Evolutionary Machine Game and ISEM

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An ordinary evolutionary game is based on the framework of game and GA. However, both game and GA are based on the functions paradigm. Therefore, that prevents us from the powerfull use of AI methods. Because it makes up an epistemological barrier in front of us. In order to solve this difficulty, we must proceed to the automata paradigm. Concretely, instead of ordinary game theory and GA, we must use another framework of machine game and ISEM. These new frameworks really need AI investigations. Therefore, the framework of evolutionary machine game and ISEM will be a major target of AI research. In other words, in order to develop the method of ISEM, we must really investigate AI.

1. Problem of Epistemological Barrier

An ordinary evolutionary game is based on the framework of game theory and GA. However, both game theory and GA are based on functions paradigm. Therefore, that prevent us from the powerfull use of AI methods. Because it makes up an epistemological barrier in front of us. In order to solve this difficulty, we must proceed to the automata paradigm.

1.1 From Functions to Automata

The notion of automaton is the central notion of the information sciences. This notion of automaton gives us the ability to think about programs. The notion of program is the most significant idea that has influenced almost every kind of science today. I propose the idea of a paradigm shift from the functions paradigm to the automata paradigm. This paradigm shift makes it easy to use automata to create new models. Situated on the functions paradigm,[*1] every one uses functions to create new models. It is as if they don't know anything but functions. Indeed we can adopt automata to create new models of phenomena or systems. Situated on the automata paradigm, every one will use automata instead of functions. The notion of automaton will replace the notion of function. Nevertheless, the notion of automaton is based upon the notion of function. In mathematics the notion of automaton is defined by the notion of function, especially the notion of Boolean function. In spite of using the notion of function in its definition, the notion of automaton is essentially new.

1.2 Game

The flameworks of the theory of game[*2] are also based upon "function paradigm". For example, let us remind the two - person zero - sum games.[*3]

Let M be a payoff matrix of a matrix game G of $m \times n$ type.

$$M = (m_{i,j}) = \begin{pmatrix} m_{1,1} & m_{1,2} & \cdots & m_{1,n} \\ m_{2,1} & m_{2,2} & \cdots & m_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ m_{m,1} & m_{m,2} & \cdots & m_{m,n} \end{pmatrix}$$

A mixed strategy for the row player is an m-tuple $\mathbf{p}$ of probabilities. Namely,

$$p_i \geq 0, \quad 1 \leq i \leq m,$$

and

$$\sum_{i=1}^{m} p_i = 1.$$

Similarly, a mixed strategy for the column player is an n-tuple $\mathbf{q}$ of probabilities. Namely,

$$q_i \geq 0, \quad 1 \leq i \leq n,$$

and

$$\sum_{i=1}^{n} q_i = 1.$$

Let f_M be a payoff function of the game G. The f_M is defined by a bilinear mapping such that

$$f_M : P \times Q \longrightarrow \mathbf{R},$$

or

$$f_M : (\mathbf{p}, \mathbf{q}) \longmapsto \langle \mathbf{p}|M|\mathbf{q}\rangle,$$

where, $\mathbf{p} \in P$, $\mathbf{q} \in Q$, P: the set of mixed strategies of the row player, Q: the set of mixed strategies of the column player, $\langle \mathbf{p}|$: a row vector made of the vector $\mathbf{p}$, $|\mathbf{q}\rangle$: a column vector made of the vector $\mathbf{q}$.

Payoff functions can be defined for almost all ordinary games in similar ways. A payoff function does not change during plays of the game as if it were a natural environment for the players.

Therefore, the framework of an ordinary game is also based upon the function paradaigm.

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∗1 The notion of function has been the central concept of mathematics. See Simmons [10].

∗2 See Mailath [5], Morris [7], Rasmusen [8], Rubinstein [9], Webb [11].

∗3 See Morris [7].

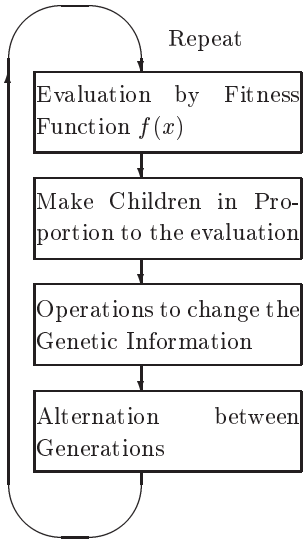
1.3 Evolutionary Game

Evolutionary games have a mechanism of evolution. Almost all evolutionary games have adopted GA as such a mechanism of evolution. However, we can think those evolutions to be evolutions of strategies toward better fitness to the payoff functions, which represent natural environments.

Therefore, these are also based upon the function paradigm.

1.4 GA

Almost all researchers of evolutional games until now adopted the method of GA (Genetic Algorithms)[*4], in spite of its faults. GA is an algorithm which emulates the evolutionary mechanism of life. GA evolves the genetic code represented by a bit sequence. GA also has a changing mechanism of the genetic code. For instance a mutation and crossing over with some randomness is adopted by GA to change the genetic code. Then GA makes a test for the performance that is measured by a fitness function. This emulates the natural selection discovered by Charles Darwin in the 19th century. The fitness function represents the natural environment to which life must adapt to survive. Evolutionary games are likely to adopt GA to represent their evolution. However, GA is only suitable to natural phenomena, and it is best to use another mechanism to represent the evolution of our society or economic systems.



2. Machine Game

Our new method of modeling should be based on the notion of automaton[*5], and it also adopts the notion of program. How do we make the new model with this new method? Fortunately, we already have a method for modeling from the stand point of the automata paradigm. A machine game[*6] is a model with automata. For a machine game, we call automata "machines". We use an automaton model to describe a subject that moves by itself. A machine game is defined as automata interacting with each other. Each automaton represents a player. Mathematically, the i th machine $M_i\,(i \in \{0, \cdots, n\})$ is defined by a three tuple $\left(Q_i, q_i^0, \tau_i\right)$ of a finite set of states Q_i, the initial state $q_i^0 \in Q_i$ and the transition function $\tau_i : Q_i \times Q_j \longrightarrow Q_i$, which represents the set of "strategies" of the player in the context of games. A machine game is composed of several automata. The number of automata is the same as the number of players of the machine game. However, machine games are based on one-to-one interactions. This means that each player in a machine game makes interactions with only one player at the same time. This feature is very convenient to represent one aspect of the bounded rationality.

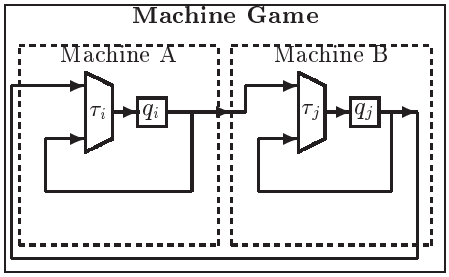
[Definition]: Machine M_i

$M_i \stackrel{def}{=} \left(Q_i, q_i^0, \tau_i\right)\,(i \in \{0, \cdots, n\})$,
where,
$\{0, \cdots, n\}$: *a set of players*,
$i(\in \{0, \cdots, n\})$: *this player*,
$j(\in \{0, \cdots, n\})$: *another player who is interacting with this player*,
Q_i : *a finite set of states*,
$q_i^0 \in Q_i$: *the initial state*,
$\tau_i : Q_i \times Q_j \longrightarrow Q_i$: *the transition function.*
[END]

[Definition]: Machine Game G

$G \stackrel{def}{=} \{M_0, M_1, \cdots, M_n\}$
[END]

In the machine game, interactions between these automata create the movement of the machine game. The program contained in the automaton is non-Neumann type program which we call NNTP for short. The NNTP consists of two factors: (1) the Boolean function of the ALU, and (2) the states of the inner memories. We can represent these two factors with "if-then" rules.



3. Evolutionary Machine Game

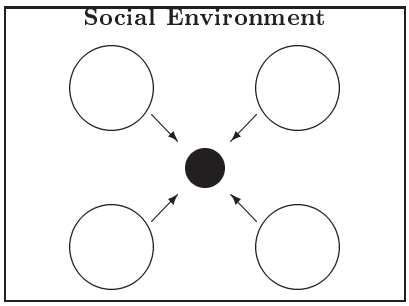
3.1 Evolutionary Mechanism

The machine game is based on the automata paradigm, but it does not evolve. In order to create a new model for describing the stationary process with fluctuations, the machine game without evolution is sufficient. However, a very important point of our society, including economic systems, is its evolution. Information science teaches us how to understand the evolution. We need the evolutionary mecha-

*4 See Epstein [3], Holland [4], Axelrod [1], Axelrod [2].
*5 See Maini [6].
*6 See Rubinstein [9].

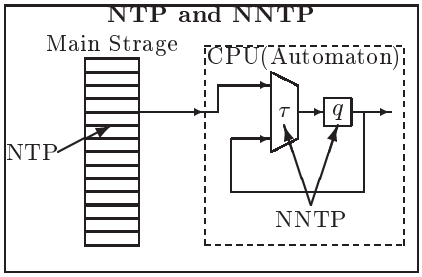
nism in order to describe social or economic phenomena or systems.

3.2 Social Selection



For evolutionary games with GA, payoff functions play the role of natural environments in the case of biological evolutions. However, machine games do not need any payoff function. Evolutionary machine game without payoff functions can not use GA as an evolutionary mechanism. Evolutionary machine game with ISEM evolve under social selections instead. Social environments replace the role of natural environments. Social environment cannot be represented by any function. Only interacting automata surounding the automaton can represent the social environment of the automaton. For an evolutionary machine game, these automata represent players.

4. NNTP



The notion of NNTP (Non-Neumann Type Program)*7 plays a very important role. For instance, in GA the genetic code is a sort of NNTP. Most computers are Neumann type computers. A Neumann type computer has a main storage to store programs and data for computation. The partition between programs and data is important because otherwise the computer will malfunction. The program and data in the main storage are read into the CPU (Central Processing Unit) of the computer. The CPU is an automaton. This structure of computers emulates the famous Turing Machine which has a computing box (that is the automaton) and a tape (that is emulated by the finite main storage) of infinite length. The program and data of the Neumann type computer, which is stored in the main storage, may be called "Neumann Type Program" (NTP). If the main storage is cut off, then there is no NTP. However, there is still a kind of program inside the automaton. That kind of program is the "Non-Neumann Type Program" (NNTP). The NNTP is composed of the circuit of ALU and the state of temporary memory inside the CPU. The ALU represents the Boolean function τ. The temporary memory represents the inner state q of the automaton. Therefore the NNTP is a set $\{\tau, q\}$.

[Definition:] NNTP of Machine M

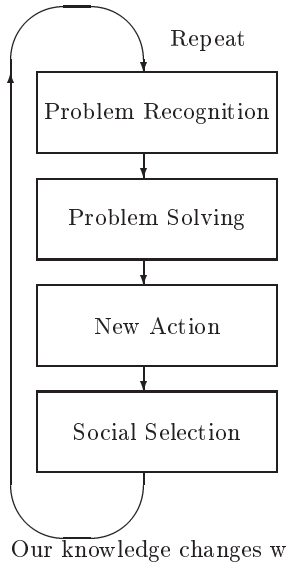
$$NNTP \stackrel{def}{=} \{\tau, q\}.$$

where,
τ: the Boolean function of M,
q: the state of the temporary memory inside M,
and both τ and q are programmable.
[END]

However, for the ordinary computer, the NNTP is not programmable. The NNTP should be programmable for the evolutionary machine game. In order to make the NNTP programmable, we can build a virtual machine on an ordinary Neumann type computer with some software. Now we understood the notion of NNTP with which we will extend GA.

5. ISEM

Intelligent Social Evolutionary Mechanism (ISEM)*8 is a mechanism of evolution applicable to social evolution. In order to create change in NNTP, ISEM adopts human intelligence instead of the randomness which is adopted by GA.



Our knowledge changes when we solve our problems. We create new knowledge to solve new problems. Our NNTP is composed of our knowledge. Hence, our NNTP changes when our knowledge changes. This new knowledge we have created will change our behavior. Then our actions will be evaluated by our social environment whether our new behavior is acceptable or not. ISEM adopts the social environment as the adapting target instead of the fitness function as is the case of GA. The fitness function of GA represents the natural environment in Darwin's natural selection. The

*7 This notion of NNTP is defined by Shinichiro Mado.
*8 The ISEM is also defined by S.Mado.

Table 1 Comparison of GA and ISEM

	GA	ISEM
Environment	Fitness function (Emulating Natural Environment. That is given a priori.)	Social environment (That is the whole system of agents. And that is also described with NNTP.)
NNTP	Chromosome (Binary Sequence)	Set of "If-Then" rules (That represents a set of knowledge.)
How to Change NNTP	Mutation, Crossing, etc. (Such operations use randomness to make change. Randomness is the most stupid intelligence.)	Problem Recognition and Problem Solution (These are activities done by intelligence.)
Alternation between Generations	Necessary (The Evolution needs many generations.)	Needless (The Evolution may occur during one generation.)
Selection	Selection by the fitness function (That is an emulation of the natural selection.)	Social Selection by the social environment. (For instance, restrictions by the law)
Change of the environment (That is the social evolution.)	Impossible (because the fitness function could not be changed during the simulation)	The evolution may change the environment to solve some problems. (Because the environment is also described with some NNTP)

adaptation in the case of GA is the adaptation to the natural environment. The adaptation in the case of ISEM is the adaptation to the social environment. It is crucial to distinguish the natural environment from the social environment.

The difference is in the fact that the social environment contains the person himself, while the natural environment does not. Therefore, if he changes then his social environment changes. For men it is possible to change their social environment to better suite themselves. It is possible for them to solve their problems by changing their environment instead of their behavior. We can make an attempt with our intelligence to change our social environment. This is a very critical point of difference between ISEM and GA. ISEM is a repeated process composed of 4 stages: (Stage 1) Problem Recognition, (Stage 2) Problem Solution, (Stage 3) New Action, and (Stage 4) Selection by the Social Environment. The process repeats these stages in this order.

6. Conclusion

We can replace the notions such as payoff functions and fitness functions with automata based social environments. These social environments are also determined by NNTP of component automata. Therefore, changes of NNTP of a component automata may cause a change of social environment. ISEM is such a mechanism of evolution that an increase of human knowledge, which is a sort of NNTP, changes the society. In order to describe the total change of agents and society, instead of GA we should adopt ISEM (Intelligent Social Evolutionary Mechanism) as the evolutionary mechanism for social phenomena.

In the ISEM, a sort of program called NNTP evolves. Then the evolutionary machine game should become the evolutionary machine game with NNTP and ISEM. Therefore, we should adopt the evolutionary machine game with NNTP and ISEM in order to describe the social evolution of economic systems or economic phenomena. In ISEM, it is nessesary for agents to be able to recognize and solve problems. It is truly a proper problem of AI research to investigate how to implement such capacity to an automaton. Therefore, ISEM is deeply based on AI investigations.This problem isn't an easy one. It should be one of the main problems of AI research. In other words, in order to develop the method of ISEM, we must really investigate AI.

For that reason I think that the framework of evolutionary machine game and ISEM has a posibility to be one of major targets of AI researchers.

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