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Simulation Analysis of Evolutionary Game Based on Multi-agent Model Knowledge Transfer Behavior

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Abstract: Based on evolutionary game theory and knowledge transfer theory, using the complex adaptive system (Multi-Agent)'s overall modeling stimulation approach, adopting Swarm simulation software platform to create the multi-agent stimulating Knowledge Transfer Behavior Model-evolutionary Game Model (KTGM), then depicting the model's main attributes, behavioral rules and algorithm, under the various parameters conducting models to analysis the symmetrical cooperative game's evolutionary game simulation of the main knowledge transfer behavior, obtain the strategy adopted from the main behavior bodies' knowledge transfer activities, meanwhile the establishment and operation of model also provide an effective way to study the knowledge transfer driving behavior at all levels.

Key words: Knowledge transfer, multi-agent, evolutionary game, awarm, overall modeling simulation

INTRODUCTION

In this knowledge-economic period, knowledge become key resource that help companies and organizations gain competitive advantages. Companies and organizations must create and update knowledge considering condition changing in order to establish and maintain their competitive advantages. The method to research to knowledge management should focus on create, maintain and transfer knowledge by companies. Knowledge transfer becomes a critical step for all individual, groups and organizations' knowledge management. Researchers study transfer theories by diversified levels, aspects, objectives and dimensions. In the gambling analysis perspective of knowledge transfer, share and encourage. Liu and Bian (2005) uses practice gambling methods analyzing the actions of knowledge transfer between employees under a certain organization. And build a cooperative gambling mechanism for inter-organization employees. Luo (2005) interprets some problems including moral risks that might raised in virtual inter-organization knowledge transfer by using cooperative gambling model and establishes the framework of knowledge transfer of virtual investigative organizations. Chen and Lin (2005) uses gambling method to study dynamic union-knowledge-share mechanism from a cooperate angle of knowledge. These analyses are based on a hypothesis that participants are all perfectly rational and focus on different levels and subjects. It is not exactly true in reality. Economic actions and effects in economic system are the results of a series of decisions of interacts. The decision making is a dual gambling action (Chen, 1999). Being an economic action, knowledge transfer activities should be taken more into account when study its behaviors and effects.

For instance, the interaction between participants, the limitations and influences of subjects' rationality exert on gambling's equilibrium (Zhao and Hua, 1999). Because of subjects of knowledge transfer activities are usually limited rational, thus they cannot make the best strategies to set up equilibrium. Instead, participants will choose an advantage strategy and imitate when the game repeats again and again and finally reach the equilibrium. This is evolutionary game theory which based on Darwin's natural selection thought and includes the progress of study and strategy adjustments of limit rational participants, the participants' action analysis and the stability of dynamic strategy. Thus the theory can be used to analyze and forecast limit rational gambling (Xie, 2001). Integrated model building and emulation based on Multi-agent is an effective method in analyzing complex system under the instruction of complex adjusted systematic theory (Gelf, 1984). Agent is able to learn, deduct, plan and assist decide. Combine the agent and emulation model building technology can fully use the representations of knowledge and researches of AI field

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of various formula's learning and deduction. This article is based on evolutionary game theory and knowledge transfer theory and is instructed by Agent based integrated model building and emulation method, constructs KTGM. Using integrated model building and emulation software Swarm, using reproductive dynamic mechanism of evolution to imitate and analyze the steady strategy of limit rational subjects' knowledge transfer action under diversified benefits. Thus infer the strategy that individual should choose when doing knowledge transfer activities.

REPLICATOR DYNAMICS AND EVOLUTIONARY STABLE GAME OF KNOWLEDGE TRANSFER AMONG AGENTS

There are two optional strategies of knowledge transfer for collaborative agents: One is knowledge transfer, another is refusing knowledge transfer but accepting other's knowledge to gain more value. In the game of knowledge transfer, we assume that there are two symmetrical players: Agent 1 and 2. If both players accept knowledge transfer, each receives a. If both refuse knowledge transfer, each receives d. If one accepts but another refuses, the transfer one receives b and the not transfer one receives c. The payoff matrixes are as follows.

In the one time game, when the level of players' rationality is very low, the result of the game may be not linked to the value of a, b, c and d. However, in the repeated game, it is linked to the value of a, b, c and d. Because little agents really accord with the completely rational assumption and most of them are limited rational. Suppose in the group, the agents of knowledge transfer account for p and the others (1-p). Besides, change with the number of game, p is the function of time t. When an agent changes strategies but another's learning speed is slow, the dynamic change speed of the rate of the agents of taking transfer strategy can be showed by the following replicated dynamic function:

$$F(p) = \frac{dp}{dt} = p(u_1 - \bar{u}) \qquad (1)$$

Here, u_1 refers to expected revenue of agents of choosing the transfer strategy, $\bar{u}$ refers to average revenue of all agents. According to Fig. 1, we can obtain expected revenue and average revenue of both strategies which are as follows:

$$F(p) = p(1-p)(u_1-u_2) = p(1-p)[p(a-c)+(1-p)(b-d)] \qquad (5)$$

		Agent 2: Transfer	Agent 2: Not Transfer
Agent 1	Transfer	a, a	b, c
	Not Transfer	c, b	d, d

Fig. 1: Payoff matrix of two agents' game

Assume F (p) = 0, to obtain the possible stable state of Eq. 5:

$$p^*_1 = 0, p^*_2 = 1, p^*_3 = \frac{(d-b)}{a-b-c+d}$$

(only when $0 \le p^*_3 \le 1$)

KTGM MODEL BUILDING

In the KTGM model, the limited rational agents make decisions of knowledge transfer according to their attribute, external environment and specific rules of behavior. Besides, they continuously adjust strategies and increase the revenue of game by learning and imitating in the process of the repeated game. Finally the game achieves a Evolutionary Stable State (ESS). Each player of the model composed of model environment and larges number of agents is an intelligent agent In the process of the game, the external environment mainly affects the topology of the interaction between the agents. And the environment of each agent is composed of external environment and internal environment. In the KTGM model, the environment of all agents is simulated into the space environment in real life and it consists of a 100×100 grid. In this study we choose the most simple environment setting. In this environment setting, the agent can move freely to four directions around in the grid which is the agent's activity space. Each agent in each simulation period t can randomly select an agent to game in four directions. In this model, the agents are made up of attributes, rules, behavior and learning algorithm. In the process of the game, an agent randomly games with another agent as long as they meet. Agent randomly selects a strategy of transfer or not transfer to start a game from time t. The agent adopts a strategy at time t+1 according to the payoff of the game at time t.

The attribute of the agent and the definitions of the rule: In the KTGM model, the key attribute of the agent include: the number of ID, Current Strategies (CS), Next Strategies (NS) and Proceed. CS can record the current strategy of the agent and calculate the revenue of the agent, then record the revenue into Procced. At last calculate the NS by learning algorithm.The main rules are the rules of the mobile agent. For the better randomness of the evolution process, we assume the rules are as follows. Firstly, the location of the agent can be randomly changed in the environment. Secondly, the topology Figure and the relationship are not fixed in the game of the agent. Thirdly, both the game rival and the game relationship are changing. Besides, at the begin of the simulation, the agents which randomly distribute in the 100×100 grid space can randomly move to four direction in the simulation clock t. If an agent encounters any other agent, it will play a game. The specific rules are as follows. Each agent randomly chooses a direction at time t. If the location of one direction is empty, the agent will move to it. However, if the location is not empty, the agent won't move to it and will game with another agent. At time t+1, the agent will move again to find the object of the game (Chen, 1999).

The description of the behavior strategy and the learning algorithm of the agent: The set of agent in the game is S = { s_1, s_2} which represents that agent can choose a pure strategy that is s_1 (transfer) or s_2 (not transfer) and can also choose a mixed strategy with a certain probability. The revenue of each agent in the model is based on the 2×2 symmetric game payoff matrixes shown in the Fig. 1. And among the figure a, b, c and d are constant. The characteristic of the game is symmetrical, namely there is no any difference that a player is in location of player one or player two. In the model, after each game, the agent immediately changes strategies and determines the strategy of the next game according to its choices and the opponent's. This process can be described by the learning algorithm of the agent which is as follow:

$$S_{i,t+1} = (S_{i,t}, S_{j,t}, E_{i,t})$$

where, $S_{i,t}$ refers to the strategy of Agent i in this game. Meanwhile, $S_{j,t}$ refers to the strategy of agent j and $S_{i,t+1}$ refers to the next strategy of agent i at time t+1. Besides, $E_{i,t}$ refers to the revenue which is determined by the payoff matrixes. The strategy choice of each agent is based on the payoff at time t. If the payoff of the last strategy is higher than expectation, the agents will keep the strategy at time t+1. Otherwise, they will change the strategy. In this study we assume E_i (t), S_i (t) is revenue and strategy respectively, $n_{s1,t}$ is the number of the agents choosing the strategy of knowledge transfer at time t, N is the total number of the agents, p_t is the probability of choosing the strategy of transfer, $p_t = n_{s1,t}/N$ ($p_t \geq 0$, $p_t \leq 1$), so the probability of choosing the strategy of not transfer is 1-p_t. Besides, W_{s1} (t), W_{s2} (t) is the fitness function of choosing strategies of transfer and not transfer respectively which are described as follows:

$$W_{s1}(t) = p_t*a+(1-p_t)*b \quad (6)$$

$$W_{s2}(t) = p_t*c+(1-p_t)*d \quad (7)$$

If S_i (t) = s_1, W_{s2} (t)>W_{s1} (t) and W_{s1} (t)> $E_{i,j}$ (t), S_i (t+1) = s_2.

If S_i (t) = s_2, W_{s1} (t)> W_{s2} (t) and W_{s2} (t)> $E_{i,j}$ (t), S_j (t+1) = s_1.

SIMULATION ANALYSIS OF EVOLUTIONARY GAME BASED ON THE KTGM MODEL

We create and run the model on Swarm simulation platform providing by Santa Fe Institute in America, according to above description and definition of the model. Then analysis the ESS of agent's knowledge transfer behavior under different payoff matrixes. In order to discuss conveniently, in the environment, we assume that the agent's dense degree is 0.5 and the number is 500. In the simulation graphic, time t is on the horizontal and the ratio of the strategy of choosing transfer on the vertical. Besides, the solid line represents the rate of choosing transfer strategy and the dotted line is the average ratio.

In the payoff matrix, a>c, b>d. Namely, the payoff of knowledge transfer is always higher than not transfer for an agent, whether the choice of the opponent is transfer or not: When this situation happens in or between the organizations, the incentive system of knowledge transfer is fully effective. The core knowledge of the agent can be protected very well and knowledge transfer cost is very low (Ma and Xu, 2006). So, agents have the motivation to transfer knowledge with others, for benefit maximization. In the case of bounded rationality, F' (p_2*)<0 and p_2* = 1 is the only ESS. As is depicted in Fig. 2, the ESS has nothing to do with the value of the initial probability p and the agents with bounded rationality are tend to choose transfer strategy in long-term repeated game.

In the payoff matrix, a<c, b<d. Namely, the revenue of knowledge transfer is always lower than not transfer for an agent, whether the choice of the opponent is transfer or not: In this case, the cost of knowledge transfer is very

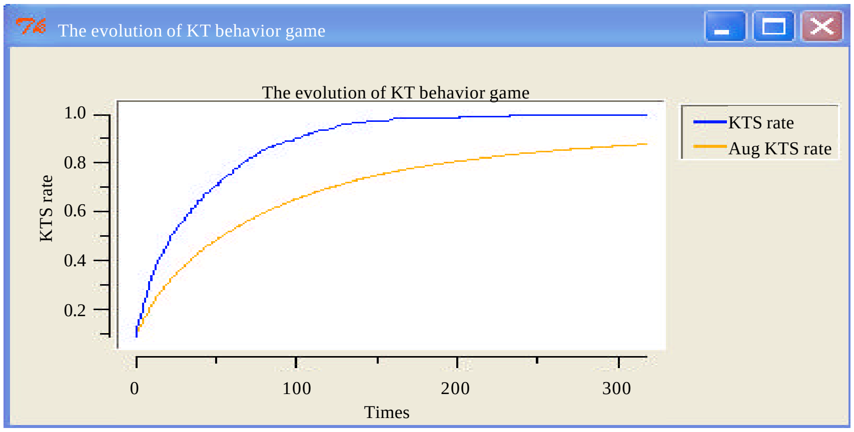

Fig. 2: Evolution of KT behavior game (Initial P = 0.1;a = 6, b = 4, c = 2 and d = 1)

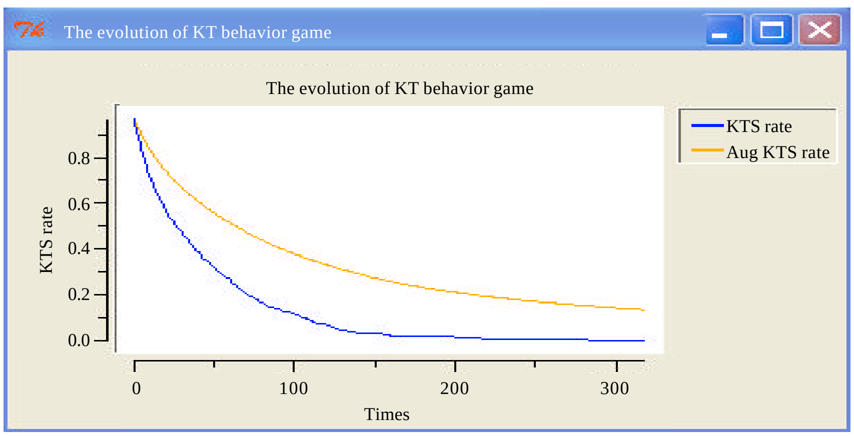

Fig. 3: Evolution of KT behavior game (Initial p = 0.98; a = 4, b = 1, c = 6 and d = 2)

high because the core knowledge of the agent can't be protected well leading to core knowledge spill-over. So, the completely rational agent will not to transfer but to wait for knowledge spill-over, for imitating other's knowledge can maximize their revenue. Finally, all agents are in the prisoner's dilemma of not transfer (Huo, 2002).

As is depicted in Fig. 3, in the case of bounded rationality, $F'(p_2^*)<0$ and $p_1^* = 0$ is the ESS. From the result, we can know the ESS has nothing to do with the value of the initial probability p and the agents with bounded rationality are tend to the strategy of choosing not transfer in long-term repeated game.

In the payoff matrix, $a>c$, $b<d$. Namely, the revenue of all agents transfer or not simultaneously is bigger than independently: In this case, the cost of knowledge transfer is very high and the core of knowledge is protected well. If both sides do not transfer but they can keep revenue not decrease. If an agent transfers independently, she will bear costs or risks of knowledge transfer leading to reducing revenue. However, if both sides take cooperative approach for knowledge transfer and share transfer costs and risks, they will acquire knowledge value of multiplication and collaboration to boost the earning ability of both sides. In the case of limited rationality, $F'(p_1^*)<0$, $F'(p_2^*)<0$ and the ESS is $p_1^* = 0$ and $p_2^* = 1$. Eventually the result of the game depends on the initial value of p. When initial $p\in(0, p_3^*)$, limited rational agents tend to choose a not transfer strategy after a long repeated game. When initial $p\in(p_3^*, 1)$, however, limited rational agents tend to choose a transfer strategy. Assume $p_3^* = 1/2$, these results are shown in Fig. 4. In order to further analysis, when $d = b$, $a\neq c$, $p_3^* = 0$, the result of repeated game is not transfer.

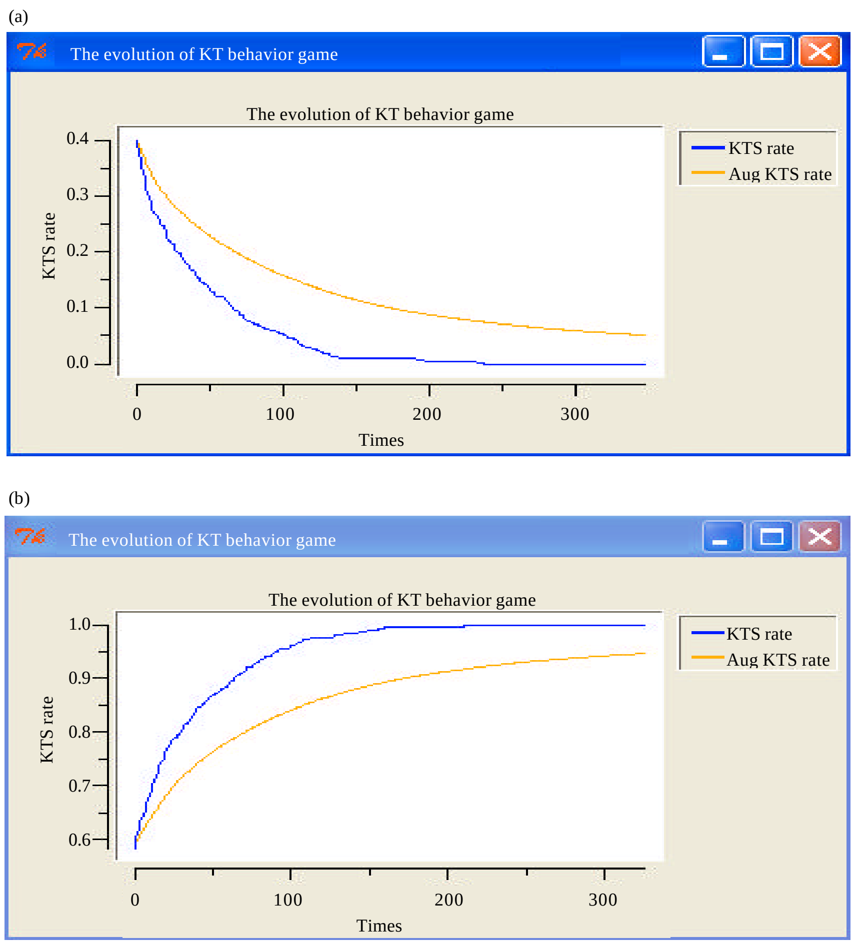

Fig. 4(a-b): Evolution of KT behavior game (a = 6, b = 1, c = 4, d = 3), A. Initial p = 0.45, B. Initial p = 0.55

And when $d \neq b$, $a = c$, $p_3^* = 1$, the result is transfer. These indicate that if the cost of knowledge transfer is bigger, the agents more likely tend to choose not transfer. However if they realize cooperation can make the revenue of knowledge transfer much bigger, they tend to choose knowledge transfer.

In the payoff matrix, $a<c$, $b>d$. Namely, the revenue of individual knowledge transfer is bigger than transfer or not transfer simultaneously: In this case, knowledge transfer activities happen in specific situation. In this situation, some agents have the knowledge that is needed for the alliance but the others don't have. If this kind of knowledge is transferred and shared in the alliance, it will greatly promote the competitive advantage of the alliance and achieve extra revenue in the process of knowledge transfer. However, they may bear higher risk. So, in the complete rational case, the equilibrium result of the game is: One transfer and another not. To make the equilibrium result change into knowledge transfer and receive much more revenue, the agents must decrease the cost of knowledge and increase ability of transferring, learning, absorbing and innovating knowledge. In the limited rational case, $F'(p_1^*)>0$, $F'(p_2^*)>0$ and $F'(p_3^*)<0$, so, $p_3^* = (d-b)/(a-b-c+d)$ is the unique ESS. After a long repeated game, the agents of tending to transfer accounted for (b-d)/(c-a+b-d), the agents of tending to not transfer accounted for (c-a)/(c-a+b-d). Apparently, the rate of agents of tending to transfer and (b-d) are positive correlation, the rate of agents of tending to not transfer and (c-a) are negative correlation. The simulation result of KTGM is depicted as Fig. 5. From it we can know the ESS is $p_3^* = 1/2$, because the ratio curve of selecting strategies of knowledge transfer is shocking at 0.5.

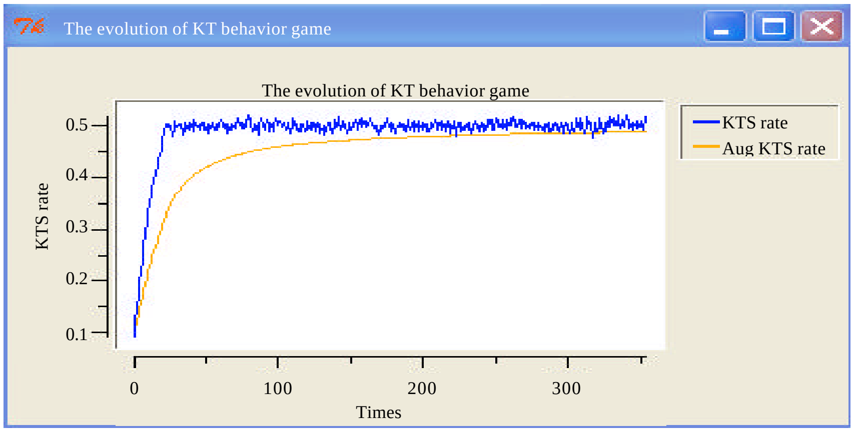

Fig. 5: Evolution of KT behavior game (a = 4, b = 3, c = 6, d = 1; initial p = 0.5)

CONCLUSION

Through modeling method based on multi-agent and SWARM simulation platform, this study sets up an evolution simulation model about game problems of limited rational agents' knowledge transfer in the complex economic system and uses the simulation of this model to make evolutionary game analysis on knowledge transfer. From above discussion, we can know that we can do as follows, in order to inspire the actions of knowledge transfer among individuals, groups and organizations and get more pay off by knowledge transfer. Firstly, we can reduce costs and risks of knowledge transfer and enhance knowledge transfer efficiency by strengthening cooperation trust between the agents. Secondly, we can increase senders' releasing and passing ability and receiver's learning and absorbing ability and decrease the cost of knowledge transfer by strengthening the protection of intellectual property rights. At last, we can set up the incentive mechanism of knowledge transfer and change the game between the agents to make the equilibrium strategies toward the optimal and behavior agents gain more benefits.

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