

OPINION FORMATION IN THE INTELLIGENT AGENTS SYSTEM*

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A model of intelligent agents system is presented in which the agents interact with environment and change their opinions as a result of mutual contacts. The agents have defined the rules of motion $\{M\}$, the rules of opinion formation $\{D\}$ and environmental rules $\{E\}$. The process of renewing of resources in a certain area, defined with $\{E\}$, determines the standard of life of agents in this area, it has also influence on their opinion. The time evolution of the system is investigated using numerical simulations and results are discussed.

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1. The model

Intelligent agent systems are a very flexible tool for investigation of dynamical phenomena in different various complex system. In particular, social phenomena, interaction with environment and evolution of population were modeled using such systems (see *e.g.* [1–7]). In this paper a model of intelligent agents system is presented where the agents interact with environment and change their opinions as a result of mutual contacts.

In the model, we used the following assumptions and rules concerning properties of agents and environment. Agents move on a rectangular grid comprised of 50×50 cells. Each cell can be occupied by only one agent.

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1.1. Environmental rules $\{E_n\}$

- Resources in the environment can be treated as determinants of the standard of life of agents *i.e.* economical, social and cultural aspects of life;
- In the cells there are different levels of resource r , ranging from 0 to 4 [8];
- Higher level of resource in the cell results in a higher standard of life for the agent occupying the cell. Below, for convenience, the resource is called “sugar”;
- During the time evolution of the system resources in each cell are renewed with intensity n units per one step (where $0 < n < 4$).

1.2. Agent movement rules $\{M\}$

- During each time step an agent can move to one of the neighboring cells in four directions: up–down, left–right;
- During each time step an agent demands p portions of sugar. This can be called metabolism level and is a parameter p of the model;
- Each agent can carry 25 portions of sugar; it is also the initial amount of sugar assigned to each agent;
- Each agent can observe the level of sugar in the cells located in four directions (mentioned above). The range of vision d , the same in all four directions, is a parameter of the model;
- Each agent identifies the cell with the highest level of sugar in his range of vision and moves in its directions;
- Each agent collects all sugar located in the cell which he reached.

1.3. Agent opinion rules $\{D_\varepsilon\}$

- Each agent has an opinion represented by the variable $x_i(t)$ with values lying in the range between 0 and 1;
- During each time step an agent can exchange opinions with one of his randomly chosen neighbors [2]. The opinions of the pair of agents (i and j), in time t , are represented by $x_i(t)$ and $x_j(t)$. As a results of this discussion, opinion of agents may change if $|x_i(t) - x_j(t)| < \varepsilon$, where ε is a threshold value from interval $[0, 1]$. New opinions of the agents are [4]:

$$\begin{aligned} x_i(t+1) &= x_i(t) + \mu[x_j(t) - x_i(t)], \\ x_j(t+1) &= x_j(t) + \mu[x_i(t) - x_j(t)]. \end{aligned}$$

Parameter μ is called convergence parameter, and its value lies in the interval $[0, \frac{1}{2}]$. In our computations $\mu = \frac{1}{2}$. As we can see, the exchange of opinions is possible only when the difference between the initial opinions is not too large. This is similar to the situation which can be observed in interpersonal contacts in the human societies, and is called bounded confidence [2, 3] in social simulations.

1.4. Strong leader opinion rules S_1

- Strong leader has an opinion represented by the variable l with values lying in the range between 0 and 1;
- In each time step, opinion of a strong leader is constant;
- Strong leader has an influence on nearest agents and can change their opinion during the conversation.

2. Results and discussion

We examined the processes of migration of agents and their opinion formation for the case of environment with heterogeneously distributed resources. In our computations, we use the following values of parameters: $p = 1$ (metabolism level), $d = 30$ (range of vision) and $\varepsilon = 1$ (bounded confidence). In Fig. 1(a) initial positions of $N = 130$ agents are shown; 30 agents are located in the lower poor part of the picture, where the level of life is given by $r = 2$. The opinions of agents in this area have values between 0 and 0.2. In the upper part of this picture lies a rich area with the level of life $r = 4$; 100 agents located in this area have the opinions with values between 0 and 1. These areas are separated by the “desert area” with $r = 0$. Agents want to avoid this part of environment because it does not contain sugar. On the other hand, agents from the poor area want to migrate to the area with higher level of life. For this case, ten simulations were performed and after some time (oscillating around the value of $t = 1200$) all agents from the poor area reached upper rich areas. Parallely to the migration process, it can be observed that agents from the poor area adjust their opinions to the level of opinions characteristic for the rich area. At the same time, the opinion of agents in the rich areas is also slightly decreased as a result of arriving “poor” agents (see Fig. 2). It is an interesting result which is also observed in the real processes of people migration. Emigrants arriving to the environment with the higher level of life adjust their opinions to the level common for the new neighbors. It is worth mentioning that there is no initial network of contacts between agents in our model. Such a social network is formed during the time evolution of the system, as a result of the properties of the environment and the interaction between agents.

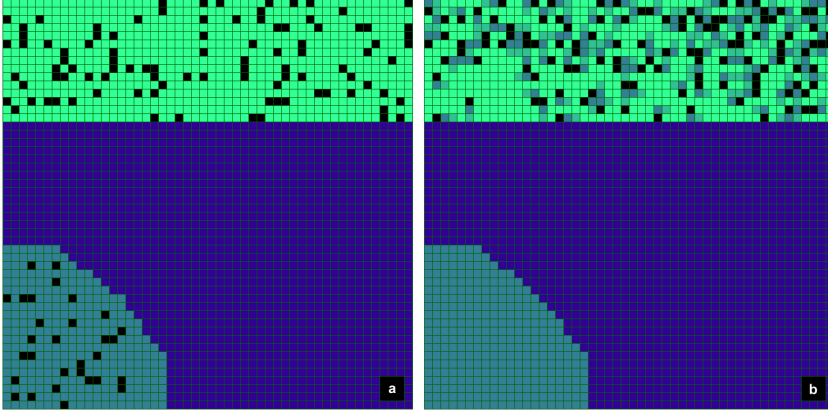


Fig. 1. (Color on-line) Time evolution of the $N = 130$ agents with the rules $\{E_1\}$, $\{M\}$, $\{D_1\}$. Area located near the lower left corner is the poor area with $r = 2$, area located in the upper part of the picture is the rich area with $r = 4$, these areas are separated by the desert area with $r = 0$ (marked in dark gray/blue). Intensity of (green) color decreases with the value of r . (a) initial state of the system; (b) typical state of simulation, when all agents are in the rich area.

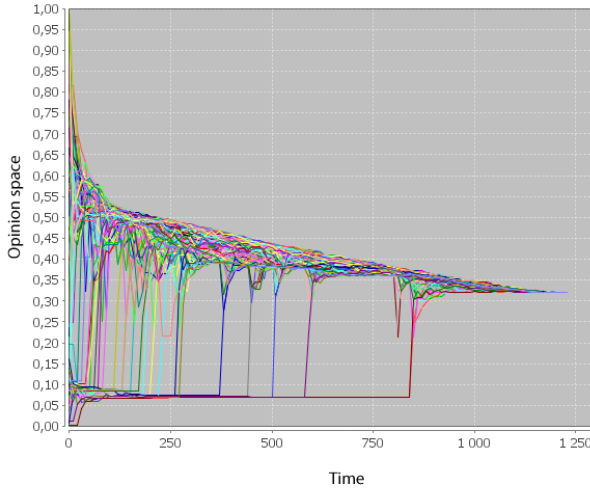


Fig. 2. Opinion formation in the agents system showed in Fig. 1. Average value of opinion decreases slightly in time as a result of the influence of agents arriving to the rich area and coming from the poor area, where the agents opinions are lower.

Next, we considered the process of agents opinion formation with two strong leaders having extreme opinions for two cases: open-minded ($\{D_1\}$) and close-minded ($\{D_{0,21}\}$) agents. In our computations, we use the follow-

ing values of parameters: $p = 1$ (metabolism level), $d = 5$ (range of vision), $\varepsilon = 1$ (see Fig. 4 (a)) and $\varepsilon = 0,21$ (see Fig. 4 (b)) (bounded confidence). In this case, we used additional rule $\{S_1\}$ (strong leader opinion rules). In the initial state of the system (see Fig. 3 (a)), strong leaders have strictly defined opinions, respectively: 0.12, 0.72. For other agents, values of opinions were assigned randomly from the interval $[0; 1]$. During the time evolution of the system (see Fig. 3 (b)), all agents move randomly in the area located in the central part of the picture with $r = 4$ (they try to avoid external area with $r = 0$). At each time step, agents may discuss with each other, if the condition $|x_i(t) - x_j(t)| < \varepsilon$ is true. As a results of numerical simulations, for the case with open-minded agents none dominating opinion in a population was found (see Fig. 4 (a)). On the other hand, for the case of close-minded agents (see Fig. 4 (b)) polarization of opinion is observed — agents chose one of the opinions of strong leaders.

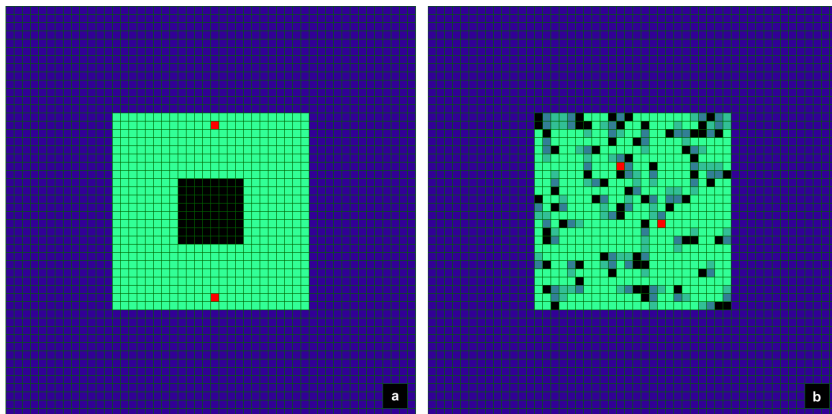


Fig. 3. (Color on-line) Time evolution of the $N = 66$ agents with the rules $\{E_1\}$, $\{M\}$, $\{S_{0,12}\}$, $\{S_{0,72}\}$. Area located in the central part of the picture is the rich one with $r = 4$. All agents are initially located in this area, where in the upper and lower parts strong leaders (marked in red) are located. External area is the desert one with $r = 0$. (a) initial state of the system; (b) time evolution of the system after certain time. Colors have the same meaning as in Fig. 1.

In conclusion, as results from our simulations during time evolution of a simple intelligent agent system a number of the complex phenomena, which emerge in a large human societies, can be observed. An example is the coupling between opinion of an agent and its level of life. Also, it was found that for population of open-minded agents ($\{D_1\}$) with two strong leaders having extreme opinions, getting a consensus or opinion polarization is not possible.

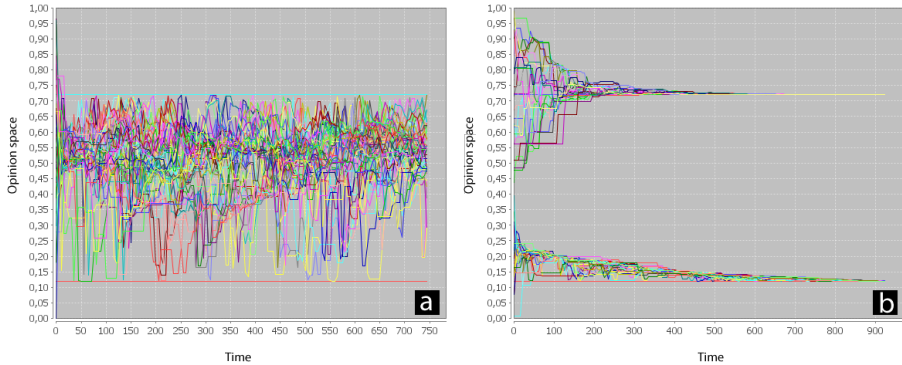


Fig. 4. Opinion formation in the agents system showed in Fig. 3. (a) opinion formation in the system with the rule $\{D_1\}$ — the interactions of agents with extreme opinions are possible; (b) opinion formation in the system with the rule $\{D_{0,21}\}$ — only the interactions of agents with similar opinions are possible.

It is worth noting that in our model the opinion is represented as a continuous variable and it was visualized on a simple diagram with opinion clusters [2, 3]. Moreover, there is no initial network of contacts between agents. Social network is formed during the time evolution of the system and depends on the properties of the environment and the interaction between agents.

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