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Social Complex Adaptive System: From Introduction To Several Scientific Conjectures

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Abstract

Social system is full of complexity, of stochastic dynamic, of criticality, of random diversity and of irrationality, which makes corresponding results hardly to be discovered. In this paper, we focus on drawing a conclusion of the invariant distribution of collective irrational behavior and the characteristics of critical phase transition in the process of system emergence due to the interaction between individuals. We also care about, if several order parameters of the system or environment changes, how the law of the collective behavior state and evolution state would change. Based on our analysis, seven preset conclusions in the aspects of local structure, individual properties and behavior, interaction rules, and environmental changes in complex adaptive systems are proposed.

Keywords Social complex adaptive system; irrationality; behavior; conjectures

1 Introduction

In the last 20 years or so, the theoretic study of complex adaptive system has become a major field, such as dynamical property [1], interactive behavior [2], phase transition and synchronization [3], and collective irrational behavior [4]. A very broad range of complex adaptive system has been studied, from abstract ones such as universal behavior of collective [5], behavior epidemic [6], dynamics of collective behavior [7], the emergence of macro behavior due to micro-interaction [8]-[9] to physical system such as species evolution [7] and stock market [5]. However, what these studies all have in common is that ones cannot explain their detailed structure and property exactly from a mathematical viewpoint because of the complexity, which keep us from seeing the law of certain objects.

In fact, the complexity of social system comes from the nonlinear interaction between individuals, which makes many scientists confused about discovering the law when faced this complexity. Interaction between individuals could make system emergence, which produces different behaviors[8]. These behaviors change dynamically, from micro-scope, the structure and behavior of collectives change constantly from one state to the next one However, from macro-scope, the statistical property of collective structure and behavior are stable [10]. Furthermore, system functions are limited by its structure and environment, and vice versa. There are always several observable factors affecting them, in turn, system structure and

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environment are limited by system function, which makes a bidirectional relationship between system and environment [11]. More importantly, environment would affect the state and property of the system [12][14], and vice versa [15], which produces closed-loop feedback such that the system becomes more complex.

Scientists have studied this interesting problem in several decades, however, there have not been a universal conclusion due to the complexity with close-loop feedback. Although it is too complex to draw a conclusion, reductionism scientists always simplify it to one and one certain solvable problems, such as rumors spreading [16], tax evasion, traffic [17][19] and so on. While considering a certain question, a corresponding Multi-Agent model is usually constructed after analyzing the property, function and environment of the system, then evolution law of different collective behavior are gotten by running this simulation model [20]-[23]. Unfortunately, this kind of simulation method is goal-driven, which aim is to explain how known events happened and/or developed by supervised learning, but not to find rules of several unknown laws [24]. To explore it profoundly, an exploratory computational experiment with non-supervision and reinforcement learning could be introduced to replace simulation, by which scientists could find certain profound laws from the inevitability and occasionality under certain conditions [25]. Although this research method has obtained several achievements, few universal conclusions have appeared, which leaves us an interesting question.

2 Function and Configuration of Social Complex Adaptive System

Supposed that there exists an "angel" outside of the system, the following properties would be "seen" from this social complex adaptive system:

Definition 2.1 The economical and management organization is a complex adaptive system with

1. There exists more enough subsystems such that the system holds in spatial dimension
   (a) The radius is small enough from macro spatial scale such that there are more enough subsystems existing in system and interacting with each other. Meanwhile, from micro spatial scale, the radius is large enough such that there are more enough individuals existing in it and interacting with each other.
   (b) Both the number of subsystems and the relationships between them are constant, from macro spatial scale, such that the system structure and function are stable. However, individuals would waver randomly from one subsystem to another, from micro spatial scale, so that they are variable.
   (c) Non-cooperation game relying on the interaction between individuals from different subsystems and cooperation game relying on the interaction between individuals in same subsystem coexist in system such that the system is so complex to analyze.
2. There exists more enough time-intervals such that the system holds in time dimension
   (a) The scale is small enough, from macro time scale, such that there is more enough time making the system evolve, and then diverse collective behaviors with corresponding interesting evolutionary law emerged. Meanwhile, the interval is large enough, from micro time scale, such that there is more enough time making individuals adjust their strategies and making the strategies shift from quantitative changes to qualitative changes.
   (b) In small time-scale, individuals improve their own strategies by updating corresponding parameters (e.g. cooperative or non-cooperative game) in the process of interaction with others to assure its payoff optimized, furthermore, they can not only update resource structure but

also revise properties of control variables in different scenarios of stochastic differential game, stochastic quantum game or stochastic continuous game. Among the series of time-scales, individuals choose more appropriate players and obtain more bountiful payoff from the interaction. Individuals adjust their local configuration according to the mechanism of preferential attachment and strategies of learning, copying and crossover-mutation when interact with others.

(c) Individuals could adjust their own strategies by adjusting local configuration adaptively in large time-scale. In arbitrary time-scale, system structure is stable and the interaction between individuals is cooperative or non-cooperative game before the system is in close proximity to criticality. The structure would be shifted even if some insignificant factors change (i.e., individual behavior, environment), which leads to system structure changed to another certain one and then individuals interact with others.

3. Diverse properties of individuals are considered. The properties of individuals are various and stochastically correlative, which reflects individuals' non-complete rationality.

4. Diverse intelligence of individuals is considered. The time-varying structure of memory length of individuals is permitted, which means certain individual could remember certain historical events with states and properties.

In general, the diversity reflected in the individual interaction process makes arbitrary individual's property transform among known property sets [26]. Furthermore, the diversity and randomness come from two aspects of individual's behavior, where one is the interaction category and the other is the preferential attachment selected in game. Interaction categories consist of differential stochastic game, stochastic adaptive game and stochastic quantum game, each of which concerning one kind of decision-maker. Preferential attachment could be driven by different mechanisms, such as individual's degree, strength, and payoff. Each mechanism describes a certain kind of individual. Suppose that several categories of interaction between individuals coexist in small time-scale, and each interactive way relys on probability. Similarly, suppose that different preferential attachment mechanisms coexist in system in large time-scale, and each mechanism relys on probability. These two probability vectors describe the transitory structure of individual behavior. Set $P(t)$ is the selection probability at time t. The deterministic behavior means that $P(t)$ is a constant, describing the fact that one selects a certain behavior with a fixed probability. However, the random one means $P(t)$ is a random number, describing one selects a behavior with a random probability with time-varying. The behavior selection process would be shown as Figure 1.

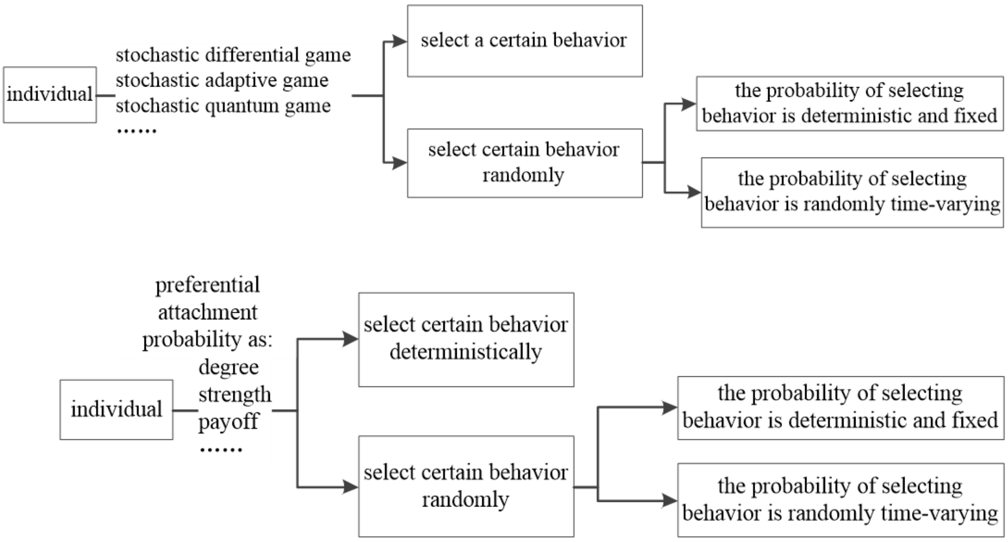


Figure 1: Diversity and randomness of individual behavior.

In fact, scientists are concerned about what properties of the system are and how the state changes, including:1. How an arbitrary individual makes decision with these complex conditions, considering not only behavior of the others and historic memories of himself but also the state of system and environment, to obtain more benefit? 2. What is the property of emergence coming from the interaction between individuals, i.e., if several kinds of collectives interact with others complying with certain rules, what properties of collective behaviors would emerge and how would collective behaviors be time-varying? 3. Could phase transition of the system state happen? if several or even few individuals change their behaviors at critical point of the system, and what would the system develop with time?

Obviously, ones could manage and control this system if these questions are resolved. Unfortunately, social phenomena are more complex by contrasting to the natural phenomena, such that scientists could not get more profound conclusion easily by using classic reductionism methods [27], therefore, a new method, exploratory computational experiment, is introduced in this paper to resolve this problem. Firstly, several basic definitions should be introduced.

3 Several Basic Definitions for Describing Irrational Behavior

3.1 Game radius

Individuals in the system interact with others directly or indirectly, which produces a directed graph as far as the relationships are considered. In fact, the gross information content of arbitrary individual getting in the process of interaction is determined by how far he can get the others' information indirectly and how many he can get the average information coming from the system. The former reflects the capability of individual sociability, which can be described by the reachability-distance of the directed graph. The maximum of reachability-distance is called game radius of a certain individual, which shown as follows:

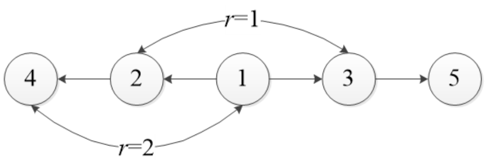


Figure 2: Game radius.

Definition 3.1. Graph $G(V, E)$ is a graph corresponding to individual interactive topological configuration, then the maximum of reachability-distance of arbitrary node $v_i \in V$ coupled with individual i, is called his game radius R_i.

Due to intelligence, autonomy and sociality, an arbitrary individual would select a fit behavior according to his property and local property such that R_i varied with time. Furthermore, each individual selects certain R_i corresponding to his personalization such that ones think these R_i satisfy a certain statistical distribution as far as individuals with the same property are considered. So, $R_i(t)$ is a stochastic process.

3.2 Memory length

Generally, arbitrary individual cannot remember all historical events, so, a parameter of memory length should be introduced to describe this irrational decision due to limited memory, shown as following Figure 3.

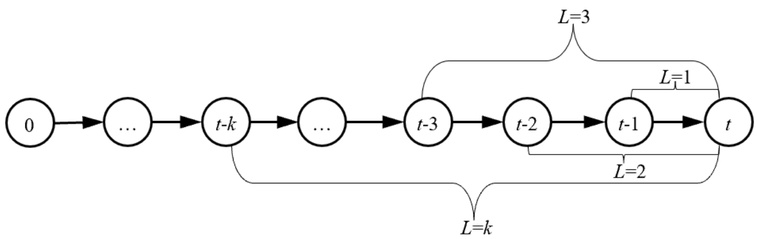


Figure 3: Memory length.

Definition 3.2. For behavior equation of individual, $x_i(t) = f(x_i(t-1), \ldots, x_i(t-k), \ldots)$, the maximum of time k that individual can be affected by historical behaviors is called memory length. Similar to game radius, $L_i(t)$ is a stochastic process.

Although there is no explicit definition, several descriptions are given to describe individual irrational behavior, such as bandwagon effect, anchoring effect, the cost of free, the chaos of social norm and market norm, calm and passion, procrastination, attachment of ownership, dilemma of multiple-choice, anticipation but not experience, price effect and honest, which relies on not only asymmetric information but also the perceptual mode of thinking. It is easy to recognize that one' s irrational behavior is the mapping of his culture consisting of not only knowledge but also decision habit and social nature. Definition 3.1 and Definition 3.2 explain the former one, then the latter one which is social nature would be defined as follows.

Definition 3.3. Set C_i is the culture of certain individual i, then $D_{ij} = ||C_i - C_j||$ is the culture distance between individual i and j, where f is the mapping from bandwagon effect, anchoring effect, the cost of free, the chaos of social norm and market norm, calm and passion, procrastination, attachment of ownership, dilemma of multiple choice, anticipation but not experience, price effect and selective honest to irrational behavior. $|| \cdot ||$ is the norm of C.

It is concluded that the larger D_{ij}, the more difference of the behavior, and vice versa. Ones can easy to see that culture distance is a stochastic process.

In fact, collective irrational behavior is produced by individual interaction. In this process, arbitrary individual firstly selects anther one as the interactive object then interacts with him for some time. If the benefit received is equal or larger than one expected, he would insist that the partner is a right one. Otherwise, he must abandon the individual selected. He perhaps learns the knowledge selectively from this interaction process, then revises and improves his behavior due to what he has learned. In this interaction process, a selective behavior with probability called preferential attachment mechanism which reflects individual' s preference behavior is defined as follows.

Definition 3.4. Preferential attachment probability $\Pi_{ij}(t)$ is a time-varying function of interest, where interest consists of economic benefit B_E and social behalf B_S, then $\Pi_{ij}(t)$ satisfies $\Pi_{ij}(t) = f(B_E, B_S)$, where economic benefit B_E is the interest from market norm, which describes how much he obtains from business. The behalf B_S means that his payoff coming from the social relationship. N_i is the set of Agent i and its neighbors, $j \in N_i$.

Obviously, $\Pi_{ij}(t)$, describing the probability that individual i selects j to play with, is a stochastic process. The forthcoming interactions of selecting, learning, copying, revising and innovating rely on $\Pi_{ij}(t)$ [28].

4 Several perhaps important conjectures

Setting the individuals' interaction to be a mixed game of stochastic differential game, stochastic quantum game and stochastic adaptive game, the collective behavior coming from emergence of complex adaptive system would be explained by following seven conjectures:

Conjecture 4.1. There exists an attractor in complex adaptive system with fixed configuration such that individual behavior converges gradually to a certain optimal strategy due to individual interacting continuously.

Note that, in this case, the topological configuration of system is a constant, which means not only the system configuration and the individual' s local one are stable, but also the individual property is deterministic or stochastic stable. The latter one means that individual game radius and memory length should be constants or converge to certain small intervals. In this process, individuals change strategies frequently such that they would obtain perfect information of others, which causes system optimal strategy would converge to a fixed trajectory [29]. The trajectory is determined by system configuration, agent' s property and noise. In sum, there exists a universal expression to describe the strategy' s property, even if different games are mixed with a certain probability.

Remark 4.1.1. Because the configuration is fixed, if individuals interact with others frequently, others' strategies would be known well, so, the information is perfect and complete. In this sense, this problem is degenerated to a multi-player game whatever cooperation game or non-cooperation game is considered or both of them are considered. So, there always exists an equilibrium solution and an optimal strategy [30].

Remark 4.1.2. If the irrational behavior is introduced, there will be much more complexity. For example, emotion, experiment and preference are hardly to describe in mathematics, so, unstructured data are always be used, such as picture, text, audio, video, which can be obtained by behavioral experiment under several strict conditions.

Remark 4.1.3. In classic economics theory, there always exists an optimal strategy trajectory such that each individual maximizes his interest due to perfect information and complete information. Here, interest consists of economic benefit and social behalf. The former coming from market and the latter coming from social relationship, furthermore, the irrational behavior more dependent on social behalf.

Remark 4.1.4. Most results of General Equilibrium Theory are given under strict hypothesis of perfect information and complete information, which is equivalent to the case that individual' s game radium is infinity and individual' s memory length is infinity. However, this ideal scenario is far away from the reality. Classic results of economics should be revised to be correct if and only if the game radius and memory length are set to a real number between 0 and infinity.

Conjecture 4.2. If the optimal strategy converges to its attractor, system structure could be changed sharply even if weak disturbance of external environment happens, such that phase transition of this CAS happens, furthermore, the attractor is the threshold value of the system structure.

If the optimal strategy converges to a limit, the system would be of non-equilibrium. Generally, the old major factors could not affect the system' s state as before or no longer affect the system, but the negligible factors could. Furthermore, even weak variation of the environment and those "negligible factors" could lead to individual select new agent to interact or abandon an old one such that system configuration changes [31]. There exists a threshold uniquely relying on system configuration and individual' s property but not on individual' s behavior if the system is at this state, called asymptotic state, such that this phase transition happens with system structure changing suddenly [32]. Once system structure is changed, individuals would adjust their strategies in a relatively long time to obtain maximum profit such that the structure approaches another certain attractor.

Remark 4.2.1. The fact of "quantitative cause qualitative changes translation" should be focused on in this process. Ones' strategies firstly converge into a stable attractor, which reflects system has already adapted to the environment after a relatively large time-scale.

Remark 4.2.2. The attractor should be written to a ratio function with the distributions of profit, local configuration of arbitrary individual' s interaction, individual' s historical actions, others' behaviors within his game radius and noise.

Remark 4.2.3. The system is a closed system, i.e., there no individuals and resources enter and exit system such that the system is independent of other systems. The entropy of system would be larger and larger according to maximum entropy principle, which causes the performance of system would be decreased gradually unless unconscionable behaviors are far away from the optimal ones.

Remark 4.2.4. Because of irrational behavior, some individuals will select some strange behaviors, which makes this equilibrium state not stable.

Conjecture 4.3. There are at least two major reasons causing system structure changes, one is preferential attachment mechanism of selecting more appropriate targets, and the other is growth.

Because the system structure is stochastic dynamic and the interaction in system is more complex in each time-scale, such that the analytic process is more complex. In this sense, coarse granularity of time-scale is considered, i.e., each time interval could be "compressed " into a time point by omitting the interacting detail of the system in this time interval. Then the structure of system is changed with time if individual changes his interactive player. Ones insist that it is the preferential attachment that make individual selects more right agents to interact within his game radius and limited memory length to get more payoff no matter that cooperative game or non-cooperative game is considered. In sum, local configuration would be changed by not only creating a new link and deleting an old link but also varied with positive growth and negative growth, as mentioned in definition 1.1. Besides, because of intelligence, agent could learn the others' behavior such that individual' s ability, speed and sustainability of copying, improving, crossed copying and varying new strategy are maximized, as defined in echo model constructed by John H. Holland and improved by Xiaojing ZHENG [33].

Remark 4.3.1. Preferential attachment is an important mechanism to describe how one individual select another to interact, which describes corresponding dynamical evolution process in essence. Without loss of generality, denotes the interest with node i to j, the local configuration to i, and suppose that there are N subsystems in system, an arbitrary Agent i who is the k agent in subsystem l would select one with probability P_i respectively due to (3) -(8) from six behaviors—adjust behavior, create a new game relationship in same sub-system, create a new game relationship to another sub-system, delete old game relationship, create a game relationship with the new agent of the system, and quit from the system.

$$P_1(i,t) = f_1(I_i, C_i(t), S(t)) \tag{1}$$
$$P_2(i,t) = f_2(I_i, C_i(t), S(t)) \tag{2}$$
$$P_3(i,t) = f_3(I_i, C_i(t), S(t)) \tag{3}$$
$$P_4(i,t) = f_4(I_i, C_i(t), S(t)) \tag{4}$$
$$P_5(i,t) = f_5(I_i, C_i(t), S(t)) \tag{5}$$
$$P_6(i,t) = f_6(I_i, C_i(t), S(t)) \tag{6}$$

where $\sum_{j=1}^{6} P_j(i,t) = 1$, $S(t)$ is the corresponding strategy, ϵ is the noise of the payoff, N_i is the set of Agent i and its neighbors, $j \in N_i$, $C_i(t)$ is the corresponding payment.

Remark 4.3.2. There always several individuals like to select abnormal behavior that far away from the behaviors (3)-(8) because of irrationality, which produces diverse collectives with different behaviors. Furthermore, the dynamical collective behaviors are much more complex as the uncertainty of collective behavior structure is increased.

Remark 4.3.3. Behavior could be learned, transferred, imitated, revised and reversed in the process of their interactions. An individual could select arbitrary one with a certain probability, and this selection process is called learning in brief. Because of irrationality, individuals could select a certain learning behavior with a relatively large probability, which is called anchoring effect or preference.

Remark 4.3.4. As defined above, interest consists of two aspects: one is the benefit from market, and the other is the behalf from social. Just like the proverb of "the gentleman and and different, with SIMS with" said, the behalf from social is more important because arbitrary irrational individual always exists in certain social relationship and this social relationship must affect his decision.

Remark 4.3.5. Irrational behavior relies more on individual thought and collective culture, which can be defined by individual' s competitiveness, social competitiveness and learning capability, defined by Echo Model.

Remark 4.3.6. If and only if the market benefit and social behalf are all satisfied, the interest produced could be selected as the game object according to preferential attachment.

Remark 4.3.7. Complex adaptive system is an open one that there always is some information flowing in and out. Just as defined of Shannon' s entropy, if the entropy out of the system is positive and the one in the system is negative, system' s structure would be changed such that innovation happens; if the former is negative and the latter is positive, the system would be rigidified; if the entropy out of and in the system both are positive or negative, whether the system would be improved or not is determined by whose absolute value is larger.

Conjecture 4.4. The optimal behavior does not exist if time-scale is large, but its distribution does and uniquely exists.

It is proven right that the optimal strategy trajectory is determined by system' s structure, i.e., dynamical structure maps dynamical trajectory. The system is degenerated to a complex networks by invoking coarse-grained time-scale, where the preferential attachment is determined by the payoff attractor within corresponding small time interval. More importantly, these system optimal strategies satisfy an invariant distribution. Associated with the property of system, invariant distribution is related to system configuration, noise and individual property distribution. As defined above, individual property distribution consists of property, game radius and memory length. Furthermore, it is behavior of replication and variation that make the property of invariant distribution varied with the interactions.

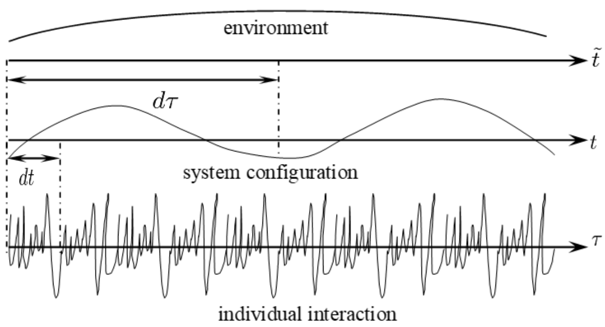
Remark 4.4.1. The optimal strategy trajectory in certain time-interval relies on its local structure, unfortunately, the local and global structure are always changed randomly according to Eq. (3)-(8), so, there must no existence of certain optimal strategy trajectory to fit for all changeable configuration.

Remark 4.4.2. It is preferential attachment mechanism that makes individual add a new player to interact and change his local configuration, which make the optimal strategy changed.

Remark 4.4.3. System configuration is always changed, which makes the configuration be a random complex networks [34] , so, the interaction in the stochastic networks is much complex than in the graph.

Remark 4.4.4. Although the configuration is time-varying, it is slower changed than the interaction between individuals, and the interaction between individuals is slower changed than the environment interaction to system.

Remark 4.4.5. The evolution process could be regarded as several time intervals with certain deterministic configuration, and each scale satisfies several properties of mixing, mixing, and so on.



Conjecture 4.5. Even a few abnormal behaviors could make system behavior phase transition if the system is of criticality.

Criticality is a universal property of social system, i.e., there always exists a strange attractor pulling system approaching to its criticality endlessly. If the system is at the state, it would boom or slump sharply without warning, no matter how small disruptions happen. Furthermore, these two criticalities corresponding to boom or slump respectively are equivalent if the scenarios are the same. As studied by many scientists, it is coexistence of robustness and vulnerability in social complex adaptive system if the system is of criticality. Furthermore, criticality probability is dependent on system evolution process and noise but not on individual' s property. In the evolution process, there always exists a giant component connected such that the phase transition of social system happens. So, the rank of giant component formed in the evolutionary process is vital to find the criticality of system percolation.

Remark 4.5.1. Critical state is a non-equilibrium one.

Remark 4.5.2. Phase transition of social complex adaptive system means that there is a non-equilibrium state such that the old main influence factors of system could not determine how system develop but the old negligible could.

Remark 4.5.3. If the individual is of little irrationality and the interactive rules are relatively simple, as what many physical systems defined to be, there must be and at least one giant component with rank $N_g > N \cdot p_c$ in the system if the system is critical such that system works as usual, where p_c is probability of propagating information or behavior intentionally. N is the population number.

Remark 4.5.4. The percolation of two-dimensional system, in fact, is a symmetric problem between growth and decay.

Remark 4.5.5. No matter how random the behavior of individual is introduced, the approximate solution of critical point could be gotten by introducing Ising model or Vicsek model if system dimension is higher than three [35] .

Remark 4.5.6. Suppose that there exist several kinds of collective behaviors, once the system is critical, it is not always true that mainstream behavior could dominate the system behavior, in fact, behavior of the minority would dominate the system if environment changes negligibly.

Conjecture 4.6. There must exist a universal law, if individual behavior is diverse, random and intelligent by selecting adaptive strategy, no matter which of small time-scale and large one is selected.

A universal conclusion is a unique existence if individual various behaviors are deterministic. If time-scale is small, different behaviors, such as stochastic differential game, stochastic quantum game, stochastic adaptive game, are selected with certain probabilities although both individuals and their behavior are uncertain. If time-scale is large, the preferential attachment probability that individual selects a fit player is a stable number. Furthermore, behavior, noise and system configuration impact significantly on the conclusions.

On the contrary, there would exist a weak solution if the individual various behaviors are random. A hybrid behavior with a stochastic probability from stochastic differential game, stochastic quantum game and stochastic adaptive game is introduced, if the small time-scale is considered. Similar, the preferential attachment is defined to be changed randomly if large time-scale is focused on. In fact, this kind of random change is reflected in the selection probability. Ones call this system is a deterministic one if it is a fixed real number between 0 and 1, otherwise, call this system is a stochastic one if it is a random one. In this case, behavior parameters, noise and system configuration are important to the conclusion, as well as the properties of corresponding probabilities.

Remark 4.6.1. If different behaviors co-exist but the selective probability is deterministic, system behaviors satisfy an invariant distribution.

Remark 4.6.2. In a sense, different games reflect different kind of behaviors, for example, differential game means that individual pursue to his benefit in a relatively large time-interval, but adaptive game means that he interacts with other for transitory payoff, and so on. In fact, each individual would select a reasonable strategy by making decision, which describes his behavior preference.

Remark 4.6.3. More importantly, if social norm and market norm are all considered, and different games mentioned above would be focused on, no matter whether a certain individual makes decision by selecting a fit strategy from game categories or selecting a fit player according to preferential attachment, there must be a universal conclusion in a relatively large time interval to explain facts.

Remark 4.6.4. As many scenarios as possible should be concerned, which not only mean that all individual structure, interaction and preferential attachment mechanisms, but also means that all noises perhaps occurs, .

Remark 4.6.5. There exists a universal conclusion for collective behavior state and evolution if and only if time and space tend to infinite.

Conjecture 4.7. The conclusions above are affected significantly by the size of time-scale and space-scale.

This conjecture means the conclusions proposed above are dependent on the dimension of time and space. Moreover, if the system is multi-hierarchical in time dimension and space dimension, the hierarchy number has significant effect on the results. Furthermore, once the dimension of system is larger than a certain number, ones cannot find the solution.

Remark 4.7.1. Granularity of time, space and function is what we should focus on, if corresponding coarse-grained data is introduced, the results would always overlook some details; however, if fine-grained data is invoked, the system would become more complex such that the corresponding model is of no solution under current methods.

Remark 4.7.2. The conjectures from Conjecture 1 to 6 all rely on system structure as well as time. Furthermore, if the dimension number is too large such that it exceeds the threshold of calculation, there is no solution for this question.

Remark 4.7.3. The level number of coarse-abstracted can be a continuous variable, which can be divided into several intervals. In a certain interval, there is a deterministic and universal conclusion to explain corresponding phenomena. However, the conclusion is closely related to representation as well as parameters and level number interval.

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