akdum=Dknow(kCtr)*Ran(L1)
        if(Akdum.le.1.0e-7)go to 10
        Akdum=amin1(Akdum,1.0-OAk)
        if(Akdum.le.1.0e-7)go to 10
        Aknow(n,kk)=OAk+Akdum
        sigma0=sigma*Akdum
        width0=width*sigma0
   14 dummyX=2.0*(Ran(L1)-0.5)*width0+Akdum
      if(dummyX.lt.0.0)go to 14
      dummy=((dummyX-Akdum)/sigma0)**2
        dummyY=cG*exp(-0.5*dummy)
        if(dummyY.le.Ran(L1))go to 14
        Atitud(n,kk)=amin1(1.0,dummyX+OAt)
        if(Mm.eq.2)go to 20
   19   Atdum=Atitud(n,kk)-OAt
        Ak0(n,kk)=amin1(1.0,Ak0(n,kk)+aguzai*Akdum)
      At0(n,kk)=amin1(1.0,At0(n,kk)+bguzai*Atdum)
        go to 10
   20   Aknow(n,kk)=OAk
        Atitud(n,kk)=OAt
   10 continue
   12 continue
      return
        end
c
c     -------------------------------------------------------------------
c
      PROGRAM SEasses
c
c     The Effect of Social Education
c
        parameter (nP=1000,nAtrbt=2,nknwlg=1)
        common /PRM/nInt,L1,L0,ntribe,Lt,Ltmax,nt0,pInt,Pcom,Mm,iOPL,
     1        nOPL(nP),nmbOPL,jOPL,iAnime,intDep,iRepet,iTmInt,rcrit,
        2           rmale(25),female(25)
        common /Var/Ax(nP),Ay(nP),Ax0(nP),Ay0(nP),iAt(nP,nAtrbt),
     1        Aknow(nP,nknwlg),Atitud(nP,nknwlg),Dknow(25),Move(nP),
        2        Dattd(25),Ak0(nP,nknwlg),At0(nP,nknwlg),ntimep(6),
        3        AAknow(nknwlg,25,3,400,2),AAtitd(nknwlg,25,3,400,2),
        4        nPSeq(30,3),OutK(nknwlg,30,3,400),OutA(nknwlg,30,3,400),
        5        ktribe(25),kCtr
        common /CNST/gamma,aguzai,bguzai,tauK,tauA,Pturn,Rint00,Rint01,
     1        tau,MNnInt,DeltaK(25),DeltaA(25),AK0(25),AA0(25),
     2        sigma,width
        common /COEF/PR(25,2),alp(25,2),bet(25,2),del(25,2,25,2),
     1        eps(25,2),GalpK,GalpA,GbetaK,GbetaA,alpha(nP),beta(nP),
        2        epsrn(nP),aTauK(nP),aTauA(nP)
        dimension AK80(25,2),A80(25,2),S80(25)
        data ntimep/ 50,100,150,200,300,400 /
        data ratio,aMult,Acrit/ 10.0, 2.0, 1.0 /
        a(ratio,b)=alog((1.0-ratio)/(ratio-exp(b)))
        b(ratio,aMult)=aMult*alog(ratio)
        c(beta0,a)=beta0*(1.0+exp(a))
```

```
        dBeta(a,b,c,X)=c/(1.0+exp(a+b*X))
        character *9 for
c
c     ntimep : time for the printout of the position of agents
c     Acrit : critical attitute above which attitude does never decrease
c
      for='formatted'
      pi=3.1415926536
        Ltmax=min0(Ltmax,400)
        ntribe=nInt**2
        R0=sqrt(1.0/float(ntribe)/pi)
        R00=R0/10.0
        Rmax=sqrt(1.0/pi)
        Ga=1.0-gamma
        GaD=1.0+gamma
        cnstnt=2.0*Ga/(Ga*R0**2+2.0*R0**GaD*(Rmax**Ga-R0**Ga))
        Rint00=amin1(Rint00,R0/3.0)
        Rint01=amin1(Rint01,Rint00/2.0)
        P01=Pcom/10.0
        P00=Pcom
      MNnInt=min0(nInt,3)
        dumb=b(ratio,aMult)
      duma=a(ratio,dumb)
      do 53 k=1,25
        ktribe(k)=0
   53 continue
      kCtr=(1+nInt**2)/2
        ktribe(kCtr)=kCtr
c
c     kCtr : only one tribe number where OPLs exist, or information is given
c
        open (unit=1001,file='file01.xls',status='old',err=101)
        close(unit=1001,disp='delete')
  101 open (unit=1001,file='file01.xls',status='new')
        open (unit=1002,file='file02.xls',status='old',err=102)
        close(unit=1002,disp='delete')
  102 open (unit=1002,file='file02.xls',status='new')
        open (unit=1003,file='file03.xls',status='old',err=103)
        close(unit=1003,disp='delete')
  103 open (unit=1003,file='file03.xls',status='new')
        open (unit=1004,file='file04.xls',status='old',err=104)
        close(unit=1004,disp='delete')
  104 open (unit=1004,file='file04.xls',status='new')
        open (unit=1005,file='file05.xls',status='old',err=105)
        close(unit=1005,disp='delete')
  105 open (unit=1005,file='file05.xls',status='new')
        open (unit=1006,file='file06.xls',status='old',err=106)
        close(unit=1006,disp='delete')
  106 open (unit=1006,file='file06.xls',status='new')
      open (unit=2002,file='file2.xls',status='old',err=202)
        close(unit=2002,disp='delete')
  202 open (unit=2002,file='file2.xls',status='new')
      open (unit=2003,file='file3.xls',status='old',err=203)
        close(unit=2003,disp='delete')
  203 open (unit=2003,file='file3.xls',status='new')
      open (unit=2004,file='file4.xls',status='old',err=204)
        close(unit=2004,disp='delete')
  204 open (unit=2004,file='file4.xls',status='new')
      open (unit=2005,file='file5.xls',status='old',err=205)
        close(unit=2005,disp='delete')
  205 open (unit=2005,file='file5.xls',status='new')
      open (unit=2006,file='file6.xls',status='old',err=206)
        close(unit=2006,disp='delete')
  206 open (unit=2006,file='file6.xls',status='new')
      open (unit=2007,file='Keffect.xls',status='old',err=207)
        close(unit=2007,disp='delete')
  207 open (unit=2007,file='Keffect.xls',status='new')
      open (unit=2008,file='Aeffect.xls',status='old',err=208)
        close(unit=2008,disp='delete')
  208 open (unit=2008,file='Aeffect.xls',status='new')
      open(unit=40,file='pstn.dat',form=for,status='old',
     1err=595)
      close(unit=40,status='delete')
  595 open(unit=40,file='pstn.dat',form=for,status='new')
      open(unit=41,file='mask.dat',form=for,status='old',
     1err=594)
```

```
      close(unit=41,status='delete')
  594 open(unit=41,file='mask.dat',form=for,status='new')
      nspcs=1
        xr=1.0
        zr=1.0
        yr=1.0
      tini=0.0
      tstep=1.0
        Ltmax1=1+Ltmax
      write(40,593)nspcs,nP,Ltmax1
      write(40,592)xr,zr,yr
      write(40,591)tini,tstep
  593 format(3i8)
  592 format(3f8.3)
  591 format(2f8.3)
c
c
c     inputting the social survey data
c
c     open (unit=300,file='Public.dat',status='old',err=99)
c       go to 11
c  99 print *, 'Data Can Not Be Found'
c     stop
c  11 read(300,*)
c
c     initialization
c
c     R00 : inner radius near the agent considered, within which region the
c           movement of the agent is assumed not to move at all substantially
c     R0  : outer radius for the movement within which the moving probability
c           of the agent is uniform
c     Rint00: threshold length of interaction between two agents similar in
c             tribe
c     Rint01: the same as Rint00 but different in tribe
c
        do 1000 Mm=1,2
        L1=L0
      call Atribt
        call Coefic
c
c     setting the C-agent condition : nOPL is the sequence number of C-agent
c     nmbOPL(or jOPL) C-agents case in the target region ktribe(kCtr)
c
      do 40 n=1,nP
        nOPL(n)=0
   40 continue
        if(Mm.gt.1)go to 44
        jOPL=0
      if(iOPL.ne.0)then
        do 43 n=1,nP
        if(jOPL.ge.nmbOPL)go to 43
      if(iAt(n,1).ne.ktribe(kCtr))go to 43
        jOPL=jOPL+1
        nOPL(n)=n
   43 continue
      endif
c
   44   Ip=max0(nP/ntribe/30,1)
        do 90 nSeq=1,MNnInt
        mSeq=0
        iSeq=0
        if(nSeq-2)91,92,93
   91 kt=ktribe(kCtr)
      go to 94
   92 kt=ktribe(kCtr)+1
      go to 94
   93 kt=ktribe(kCtr)+1+nInt
   94 do 95 n=1,nP
      if(iAt(n,1).ne.kt)go to 95
        mSeq=mSeq+1
        if(amod(float(mSeq),float(Ip)).ne.0.0)go to 95
        iSeq=iSeq+1
        if(iSeq.gt.30)go to 95
        nPSeq(iSeq,nSeq)=n
   95 continue
   90 continue
```

```
c
        if(Mm.eq.1)call PlotD
        Lt=1
        LLt=1
c
c     movement of agents in a multi-agent system within a square
c     region with a unit length side : cyclic boundary condition
c
   99   if(iRepet.eq.0.or.Mm.eq.2)go to 51
      if(LLt.eq.iTmInt)then
        call OfferI
        LLt=1
        else
        LLt=LLt+1
      endif
   51   if(iOPL.eq.0.or.Mm.eq.2)go to 50
        do 69 n=1,nP
        do 69 nk=1,nknwlg
        if(nOPL(n).ne.n)go to 69
        Aknow(n,nk)=1.0
        Atitud(n,nk)=1.0
   69 continue
   50 do 12 n=1,np
        if(Move(n).ne.0)then
        if(n-nOPL(n))61,60,61
   61 Ptdumy=Pturn
      go to 63
   60 Ptdumy=10.0*Pturn
   63   if(Ran(L1).gt.Ptdumy)go to 13
        Ax(n)=Ax0(n)
        Ay(n)=Ay0(n)
        Move(n)=0
        endif
   13   const=cnstnt*PR(iAt(n,1),iAt(n,2))
      if(n.eq.nOPL(n))const=10.0*const
      Rdummy=Rmax*Ran(L1)
        if(Rdummy.gt.R0)then
        Pdummy=const*R0**GaD/Rdummy**gamma
        else
        Pdummy=const*Rdummy
        endif
        if(Ran(L1).gt.Pdummy)go to 12
        if(Rdummy.lt.R00)then
        Ax(n)=Ax0(n)
        Ay(n)=Ay0(n)
        Move(n)=0
        else
        angl=2.0*pi*Ran(L1)
        Ax(n)=Ax(n)+Rdummy*cos(angl)
        Ay(n)=Ay(n)+Rdummy*sin(angl)
      Move(n)=9999
        endif
        if(Ax(n).gt.1.0)then
        Ax(n)=Ax(n)-1.0
        else
        if(Ax(n).lt.0.0)then
        Ax(n)=Ax(n)+1.0
        endif
        endif
        if(Ay(n).gt.1.0)then
        Ay(n)=Ay(n)-1.0
        else
        if(Ay(n).lt.0.0)then
        Ay(n)=Ay(n)+1.0
        endif
        endif
   12 continue
c
c     interaction between agents : threshold model of attitude change
c
        do 14 n=1,nP
        do 15 nj=1,nP
        Pmf=P00
c
        if(iAt(n,2).ne.iAt(nj,2))Pmf=P01
c
```

```
        if(nj.eq.n)go to 15
        dist=sqrt((Ax(n)-Ax(nj))**2+(Ay(n)-Ay(nj))**2)
        Rint=Rint00
c
        if(iAt(n,1).ne.iAt(nj,1))Rint=Rint01
c
        if(dist.gt.Rint)go to 15
        if(Ran(L1).gt.pInt)go to 15
        if(Ran(L1).gt.Pmf)go to 15
        if(Ran(L1).gt.exp(-(Lt-1)/tau))go to 15
        do 16 nk=1,nknwlg
        Aknowj=Aknow(nj,nk)
        Aknown=Aknow(n,nk)
        if(n.eq.nOPL(n).and.nj.eq.nOPL(nj))go to 16
        if(n.eq.nOPL(n))go to 30
        if(nj.eq.nOPL(nj))go to 31
        if(Aknown.le.Aknowj)go to 31
   30   Aknow(nj,nk)=Aknowj+alpha(nj)*(Aknown-Aknowj)
        AkO(nj,nk)=AkO(nj,nk)+alpha(nj)*aguzai*(Aknown-Aknowj)
        go to 16
   31 Aknow(n,nk)=Aknown+alpha(n)*(Aknowj-Aknown)
        AkO(n,nk)=AkO(n,nk)+alpha(n)*aguzai*(Aknowj-Aknown)
   16 continue
        delta=del(iAt(n,1),iAt(n,2),iAt(nj,1),iAt(nj,2))
c
        if(n.eq.nOPL(n).or.nj.eq.nOPL(nj))delta=1.0
c
        do 17 nk=1,nknwlg
      if(abs(Atitud(nj,nk)-Atitud(n,nk)).gt.delta)go to 17
        Atnj0=Atitud(nj,nk)
        Atn0=Atitud(n,nk)
        Atndum=Atn0-Atnj0
        if(n.ne.nOPL(n).and.nj.ne.nOPL(nj))go to 32
        if(n.eq.nOPL(n).and.nj.eq.nOPL(nj))go to 17
        if(n.eq.nOPL(n))then
        if(intDep.ne.0)then
      dumc=c(beta(nj),duma)
        betanj=dBeta(duma,dumb,dumc,Aknow(nj,nk))
        else
        betanj=beta(nj)
        endif
        if(Atndum.lt.0.0.and.Atnj0.ge.Acrit)go to 504
        Atitud(nj,nk)=Atnj0+betanj*Atndum
        At0(nj,nk)=At0(nj,nk)+betanj*bguzai*Atndum
  504 continue
        endif
        if(nj.eq.nOPL(nj))then
        if(intDep.ne.0)then
        dumc=c(beta(n),duma)
        betan=dBeta(duma,dumb,dumc,Aknow(n,nk))
        else
        betan=beta(n)
        endif
      if(Atndum.gt.0.0.and.Atn0.ge.Acrit)go to 505
        Atitud(n,nk)=Atn0-betan*Atndum
        At0(n,nk)=At0(n,nk)-betan*bguzai*Atndum
  505 continue
        endif
        go to 17
   32 if(intDep.ne.0)then
        dumc=c(beta(nj),duma)
        betanj=dBeta(duma,dumb,dumc,Aknow(nj,nk))
        dumc=c(beta(n),duma)
        betan=dBeta(duma,dumb,dumc,Aknow(n,nk))
        else
        betanj=beta(nj)
        betan=beta(n)
        endif
        if(Atndum.lt.0.0.and.Atnj0.ge.Acrit)go to 503
        Atitud(nj,nk)=Atnj0+betanj*Atndum
        At0(nj,nk)=At0(nj,nk)+betanj*bguzai*Atndum
  503 if(Atndum.gt.0.0.and.Atn0.ge.Acrit)go to 17
      Atitud(n,nk)=Atn0-betan*Atndum
      At0(n,nk)=At0(n,nk)-betan*bguzai*Atndum
   17 continue
   15 continue
```

```
   14 continue
c
c      relaxation
c
      do 22 nk=1,nknwlg
      do 22 n=1,nP
        if(n.eq.nOPL(n))go to 22
        nA1=iAt(n,1)
        nA2=iAt(n,2)
        sum=0.0
        nsum=0.0
        do 19 nj=1,nP
        if(iAt(nj,1).ne.nA1.or.iAt(nj,2).ne.nA2)go to 19
        dist=sqrt((Ax(n)-Ax(nj))**2+(Ay(n)-Ay(nj))**2)
      if(dist.gt.rcrit)go to 19
        sum=sum+Atitud(nj,nk)
        nsum=nsum+1
   19 continue
      if(nsum.eq.0)go to 22
        sum=sum/float(nsum)
   21 Atitud(n,nk)=Atitud(n,nk)+epsrn(n)*(sum-Atitud(n,nk))
   22 continue
      do 24 nk=1,nknwlg
      do 23 n=1,nP
        if(n.eq.nOPL(n))go to 23
      Aknow(n,nk)=AkO(n,nk)+(Aknow(n,nk)-AkO(n,nk))*(1.0-1.0/aTauK(n))
        Atitud(n,nk)=AtO(n,nk)+(Atitud(n,nk)-AtO(n,nk))*(1.0-1.0/
     1aTauA(n))
   23 continue
   24 continue
c
      call Averag
        call DatSeq
        index=0
        ntime=999999
        do 98 nt=1,6
        if(Lt.ne.ntimep(nt))go to 98
        index=9999
        nt0=nt
   98 continue
      if(Mm.eq.1.and.index.ne.0)call OutSeq
        if(Mm.eq.1)call PlotD
      Lt=Lt+1
        if(Lt.le.Ltmax)go to 99
c
c      final output of results
c
      if(Mm.eq.1)then
        call Output
c
      print *,'       tribe     K(>=50%)       A(>=50%)
     1       K(>=80%)       A(>=80%)'
        write(1006,49)
   49 format(///,' trb',3x,'K(>=50%)',3x,'A(>=50%)',3x,
     1'K(>=80%)',3x,'A(>=80%)')
        do 55 nt=1,ntribe
        S80(nt)=0.0
        do 57 nr=1,2
        AK80(nt,nr)=0.0
        A80(nt,nr)=0.0
   57 continue
   55 continue
      do 56 n=1,nP
        S80(iAt(n,1))=S80(iAt(n,1))+1.0
        do 58 nr=1,2
        ratio=0.5
        if(nr.eq.2)ratio=0.8
        if(Aknow(n,1).ge.ratio)AK80(iAt(n,1),nr)=AK80(iAt(n,1),nr)+1.0
        if(Atitud(n,1).ge.ratio)A80(iAt(n,1),nr)=A80(iAt(n,1),nr)+1.0
   58 continue
   56 continue
      do 59 nt=1,ntribe
        RK1=AK80(nt,1)/S80(nt)
        RA1=A80(nt,1)/S80(nt)
        RK2=AK80(nt,2)/S80(nt)
        RA2=A80(nt,2)/S80(nt)
```

```
        print *,nt,RK1,RA1,RK2,RA2
        write(1006,48)nt,RK1,RA1,RK2,RA2
   48 format(i4,4(1pe11.3))
   59 continue
      endif
c
 1000 continue
      call Effect
        print *,'      tribe    Delta K        Delta A
     1       Orgnl K        Orgnl A'
        do 47 nt=1,ntribe
        print *,nt,DeltaK(nt),DeltaA(nt),AK0(nt),AA0(nt)
   47 continue
        stop
        end
c
c     ------------------------------------------------------------------
c     Outputting the final results for the particle animation (IV) :
c     agent position with varied knowledge and/or attitude
c
      subroutine  PlotD
c
        parameter (nP=1000,nAtrbt=2,nknwlg=1)
        parameter (ic=5)
        common /PRM/nInt,L1,L0,ntribe,Lt,Ltmax,nt0,pInt,Pcom,Mm,iOPL,
     1        nOPL(nP),nmbOPL,jOPL,iAnime,intDep,iRepet,iTmInt,rcrit,
        2            rmale(25),female(25)
        common /Var/Ax(nP),Ay(nP),Ax0(nP),Ay0(nP),iAt(nP,nAtrbt),
     1        Aknow(nP,nknwlg),Atitud(nP,nknwlg),Dknow(25),Move(nP),
        2        Dattd(25),AK0(nP,nknwlg),At0(nP,nknwlg),ntimep(6),
        3        AAknow(nknwlg,25,3,400,2),AAtitd(nknwlg,25,3,400,2),
        4        nPSeq(30,3),OutK(nknwlg,30,3,400),OutA(nknwlg,30,3,400),
        5        ktribe(25),kCtr
        common /CNST/gamma,aguzai,bguzai,tauK,tauA,Pturn,Rint00,Rint01,
     1        tau,MNnInt,DeltaK(25),DeltaA(25),AK0(25),AA0(25),
     2        sigma,width
        common /COEF/PR(25,2),alp(25,2),bet(25,2),del(25,2,25,2),
     1        eps(25,2),GalpK,GalpA,GbetaK,GbetaA,alpha(nP),beta(nP),
        2        epsrn(nP),aTauK(nP),aTauA(nP)
      dimension Icolor(Ic),f16(Ic)
      data (Icolor(i),i=1,ic)/ 0, 1, 14, 7, 15 /
c     data (Icolor(i),i=1,ic)/ 1, 6, 9, 14 /
c      data (Icolor(i),i=1,ic)/ 1,7,14 /
c       data (f16(i),i=1,ic)/ 0.3, 0.65, 1.0 /
        data (f16(i),i=1,ic)/ 0.2, 0.4, 0.6, 0.8, 1.0 /
c
      Az=0.0
      do 10 n=1,nP
        write(40,1000)Ax(n),Az,Ay(n)
      jc=1
      do 20 i=1,ic-1
        go to (31,32) iAnime
   32 if(Atitud(n,nknwlg).le.f16(i))go to 20
      go to 21
   31 if(Aknow(n,nknwlg).le.f16(i))go to 20
   21 jc=jc+1
   20 continue
        write(41,1100)Icolor(jc)
   10 continue
 1000 format(3f8.4)
 1100 format(I6)
        return
        end
c
c     ------------------------------------------------------------------
c     Outputting the final results in the form of EXCEL (III): Effect of PRs
c     Difference of AAknow and AAtitd between two cases with and without PRs
c
      subroutine Effect
        parameter (nP=1000,nAtrbt=2,nknwlg=1)
        common /PRM/nInt,L1,L0,ntribe,Lt,Ltmax,nt0,pInt,Pcom,Mm,iOPL,
     1        nOPL(nP),nmbOPL,jOPL,iAnime,intDep,iRepet,iTmInt,rcrit,
        2           rmale(25),female(25)
        common /Var/Ax(nP),Ay(nP),Ax0(nP),Ay0(nP),iAt(nP,nAtrbt),
     1        Aknow(nP,nknwlg),Atitud(nP,nknwlg),Dknow(25),Move(nP),
        2        Dattd(25),AK0(nP,nknwlg),At0(nP,nknwlg),ntimep(6),
```

```
     3        AAknow(nknwlg,25,3,400,2),AAtitd(nknwlg,25,3,400,2),
     4        nPSeq(30,3),OutK(nknwlg,30,3,400),OutA(nknwlg,30,3,400),
     5        ktribe(25),kCtr
      common /CNST/gamma,aguzai,bguzai,tauK,tauA,Pturn,Rint00,Rint01,
     1        tau,MNnInt,DeltaK(25),DeltaA(25),AK0(25),AA0(25),
     2        sigma,width
      common /COEF/PR(25,2),alp(25,2),bet(25,2),del(25,2,25,2),
     1        eps(25,2),GalpK,GalpA,GbetaK,GbetaA,alpha(nP),beta(nP),
     2        epsrn(nP),aTauK(nP),aTauA(nP)
      dimension namet(30),Dif(25,3,400)
c
      do 91 nk=1,nknwlg
        do 90 n=1,30
        namet(n)=n
   90 continue
        do 92 n=1,ntribe
        do 93 ncase=1,3
        do 94 nt=1,Ltmax
      Dif(n,ncase,nt)=AAknow(nk,n,ncase,nt,1)-AAknow(nk,n,ncase,nt,2)
   94 continue
   93 continue
   92 continue
        write(2007,80)
   80 format('Enhanced extent of knowledge in each tribe (1)
     1: male case')
      write(2007,30)nk,jOPL
   30 format(/'knowledge =',i3,'  number of OPL =',i3)
      write(2007,10)(namet(n),n=1,ntribe)
   10 format(/4x,'time',9i11)
      do 11 nt=1,Ltmax
        write(2007,12)nt,(Dif(n,1,nt),n=1,ntribe)
   12 format(i8,9(1pe11.3))
   11 continue
      write(2007,13)
   13 format(///)
      write(2007,81)
   81 format('Enhanced extent of knowledge in each tribe (2)
     1: female case')
        write(2007,30)nk,jOPL
      write(2007,10)(namet(n),n=1,ntribe)
      do 14 nt=1,Ltmax
        write(2007,12)nt,(Dif(n,2,nt),n=1,ntribe)
   14 continue
      write(2007,13)
      write(2007,83)
   83 format('Enhanced extent of knowledge in each tribe (3) : total
     1 average')
      write(2007,30)nk,jOPL
      write(2007,10)(namet(n),n=1,ntribe)
      do 15 nt=1,Ltmax
        write(2007,12)nt,(Dif(n,3,nt),n=1,ntribe)
   15 continue
      do 20 n=1,ntribe
      DeltaK(n)=Dif(n,3,Ltmax)
        AK0(n)=AAknow(nk,n,3,Ltmax,2)
   20 continue
c
        do 95 n=1,ntribe
        do 96 ncase=1,3
        do 97 nt=1,Ltmax
      Dif(n,ncase,nt)=AAtitd(nk,n,ncase,nt,1)-AAtitd(nk,n,ncase,nt,2)
   97 continue
   96 continue
   95 continue
      write(2008,84)
   84 format('Enhanced extent of attitude in each tribe (1)
     1: male case')
      write(2008,30)nk,jOPL
      write(2008,10)(namet(n),n=1,ntribe)
      do 16 nt=1,Ltmax
        write(2008,12)nt,(Dif(n,1,nt),n=1,ntribe)
   16 continue
      write(2008,13)
      write(2008,85)
   85 format('Enhanced extent of attitude in each tribe (2)
     1: female case')
```

```
      write(2008,30)nk,jOPL
      write(2008,10)(namet(n),n=1,ntribe)
      do 17 nt=1,Ltmax
        write(2008,12)nt,(Dif(n,2,nt),n=1,ntribe)
   17 continue
      write(2008,13)
      write(2008,86)
   86 format('Enhanced extent of attitude in each tribe (3) : total
     1 average')
      write(2008,30)nk,jOPL
      write(2008,10)(namet(n),n=1,ntribe)
      do 18 nt=1,Ltmax
        write(2008,12)nt,(Dif(n,3,nt),n=1,ntribe)
   18 continue
      do 21 n=1,ntribe
      DeltaA(n)=Dif(n,3,Ltmax)
        AA0(n)=AAtitd(nk,n,3,Ltmax,2)
   21 continue
   91 continue
      return
        end
c
c
c     ------------------------------------------------------------------
c     Outputting the final results in the form of EXCEL (I)
c
      subroutine OutSeq
        parameter (nP=1000,nAtrbt=2,nknwlg=1)
        common /PRM/nInt,L1,L0,ntribe,Lt,Ltmax,nt0,pInt,Pcom,Mm,iOPL,
     1        nOPL(nP),nmbOPL,jOPL,iAnime,intDep,iRepet,iTmInt,rcrit,
        2           rmale(25),female(25)
        common /Var/Ax(nP),Ay(nP),Ax0(nP),Ay0(nP),iAt(nP,nAtrbt),
     1        Aknow(nP,nknwlg),Atitud(nP,nknwlg),Dknow(25),Move(nP),
        2        Dattd(25),AK0(nP,nknwlg),At0(nP,nknwlg),ntimep(6),
        3        AAknow(nknwlg,25,3,400,2),AAtitd(nknwlg,25,3,400,2),
        4        nPSeq(30,3),OutK(nknwlg,30,3,400),OutA(nknwlg,30,3,400),
        5        ktribe(25),kCtr
        common /CNST/gamma,aguzai,bguzai,tauK,tauA,Pturn,Rint00,Rint01,
     1        tau,MNnInt,DeltaK(25),DeltaA(25),AK0(25),AA0(25),
     2        sigma,width
        common /COEF/PR(25,2),alp(25,2),bet(25,2),del(25,2,25,2),
     1        eps(25,2),GalpK,GalpA,GbetaK,GbetaA,alpha(nP),beta(nP),
        2        epsrn(nP),aTauK(nP),aTauA(nP)
c
      go to (101,102,103,104,105,106)nt0
  101 write(1001,*) 'status of agents at the time =',ntimep(nt0),
     1'  number of OPL =',jOPL
      write(1001,10)
   10 format(/2x,'n',5x,'X(n)',7x,'Y(n)',5x,'Knowledge',4x,'Attitud'
     16x,'Tribe',5x,'Gender')
      do 11 nk=1,nknwlg
      do 11 n=1,np
        write(1001,17)n,Ax(n),Ay(n),Aknow(n,nk),Atitud(n,nk)
     1,iAt(n,1),iAt(n,2)
   17 format(i4,4(1pe11.3),2i11)
   11 continue
      return
  102 write(1002,*) 'status of agents at the time =',ntimep(nt0),
     1'  number of OPL =',jOPL
      write(1002,10)
      do 12 nk=1,nknwlg
      do 12 n=1,np
        write(1002,17)n,Ax(n),Ay(n),Aknow(n,nk),Atitud(n,nk)
     1,iAt(n,1),iAt(n,2)
   12 continue
      return
  103 write(1003,*) 'status of agents at the time =',ntimep(nt0),
     1'  number of OPL =',jOPL
      write(1003,10)
      do 13 nk=1,nknwlg
      do 13 n=1,np
        write(1003,17)n,Ax(n),Ay(n),Aknow(n,nk),Atitud(n,nk)
     1,iAt(n,1),iAt(n,2)
   13 continue
      return
  104 write(1004,*) 'status of agents at the time =',ntimep(nt0),
```

```
     1'  number of OPL =',jOPL
      write(1004,10)
      do 14 nk=1,nknwlg
      do 14 n=1,np
        write(1004,17)n,Ax(n),Ay(n),Aknow(n,nk),Atitud(n,nk)
     1,iAt(n,1),iAt(n,2)
   14 continue
      return
  105 write(1005,*) 'status of agents at the time =',ntimep(nt0),
     1'  number of OPL =',jOPL
      write(1005,10)
      do 15 nk=1,nknwlg
      do 15 n=1,np
        write(1005,17)n,Ax(n),Ay(n),Aknow(n,nk),Atitud(n,nk)
     1,iAt(n,1),iAt(n,2)
   15 continue
      return
  106 write(1006,*) 'status of agents at the time =',ntimep(nt0),
     1'  number of OPL =',jOPL
      write(1006,10)
      do 16 nk=1,nknwlg
      do 16 n=1,np
        write(1006,17)n,Ax(n),Ay(n),Aknow(n,nk),Atitud(n,nk)
     1,iAt(n,1),iAt(n,2)
   16 continue
      return
        end
c
c     ----------------------------------------------------------------------
c     Outputting the final results in the form of EXCEL (II)
c
      subroutine Output
        parameter (nP=1000,nAtrbt=2,nknwlg=1)
        common /PRM/nInt,L1,L0,ntribe,Lt,Ltmax,nt0,pInt,Pcom,Mm,iOPL,
     1        nOPL(nP),nmbOPL,jOPL,iAnime,intDep,iRepet,iTmInt,rcrit,
        2           rmale(25),female(25)
        common /Var/Ax(nP),Ay(nP),Ax0(nP),Ay0(nP),iAt(nP,nAtrbt),
     1        Aknow(nP,nknwlg),Atitud(nP,nknwlg),Dknow(25),Move(nP),
        2        Dattd(25),AK0(nP,nknwlg),At0(nP,nknwlg),ntimep(6),
        3        AAknow(nknwlg,25,3,400,2),AAtitd(nknwlg,25,3,400,2),
        4        nPSeq(30,3),OutK(nknwlg,30,3,400),OutA(nknwlg,30,3,400),
        5        ktribe(25),kCtr
        common /CNST/gamma,aguzai,bguzai,tauK,tauA,Pturn,Rint00,Rint01,
     1        tau,MNnInt,DeltaK(25),DeltaA(25),AK0(25),AA0(25),
     2        sigma,width
        common /COEF/PR(25,2),alp(25,2),bet(25,2),del(25,2,25,2),
     1        eps(25,2),GalpK,GalpA,GbetaK,GbetaA,alpha(nP),beta(nP),
        2        epsrn(nP),aTauK(nP),aTauA(nP)
        dimension namet(30),dummy(30)
        data Lt0,dummy / 0, 30*0.0 /
c
        do 91 nk=1,nknwlg
        do 90 n=1,30
        namet(n)=n
   90 continue
        write(2002,80)
   80 format('the extent of knowledge in each tribe (1) : male case')
      write(2002,30)nk,jOPL
   30 format(/'knowledge =',i3,'  number of OPL =',i3)
      write(2002,10)(namet(n),n=1,ntribe)
   10 format(/4x,'time',9i11)
      write(2002,12)Lt0,(dummy(n),n=1,ntribe)
      do 11 nt=1,Ltmax
        write(2002,12)nt,(AAknow(nk,n,1,nt,Mm),n=1,ntribe)
   12 format(i8,9(1pe11.3))
   11 continue
      write(2002,13)
   13 format(///)
      write(2002,81)
   81 format('the extent of knowledge in each tribe (2) : female case')
        write(2002,30)nk,jOPL
      write(2002,10)(namet(n),n=1,ntribe)
        write(2002,12)Lt0,(dummy(n),n=1,ntribe)
      do 14 nt=1,Ltmax
        write(2002,12)nt,(AAknow(nk,n,2,nt,Mm),n=1,ntribe)
   14 continue
```

```
      write(2002,13)
      write(2002,83)
   83 format('the extent of knowledge in each tribe (3) : total
     1 average')
      write(2002,30)nk,jOPL
      write(2002,10)(namet(n),n=1,ntribe)
      write(2002,12)Lt0,(dummy(n),n=1,ntribe)
      do 15 nt=1,Ltmax
        write(2002,12)nt,(AAknow(nk,n,3,nt,Mm),n=1,ntribe)
   15 continue
      write(2002,13)
c
      write(2003,84)
   84 format('the extent of attitude in each tribe (1) : male case')
      write(2003,30)nk,jOPL
      write(2003,10)(namet(n),n=1,ntribe)
      write(2003,12)Lt0,(dummy(n),n=1,ntribe)
      do 16 nt=1,Ltmax
        write(2003,12)nt,(AAtitd(nk,n,1,nt,Mm),n=1,ntribe)
   16 continue
      write(2003,13)
      write(2003,85)
   85 format('the extent of attitude in each tribe (2) : female case')
      write(2003,30)nk,jOPL
      write(2003,10)(namet(n),n=1,ntribe)
      write(2003,12)Lt0,(dummy(n),n=1,ntribe)
      do 17 nt=1,Ltmax
        write(2003,12)nt,(AAtitd(nk,n,2,nt,Mm),n=1,ntribe)
   17 continue
      write(2003,13)
      write(2003,86)
   86 format('the extent of attitude in each tribe (3) : total
     1 average')
      write(2003,30)nk,jOPL
      write(2003,10)(namet(n),n=1,ntribe)
      write(2003,12)Lt0,(dummy(n),n=1,ntribe)
      do 18 nt=1,Ltmax
        write(2003,12)nt,(AAtitd(nk,n,3,nt,Mm),n=1,ntribe)
   18 continue
      write(2003,13)
c
      write(2004,87)
   87 format('time behavior of knowledge for 30 agents in the tribe 1')
      write(2004,30)nk,jOPL
      write(2004,25)(namet(n),n=1,30)
        write(2004,26)Lt0,(dummy(n),n=1,30)
      do 19 nt=1,Ltmax
        write(2004,26)nt,(OutK(nk,n,1,nt),n=1,30)
   19 continue
      write(2004,13)
        write(2004,88)
   88 format('time behavior of attitude for 30 agents in the tribe 1')
      write(2004,30)nk,jOPL
      write(2004,25)(namet(n),n=1,30)
        write(2004,26)Lt0,(dummy(n),n=1,30)
      do 22 nt=1,Ltmax
        write(2004,26)nt,(OutA(nk,n,1,nt),n=1,30)
   22 continue
      if(MNnInt.eq.1)go to 91
c
        write(2005,89)
   89 format('time behavior of knowledge for 30 agents in the tribe 2')
      write(2005,30)nk,jOPL
      write(2005,25)(namet(n),n=1,30)
        write(2005,26)Lt0,(dummy(n),n=1,30)
      do 20 nt=1,Ltmax
        write(2005,26)nt,(OutK(nk,n,2,nt),n=1,30)
   20 continue
      write(2005,13)
        write(2005,13)
        write(2005,79)
   79 format('time behavior of attitude for 30 agents in the tribe 2')
      write(2005,30)nk,jOPL
      write(2005,25)(namet(n),n=1,30)
        write(2005,26)Lt0,(dummy(n),n=1,30)
      do 23 nt=1,Ltmax
```

```
        write(2005,26)nt,(OutA(nk,n,2,nt),n=1,30)
   23 continue
c
      write(2006,78)
   78 format('time behavior of knowledge for 30 agents in the tribe 3')
      write(2006,30)nk,jOPL
      write(2006,25)(namet(n),n=1,30)
   25 format(/4x,'time',30i11)
      write(2006,26)Lt0,(dummy(n),n=1,30)
      do 21 nt=1,Ltmax
        write(2006,26)nt,(OutK(nk,n,3,nt),n=1,30)
   26 format(i8,30(1pe11.3))
   21 continue
      write(2006,13)
        write(2006,77)
   77 format('time behavior of attitude for 30 agents in the tribe 3')
      write(2006,30)nk,jOPL
      write(2006,25)(namet(n),n=1,30)
        write(2006,26)Lt0,(dummy(n),n=1,30)
      do 24 nt=1,Ltmax
        write(2006,26)nt,(OutA(nk,n,3,nt),n=1,30)
   24 continue
   91 continue
      return
        end
c
c     ------------------------------------------------------------------
c     keeping the sequential data of knowledge and attitude for
c     representative agents
c
      subroutine DatSeq
        parameter (nP=1000,nAtrbt=2,nknwlg=1)
        common /PRM/nInt,L1,L0,ntribe,Lt,Ltmax,nt0,pInt,Pcom,Mm,iOPL,
     1        nOPL(nP),nmbOPL,jOPL,iAnime,intDep,iRepet,iTmInt,rcrit,
        2           rmale(25),female(25)
        common /Var/Ax(nP),Ay(nP),Ax0(nP),Ay0(nP),iAt(nP,nAtrbt),
     1        Aknow(nP,nknwlg),Atitud(nP,nknwlg),Dknow(25),Move(nP),
        2        Dattd(25),AK0(nP,nknwlg),At0(nP,nknwlg),ntimep(6),
        3        AAknow(nknwlg,25,3,400,2),AAtitd(nknwlg,25,3,400,2),
        4        nPSeq(30,3),OutK(nknwlg,30,3,400),OutA(nknwlg,30,3,400),
        5        ktribe(25),kCtr
        common /CNST/gamma,aguzai,bguzai,tauK,tauA,Pturn,Rint00,Rint01,
     1        tau,MNnInt,DeltaK(25),DeltaA(25),AK0(25),AA0(25),
     2        sigma,width
        common /COEF/PR(25,2),alp(25,2),bet(25,2),del(25,2,25,2),
     1        eps(25,2),GalpK,GalpA,GbetaK,GbetaA,alpha(nP),beta(nP),
        2        epsrn(nP),aTauK(nP),aTauA(nP)
        do 13 nk=1,nknwlg
        do 10 n=1,nP
        do 11 nS=1,MNnInt
        do 12 m=1,30
        if(n.ne.nPSeq(m,nS))go to 12
        OutK(nk,m,nS,Lt)=Aknow(n,nk)
        OutA(nk,m,nS,Lt)=Atitud(n,nk)
   12 continue
   11 continue
   10 continue
   13 continue
      return
        end
c
c     ------------------------------------------------------------------
c     Averaging the results with regard to tribe and gender
c
      subroutine Averag
        parameter (nP=1000,nAtrbt=2,nknwlg=1)
        common /PRM/nInt,L1,L0,ntribe,Lt,Ltmax,nt0,pInt,Pcom,Mm,iOPL,
     1        nOPL(nP),nmbOPL,jOPL,iAnime,intDep,iRepet,iTmInt,rcrit,
        2           rmale(25),female(25)
        common /Var/Ax(nP),Ay(nP),Ax0(nP),Ay0(nP),iAt(nP,nAtrbt),
     1        Aknow(nP,nknwlg),Atitud(nP,nknwlg),Dknow(25),Move(nP),
        2        Dattd(25),AK0(nP,nknwlg),At0(nP,nknwlg),ntimep(6),
        3        AAknow(nknwlg,25,3,400,2),AAtitd(nknwlg,25,3,400,2),
        4        nPSeq(30,3),OutK(nknwlg,30,3,400),OutA(nknwlg,30,3,400),
        5        ktribe(25),kCtr
        common /CNST/gamma,aguzai,bguzai,tauK,tauA,Pturn,Rint00,Rint01,
```

```
     1        tau,MNnInt,DeltaK(25),DeltaA(25),AK0(25),AA0(25),
     2        sigma,width
        common /COEF/PR(25,2),alp(25,2),bet(25,2),del(25,2,25,2),
     1        eps(25,2),GalpK,GalpA,GbetaK,GbetaA,alpha(nP),beta(nP),
        2        epsrn(nP),aTauK(nP),aTauA(nP)
        dimension sumK(nknwlg,25,3),sumA(nknwlg,25,3),nsum(nknwlg,25,3)
c
c      n3 in sumK(n1,n2,n3),sumA(n1,n2,n3) and nsum(n1,n2,n3) is for
c         gendar parameter: n3=1 for male, =2 for female and =3 for all
c
      do 11 nk=1,nknwlg
        do 11 nt=1,25
        do 11 nA=1,3
        sumK(nk,nt,nA)=0.0
        sumA(nk,nt,nA)=0.0
        nsum(nk,nt,nA)=0
        AAknow(nk,nt,nA,Lt,Mm)=0.0
        AAtitd(nk,nt,nA,Lt,Mm)=0.0
   11 continue
      do 13 nk=1,nknwlg
        do 10 n=1,nP
        sumK(nk,iAt(n,1),3)=sumK(nk,iAt(n,1),3)+Aknow(n,nk)
        sumA(nk,iAt(n,1),3)=sumA(nk,iAt(n,1),3)+Atitud(n,nk)
        nsum(nk,iAt(n,1),3)=nsum(nk,iAt(n,1),3)+1
      sumK(nk,iAt(n,1),iAt(n,2))=sumK(nk,iAt(n,1),iAt(n,2))
     1+Aknow(n,nk)
        sumA(nk,iAt(n,1),iAt(n,2))=sumA(nk,iAt(n,1),iAt(n,2))
     1+Atitud(n,nk)
        nsum(nk,iAt(n,1),iAt(n,2))=nsum(nk,iAt(n,1),iAt(n,2))+1
   10 continue
   13 continue
      do 14 nk=1,nknwlg
      do 15 nt=1,25
        do 16 nAv=1,3
        denm=float(nsum(nk,nt,nAv))
        if(denm.eq.0.0)go to 16
        AAknow(nk,nt,nAv,Lt,Mm)=sumK(nk,nt,nAv)/denm
      AAtitd(nk,nt,nAv,Lt,Mm)=sumA(nk,nt,nAv)/denm
   16 continue
   15 continue
   14 continue
      return
        end
c
c     ---------------------------------------------------------------------
c     Determination of initial position and attributes, and
c     the states of knowledge and vector attitudes after the offer of initial
c     information at t=0 for the agent particles of the total number nP
c     distributed throughout the two dimensional model space
c
        subroutine Atribt
        parameter (nP=1000,nAtrbt=2,nknwlg=1)
        common /PRM/nInt,L1,L0,ntribe,Lt,Ltmax,nt0,pInt,Pcom,Mm,iOPL,
     1        nOPL(nP),nmbOPL,jOPL,iAnime,intDep,iRepet,iTmInt,rcrit,
        2           rmale(25),female(25)
        common /Var/Ax(nP),Ay(nP),Ax0(nP),Ay0(nP),iAt(nP,nAtrbt),
     1        Aknow(nP,nknwlg),Atitud(nP,nknwlg),Dknow(25),Move(nP),
        2        Dattd(25),AK0(nP,nknwlg),At0(nP,nknwlg),ntimep(6),
        3        AAknow(nknwlg,25,3,400,2),AAtitd(nknwlg,25,3,400,2),
        4        nPSeq(30,3),OutK(nknwlg,30,3,400),OutA(nknwlg,30,3,400),
        5        ktribe(25),kCtr
        common /CNST/gamma,aguzai,bguzai,tauK,tauA,Pturn,Rint00,Rint01,
     1        tau,MNnInt,DeltaK(25),DeltaA(25),AK0(25),AA0(25),
     2        sigma,width
        common /COEF/PR(25,2),alp(25,2),bet(25,2),del(25,2,25,2),
     1        eps(25,2),GalpK,GalpA,GbetaK,GbetaA,alpha(nP),beta(nP),
        2        epsrn(nP),aTauK(nP),aTauA(nP)
      dimension OxTrb(25),OyTrb(25)
c
c     nAtrbt : the number of attributes attached to each agent:when nAtrbt=2,
c     iAt(nP,1) : dwelling place, the difference of it meaning to
c                 the difference of tribe in rural Jordan
c     iAt(nP,2) : gender
c     ntribe   : the number of different tribes whose dwelling places differ
c                 to each other: ntribe=(some integer, nInt)**2
c     sigma : standard deviation of the normal distribution for Atitud
```

```
c
      nInt=min0(5,nInt)
        nTribe=nInt**2
      dxy=1.0/float(nInt)
        do 11 jx=1,nInt
        do 11 jy=1,nInt
        nT=jx+(jy-1)*nInt
        OxTrb(nT)=dxy*float(jx-1)
        OyTrb(nT)=dxy*float(nInt-jy)
   11 continue
c     random distribution of agents
        do 10 n=1,nP
        Ax(n)=Ran(L1)
        Ay(n)=Ran(L1)
        Ax0(n)=Ax(n)
        Ay0(n)=Ay(n)
        Move(n)=0
        index=0
      do 12 jx=1,nInt
        do 12 jy=1,nInt
        if(index.ne.0)go to 12
        nT=jx+(jy-1)*nInt
        if(Ax(n).le.Oxtrb(nT).or.Ax(n).gt.Oxtrb(nT)+dxy)go to 12
      if(Ay(n).le.Oytrb(nT).or.Ay(n).gt.Oytrb(nT)+dxy)go to 12
        iAt(n,1)=nT
        index=99999
   12 continue
      iAt(n,2)=min0(ifix(Ran(L1)/0.5)+1,2)
   10 continue
      Xmax=(GalpA-1.0)*GbetaA
        cA=Xmax**(1.0-GalpA)*exp(GalpA-1.0)
        cG=0.39894/sigma
        width0=width*sigma
      if(GalpK.eq.0.0.and.GbetaK.eq.0.0)go to 18
c
c     supposition of gamma distributions for the initial knowledge and
c     attitude among the public
c
      Xmax=(GalpK-1.0)*GbetaK
        cK=Xmax**(1.0-GalpK)*exp(GalpK-1.0)
        do 14 nk=1,nknwlg
      do 13 n=1,nP
        Ak0(n,nk)=0.0
        At0(n,nk)=0.0
        Aknow(n,nk)=0.0
        Atitud(n,nk)=0.0
c
        if(iAt(n,1).ne.Ktribe(kCtr))go to 13
c
        reach=female(kCtr)
        if(iAt(n,2).eq.1)reach=rmale(kCtr)
        if(Ran(L1).gt.reach)go to 13
   15   dummyX=Ran(L1)
        dummyY=cK*dummyX**(GalpK-1.0)*exp(-dummyX/GbetaK)
        if(dummyY.le.Ran(L1))go to 15
        Aknow(n,nk)=dummyX*Dknow(kCtr)
c
c     case 1) independent distribution between Atitud and Aknow
c
c    16 dummyX=Ran(L1)
c       dummyY=cA*dummyX**(GalpA-1.0)*exp(-dummyX/GbetaA)
c       if(dummyY.le.Ran(L1))go to 16
c      Atitud(n,nk)=dummyX
c      go to 13
c
c     case 2) dependent distribution of Atitud on Aknow
c
   17 dummyX=2.0*(Ran(L1)-0.5)*width0+Aknow(n,nk)
      if(dummyX.lt.0.0.or.dummyX.gt.1.0)go to 17
      dummyY=cG*exp(-0.5*((dummyX-Aknow(n,nk))/sigma)**2)
        if(dummyY.le.Ran(L1))go to 17
        Atitud(n,nk)=dummyX
        Ak0(n,nk)=amin1(1.0,aguzai*Aknow(n,nk))
      At0(n,nk)=amin1(1.0,bguzai*Atitud(n,nk))
   13 continue
   14 continue
```

```
      return
c
c     case 3) uniform distribution of Ak in between [0,1.0]
c
   18 do 19 nk=1,nknwlg
      do 19 n=1,nP
        Ak0(n,nk)=0.0
        At0(n,nk)=0.0
        Aknow(n,nk)=0.0
        Atitud(n,nk)=0.0
c
        if(iAt(n,1).ne.Ktribe(kCtr))go to 19
c
        reach=female(kCtr)
        if(iAt(n,2).eq.1)reach=rmale(kCtr)
        if(Ran(L1).gt.reach)go to 19
        Aknow(n,nk)=Dknow(kCtr)*Ran(L1)
   27 dummyX=2.0*(Ran(L1)-0.5)*width0+Aknow(n,nk)
      if(dummyX.lt.0.0.or.dummyX.gt.1.0)go to 27
      dummyY=cG*exp(-0.5*((dummyX-Aknow(n,nk))/sigma)**2)
        if(dummyY.le.Ran(L1))go to 27
        Atitud(n,nk)=dummyX
        Ak0(n,nk)=amin1(1.0,aguzai*Aknow(n,nk))
      At0(n,nk)=amin1(1.0,bguzai*Atitud(n,nk))
   19 continue
      return
        end
c
c     ----------------------------------------------------------------------
c     Values of some coefficents intrinsic to each individual agents, which
c     are determined randomly
c
      subroutine Coefic
        parameter (nP=1000,nAtrbt=2,nknwlg=1)
        common /PRM/nInt,L1,L0,ntribe,Lt,Ltmax,nt0,pInt,Pcom,Mm,iOPL,
     1        nOPL(nP),nmbOPL,jOPL,iAnime,intDep,iRepet,iTmInt,rcrit,
        2           rmale(25),female(25)
        common /Var/Ax(nP),Ay(nP),Ax0(nP),Ay0(nP),iAt(nP,nAtrbt),
     1        Aknow(nP,nknwlg),Atitud(nP,nknwlg),Dknow(25),Move(nP),
        2        Dattd(25),Ak0(nP,nknwlg),At0(nP,nknwlg),ntimep(6),
        3        AAknow(nknwlg,25,3,400,2),AAtitd(nknwlg,25,3,400,2),
        4        nPSeq(30,3),OutK(nknwlg,30,3,400),OutA(nknwlg,30,3,400),
        5        ktribe(25),kCtr
        common /CNST/gamma,aguzai,bguzai,tauK,tauA,Pturn,Rint00,Rint01,
     1        tau,MNnInt,DeltaK(25),DeltaA(25),AK0(25),AA0(25),
     2        sigma,width
        common /COEF/PR(25,2),alp(25,2),bet(25,2),del(25,2,25,2),
     1        eps(25,2),GalpK,GalpA,GbetaK,GbetaA,alpha(nP),beta(nP),
        2        epsrn(nP),aTauK(nP),aTauA(nP)
c
      do 10 n=1,nP
        alpha(n)=alp(iAt(n,1),iAt(n,2))*Ran(L1)
        beta(n)=bet(iAt(n,1),iAt(n,2))*Ran(L1)
        epsrn(n)=eps(iAt(n,1),iAt(n,2))*Ran(L1)
        aTauK(n)=amax1(1.0,0.5*tauK*(1.0+3.0*Ran(L1)))
        aTauA(n)=amax1(1.0,0.5*tauA*(1.0+3.0*Ran(L1)))
   10 continue
      return
        end
```