Evolutionary minority game based on genetic algorithm

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***Abstract*—Minority game as a dynamic game with a minority method has attracted most of academic societies. Every one of methods presented, so far to improve minority game have had limitations or they're not applicable for all issues. One of these methods is evolutionary minority game using a probability for each agent to evolve. The method we present is based on evolutionary computing and genetic algorithm. Experimental results show that this presented method has better effect to evolve the agents compare to former methods and eventually improves the systems efficiency. (Abstract)**

Keywords-Dynamic game; Evolutionary computing; Genetic algorithm; Minority game (key words)

I. INTRODUCTION

In recent years, the complex adaptive systems have attracted many academic societies' especially statistical mechanics councils, statistical physics and computer sciences. This system involves many agents interacting with other [3]. Each agent in such systems selects an action according to the environment. The collective behavior of the agents must not have a central coordinator.

The model considered in this article is called "minority game", presented for the first time by Challet and Zhang [1] in 1997, which was the mathematical formulation of "El Farol Bar" problem presented by Arthur [2], in 1994.

Minority game is a system with many dynamic interactions. There is an odd number N of agents with S number of strategies in minority game. All agents have access to a common memory with the length m which is a binary sequence and stores the last results of the game; that is the last m winning group. Each agent should choose either A or B (1 or 0) in each time step. At the end of each turn, agents belonging to the similar group are the winner, so the minority group is the winner. The winning agents are awarded while the losing agents are fined. It is also given prize to the strategy causing an agent win and like the last one, the strategy causing an agent lose is fined. This "prize and fine" can be done by an obtained function or it can be by a rate to the agents and their strategies. You can see the complete procedure of minority game in [4].

In section 2, we evaluate the works done on minority game. In section 3, we consider the evolutionary minority games and present the new evolutionary method for minority game. In section 4, we evaluate the experimental tests and finally in section 5, we explain the results of this article.

II. RELATED WORKS

Generally, many works have done on minority game and it is used in various ways that can be classified in different fields. One of the most important applications of minority game is in economic field. Reviewing on minority game literatures, W.Kets in his article [5,6], want to present new perspectives of these writings in order to understand players behaviors in group games. He also evaluates the organizing itself in economics through minority game. He also retells learning model of minority game in learning model of game theory and shows that it has some common features with these models. He tests some economic issues and criticized that such games are not perfect, so the feedback on the game is not clear.

In addition to economic articles and economic aspects of minority game; some articles are presented about effective parameters in minority game such as minority game phases, the effect of the agent's memory length in minority game, etc. Liaw et al [7] evaluate the three phases of the game. They mention the importance of phases in their article, because the time sequence of population in a room (options) has distinctive features in different phases. In brief, the results of this article shows that we have pseudo periodic structure in the first phase $\alpha<\alpha_{c1}$. In the second phase $\alpha_{c1}<\alpha<\alpha_{c2}$, agents have more coordination than they have in other phases. In the third phase $\alpha_{c2}<\alpha$, the agents have the best efficiency in reducing the variance of the population. According to the authors of this article, the bad factor which is an obstacle for the system to obtain its best efficiency in the first and second phases is the numerous agents changing the strategy at the same time, because there is no evolution in the strategies.

On the other hand, Liaw and Hung [8] show that the memory length affects on the variance of the system, and analysis on effective memory length strongly supports the existence of three phases in minority game. Marsili [9] considers the connection of minority game and finds out a natural theory about memory length and its effect on the system; of course the more the more the agents evolve, the less the efficiency of these parameters will be.

One of the newest and the most important applications of minority game is resource allocation [10,11,12,13,14,15]. Galestyan et al [14] suggest that most of discussed issues on computer networks, especially sensor networks can be seen as a resource allocation issue. Therefore in their paper, they assumed the bound width of communicative channel as a resource and obtained good results in experiments for getting more efficiency from channel by minority game. But if these agents had been able to evolve in those networks, we could have seen more efficiency.

One of the considerable matters in minority game is the subject evolution, which caused evolutionary minority game to be discussed [3,16,17,18], but evolution haven't been done completely in these articles. In [17], evolution considered as a probability for each agent. Shong et al [3] did his on the graph and improved it. In [16], the resource allocation issue was done by evolutionary minority game in such a way that had better results compare to other methods and simple minority game. But, an important matter that has not been considered in evolutionary computing methods of evolution and specially genetic algorithm. In this paper, we present evolution based on genetic algorithm for minority game in which the results of the experiments show that it improves the efficiency of simple minority game and former evolutionary minority game.

III. EVOLUTIONARY MINORITY GAME

In any case, minority game is not integrated evolution [17]. The agents stick to their initial strategies, so the system can't prevent failures in the works. There is an exception in the real world in which the agents are able to evolve or even change the strategies to obtain more successes or at least prevent or omit calamitous strategies. These matters make us care more about the possibility of evolution in minority game and present a better model for evolutionary minority game.

A. Previous evolutionary minority games

The evolutionary minority game considered before [3,17] were like this case that each agent stored a probability p itself. Probability p means that the agent by seeing m latest winning group and taking the strategy with highest score did the analogous act with probability p and did the opposite act with probability $1-p$. After each time step, the winning agent and its strategy causing the agent win received prized and the losing agent and its strategy causing the defeat were fined.

Confirm After each time step, the agents' scores were considered. If the score of an agent is below the threshold, the agent must evolve its gene amount which is p. This evolution is like the case that the new p of this agent is accidentally chosen from a span with the radius of R and center of P_c . There three approaches to determine P_c :

- Approach 1: At first, We define a fixed P_c.
- Approach 2: We choose the probability of selection p related to the agent with the heist score as P_c .
- Approach 3: This view is applicable in graph model or the network (lattice) model. In this view, among the neighbors of the mentioned agent, probability p of the neighbor with highest score is chosen as P_c of this agent. This kind of evolutionary minority game is called "networked evolutionary minority game".

As you see, there is just one probability p for each agent to evolve. In fact, probability p is a cover on the strategies, so that the agent can see the strategy in other way. Of course, there is probability of failure for this system, too; because the selected probability which is replaced may be worse for given agent. In this model, the strategies of the agents don't change and don't evolve, but just their cover –probability of p– changes.

B. The evolutionary minority game based on genetic algorithm

One of the most important and complete methods of evolutionary computing is genetic algorithm. We need to improve the agents' strategies in minority game or more completely, we should evolve the agents' strategies in order to improve the efficiency of the systems. For this goal, we suppose the strategies of each agent as the genes of that agent for propagating. At the end of each time step, if the score of an agent is less than a threshold, its strategies should propagate with each other and new children strategies are produced. Among these children, we select the strategies with the most efficiency as the agent's new strategies. As mentioned, there is a memory with m length storing m group of winners. We introduce long term memory M which places the last 2^m+m group of last winner inside. By using this memory, we obtain the strategy resultants which have been so far. The Manhattan distance of each children strategy which is closer to the strategy resultant is chosen as the new strategy. In fact we use from Manhattan distance with the best strategy resultant as the evolutionary function of genetic method. The steps of new presented algorithm are as following:

Step1: We store 2^m+m number of last winning group and call it long-term memory. The most rightist wing of binary number shows the outcome of the game.

Step2: Like m number groups from the second bit from the right wing, we compute binary amount and we go forward one bit each time to the left wing.

Step3: We compute the table showing the obtained binary number and the next win (its right binary number).

Step4: We place in order the analogous bits of each number to related bit from the right wing, if we see repetitive number, it should be omitted. At last the bits which are empty can be filled using one of these two ways:

a) They are filled random and their effect should be less in computing.

b) From the right, the bits of the last table and the empty bits of the new table are scanned and the obtained amount of analogous bit from the last table is placed in the empty bit of the new.

The obtained binary number of this step is called "the Best Resultant Strategy" (BRS). Fig.1 shows an example of beyond steps (where $m=3$). In this example, the 0 and 7 bits remain empty that we fill them by B way.

Step5: Mutation and crossover and propagation operators are performed on the agent's strategies. So that the new children of the strategies of this agent are obtained.

Step6: The suitable children are kept in order by opposite Manhattan distance of the best resultant strategy obtained in step4. The *S* numbers of first children (i.e. the children strategies with the closest distance to the best resultant strategy) are selected as the agent's new strategies.

Step7: The agent score becomes zero or a basic amount.

I. 11010110010

II.

1- 001=1
2- 100=4
3- 110=6
4- 011=3
5- 101=5
6- 010=2
7- 101=5
8- 110=6

III.

Binary number	6	5	2	5	3	6	4	1
Next win	1	0	1	1	0	0	1	1

IV.

7	6	5	4	3	2	1	0
0	0	1	1	0	1	1	0

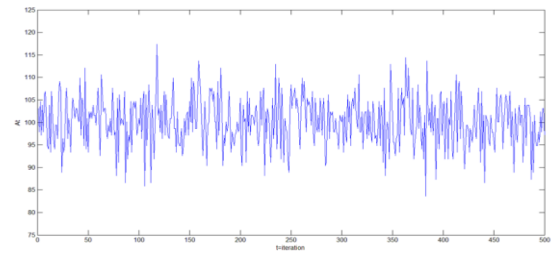
Figure 1. An example for presented algorithm (*m=3*).

IV. Experimental Results

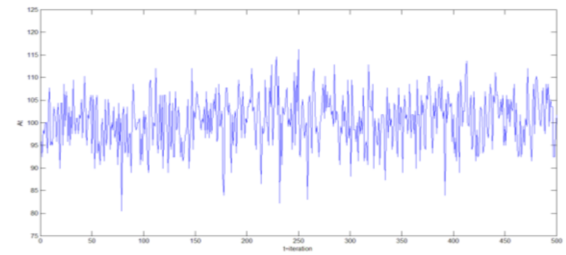
We compare four kinds of minority game: simple minority game, previous evolutionary minority game, networked evolutionary minority game (on random networks) and genetic minority game. In all of these simulations, the options of agent's act are considered '0' and '1'. Fig.2 illustrates the number of agent's presence that is the sum of the selected actions of each agent. As you see, the fluctuations of the agent's presence in the genetic evolutionary minority game(Fig.1-a) is less than other kinds of minority game. It means that more agents win in each round and the efficiency of the system is better because in each iteration more agents use from resources and this usage disseminate among the agents.

The networked evolutionary minority game(Fig.2-b), is a little better than former evolutionary minority game, but both of them have less fluctuations compare to simple minority game (Fig.2-d) and have more fluctuations than genetic evolutionary minority game(Fig.2-a).

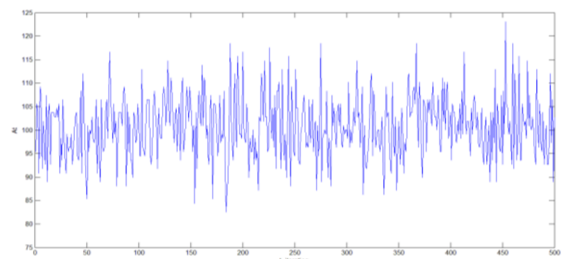
The reason that evolutionary minority games specially genetic minority game have less fluctuations and more efficiency compare to simple minority game can be this fact that after each time step, in evolutionary minority game, the weak agents with less success and score, evolve their strategies, so more agents can be successful each time and as mentioned, the success share among the all of the agents, almost uniformly, and it is not like the case that just a special number of agents succeed. Also, pseudo periodic structure is observed in all of them.



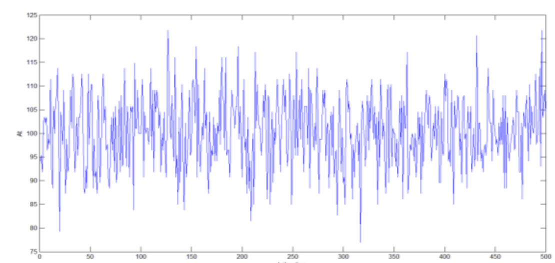
(a)



(b)



(c)



(d)

Figure 2. The number of presence based on time steps. (a)genetic evolutionary minority game (b)networked evolutionary minority game (c)former evolutionary minority game (d)simple minority game. (*N=201, m=8, s=3*, number of runs=10)

The agent's variance presence (choosing option) can be seen in Fig.3. In this Figure, the agent's variance of presence is demonstrated with different memory capacities. When the memory measure is more than 6, the agent's variance of presence in genetic evolutionary minority game have the least amount compare to other versions. In memory measure below 6, former evolutionary minority game and networked evolutionary minority game have almost less variance. The justification of this behavior can be this reason the effect of probability factor in little measure *m* is more and also it is better for genetic propagation with bigger *m*, we have vast area for propagation.

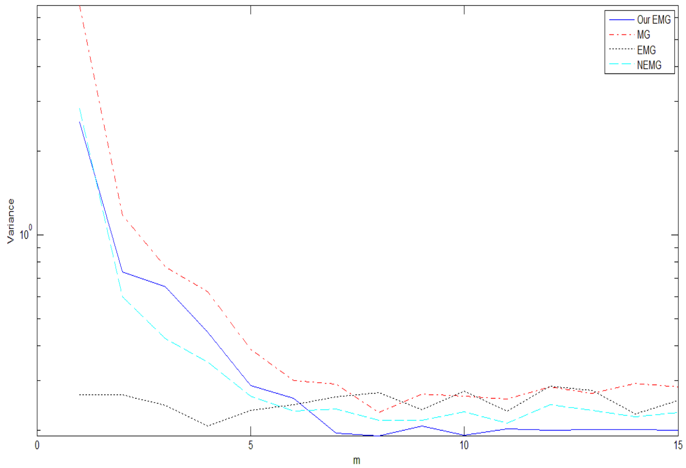


Figure 3. The variance of the presence of the agents.

Another measurements of evaluation is the successful rate of the agents, it means that each agent has what fraction of runs in the winner group. If there are more fluctuations among the agents and in fact the differences among the successful rate of the agents are high, it demonstrates that all the agents couldn't catch the suitable successful amount and just a group of agents were mostly successful, that is not good for the efficiency of the system at all. Fig.4 illustrates the successful rate of the agents. We see again that the agents in genetic evolutionary minority game (Fig 4.a) have better performance because their successful rate are closer to each other and mostly are more than 0.47, while in other methods, the successful rates of the agents have more differences with each other and they are usually less than 0.45 indicates that most of the agents had less success and it means that the efficiency of the system is low.

V. CONCLUSION

In this paper, we present an evolutionary minority game based on genetic algorithm. In this kind of evolutionary minority game, the strategies of agent evolve to the best strategy of resultant.

The results of the experiments show that the system by using if genetic evolutionary minority game has less fluctuations of presence and therefore more efficiency compare to former kinds of minority game. This kind of evolutionary minority game can be used in multiagent system performed based on the minority theories.

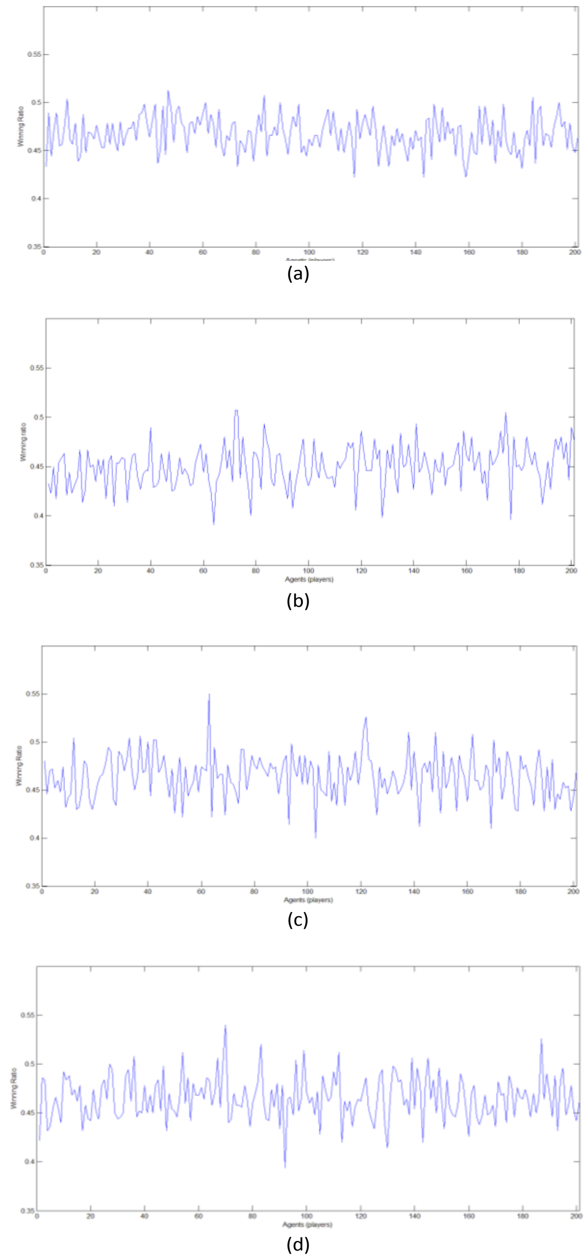


Figure 4. The successful rate of agents in all kinds of evolutionary minority game a) genetic evolutionary minority game b) networked evolutionary minority game c) former evolutionary minority game d) simple minority game (*N=201, m=8, s=3,* number of runs=10).

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