

A novel simulation framework for crowd co-evolutions

Framework for crowd co-evolutions

Kun Wang and Hongbo Sun

School of Computer and Control Engineering, Yantai University, Yantai, China

245

Abstract

Purpose – Evolution can be easily observed in nature world, and this phenomenon is a research hotspot no matter in natural science or social science. In crowd science and technology, evolutionary phenomenon exists also among many agents in crowd network systems. This kind of phenomenon is named as crowd co-evolutionary, which cannot be easily studied by most existing methods for its nonlinearity. This paper aims to propose a novel simulation framework for co-evolution to discover improvements and behaviors of intelligent agents in crowd network systems.

Design/methodology/approach – This paper introduces a novel simulation framework for crowd co-evolutions. There are three roles and one scene in the crowd. The scene represented by a band-right to a ringless diagram. The three roles are unit, advisor and monitor. Units find path in the scene. Advisors give advice to units. Monitors supervise units' behavior in the scene. Building a network among these three kinds member, influencing individual relationships through information exchange, and finally enable the individual to find the optimal path in the scene.

Findings – Through this simulation framework, one can record the behavior of an individual in a group, the reasons for the individual's behavior and the changes in the relationships of others in the group that cause the individual to do so. The speed at which an individual finds the optimal path can reflect the advantages and disadvantages of the relationship change function.

Originality/value – The framework provides a new way to study the evolution of inter-individual relationships in crowd networks. This framework takes the first-person perspective of members of the crowd-sourced network as the starting point. Through this framework, the user can design relationship evolution methods and mathematical models for the members of different roles, so as to verify that the level of public intelligence of the crowd network is actually the essence of the rationality of the membership relationship.

Keywords Relationship, Crowd co-evolution, Crowd network system, Framework for crowd co-evolution

Paper type Technical paper

1. Introduction

Since Darwin proposed the theory of evolution, the word “evolution” has become familiar to the general public. With the development of science, the concept of evolution has been widely used to explain various phenomena in the natural and social sciences. No matter in natural science or social science, evolutionary phenomenon is a research hotspot. Evolution is widespread in nature. Similarly, evolutionary phenomenon also exists in intelligent agents in the crowd network system. [Chai et al. \(2017\)](#) argue that intelligent entity is connected on a

© Hongbo Sun and Kun Wang. Published in the *International Journal of Crowd Science*. Published by Emerald Publishing Limited. This article is published under the Creative Commons Attribution (CC BY 4.0) license. Anyone may reproduce, distribute, translate and create derivative works of this article (for both commercial and non-commercial purposes), subject to full attribution to the original publication and authors. The full terms of this license may be seen at <http://creativecommons.org/licenses/by/4.0/legalcode>

This work is supported by National Key R&D Program of China (Grant No. 2017YFB1400105).

Received 13 February 2020
Revised 10 March 2020
Accepted 14 March 2020



large scale by networks nowadays. These kinds of networks are called crowd networks. In this background, his team came up with crowd science and engineering and aimed to explore the activity rules and basic theory of intelligent activities in large interconnected groups.

Intelligent entities in crowd-intelligence network reflect types of collective intelligence. Similarly, collective intelligence appears in many fields such as public decisions, voting activities, social networks and crowdsourcing (Yu *et al.*, 2018). Collective intelligence related to the equality of group communication and the social perception of group rather than to the average or maximum group intelligence (Woolley *et al.*, 2010). It shows that adequate communication can improve the group's intelligence, and the premise of communication is the establishment of relations.

In real life, people can adjust their relationship with others to get along with others harmoniously. For a rational person, harmony does not mean having a good relationship with everyone but with the right people. The right person is to be able to have a positive effect on oneself or helpful person. For example, an average student wants to build a good relationship with someone who can help him achieve his best personal goal (Collie *et al.*, 2016). There is no exception for individuals in crowd network system. For an individual M in crowd network system, other individuals which have relationships with M can be regarded as M 's circumstance. M can adjust the relationship with the circumstance according to its information interaction with the circumstance actively so that it can make better use of the circumstance to make the correct decision as possible. Harmony with people around you not only leads to a comfortable social relationship but also, more importantly, is an important means to achieve your goals (orehek *et al.*, 2018).

However, the exchange of information between individuals in a group is not always beneficial. Lorenz *et al.* (2011) proved the diversity of group views decreases as groups exchange information. In another word, public opinion in social media or society has the possibility of influencing different individuals' thinking, preferences, opinions and decisions to varying degrees. If the information about a problem in the group is homogenized too quickly, the individuals in the group may not be able to find a global optimal solution for the problem, and the sum of individual benefits in the group may converge at an unsatisfactory extreme value. Therefore, for individuals in a group, how to deal with the influence of information of other individuals on themselves is a very important problem. A person who correctly processes the information he receives about a problem can certainly achieve more when confronted with the problem. In real life, one's interpersonal relationship will change for many reasons, but the most fundamental reason is the information from others (Barnlund, 2017), of course, "no information" itself is a kind of information.

We propose the following hypothesis: The relationship between intelligent individuals reflects the overall intelligence level of this crowd-intelligence network. Two crowd-intelligence networks have same individuals; more reasonable the relationship between individuals is, higher the overall intelligence level the crowd-intelligence network has. For verifying these two hypotheses, we propose using simulation to simulate activities of the intelligent individuals' in crowd network.

2. Related work

Individuals who can adapt to environment better grow up always. This criterion is regarded as a norm not only in the field of biological sciences but also in the field of social sciences. Studying these questions from an evolutionary perspective has always led to new research. Economics and computer bionics derived from biology have all studied the phenomenon of evolution.

2.1 Studies in economics

The concept of evolution was first introduced into economics in 1982 (Nelson, 2009). In the same year, evolutionary game theory was created (Smith, 1982). Evolutionary equilibrium hypothesis is used by evolutionary economists to model and analyze various heterogeneous, diversified and unbalanced dynamic evolutionary processes (Nurmi and Parvinen, 2013) such as random fluctuation of voters' voting tendency and decision-making process (Boccaro, 2010); the immediate dynamic change and formation process of public opinion (Janutka and Magnuszewski, 2010); random evolutionary equilibrium between individual preferences and individual beliefs of social members (Brennan and Andrew, 2012); and random evolution process and dynamic equilibrium mechanism of network information transmission (Pohorecki *et al.*, 2012). The problem of crowd evolution is how individuals learn from their circumstance and change themselves actively to adapt their circumstance. This process is subjective. Methods of studying evolution in economics have many enlightening effects on the study of crowd evolution. But there are differences between the phenomenon of evolution and the phenomenon of crowd evolution in economics. First, in the current research on evolution in economics, the relationships between individuals are mostly game objects, and the roles of individuals are more homogeneous, lacking of more detailed role division. Second, the basis of economic evolutionary game is to make their own decisions based on the prediction of each other's decisions. There is no game in crowd evolution. Last, the intelligence of crowd intelligence network is reflected in the relationship between these individuals, which is different from general evolutionary economics.

2.2 Studies in computer bionics

Evolutionary algorithm is a kind of heuristic algorithm based on ecology. In the case of genetic algorithms (Holland, 1962), solutions of a problem are regarded as chromosomes. Weeding out bad chromosomes and increasing the better repeatedly, at last selecting the best one as the optimal solution of the problem. Heuristic algorithms are often used to solve NP-hard problems such as traveling salesman problem (Grefenstette *et al.*, 1985). In crowd evolution, individuals will actively change to adapt to the environment, and they could neither be deleted nor born into memory. Similarly, the concept of evolution in ecology is different from crowd evolution. We need to new ways to study the phenomenon.

3. Simulation framework

We proposed pattern, individuals, networks and the process of crowd evolution simulation for simulating an individual in crowd-intelligence network. Individuals involved in decision-making can only find the local optimal path in the pattern because of resource limitations or judgment limitations.

3.1 Pattern

Pattern is the mapping of a real problem. A pattern is a directed acyclic graph composed of decisions on time series. Arcs in the pattern represent behaviors which can be executed by some individuals. Arcs weights represent costs of behaviors and arcs rate mean the success rate of the behavior. Nodes in the pattern means position or results of behaviors and nodes weights means earning of behaviors. There is a global optimal path in the pattern. Due to the limitation of individual resources or individual judgment, individuals involved in decision-making can only find the local optimal path in the pattern.

As Figure 1, there are three types of nodes in the pattern: beginning nodes named B, intermediate nodes named p and ending node named E. The weight on nodes represent the revenue, and the weights on arcs represent the costs of behavior.

3.2 Three types member

Every primitive unit has its goal which comes from ending nodes in pattern (Figure 2). Primitive units have no way to traverse the pattern. They need to find path to their goals with limited visible range and suggestions from advisors who are connected with their units. It is possible for primitive unit that unit's behavior is different from unit's decision, primitive unit need monitor for monitoring its behavior. Primitive unit would compare its behavior with others who has same goal when the behavior been finished. The result of comparison would reflect on the connected relation between advisors and other primitive units.

Advisors (Figure 3) are responsible for advising primitive units who connected with themselves based on their given position in pattern. The main body of the advisor is suggestion maker and preference path in pattern. Primitive unit broadcasts its position in

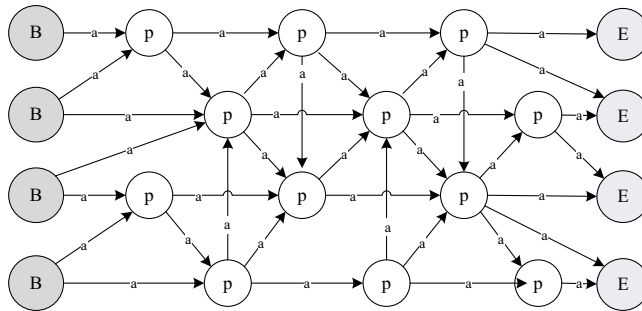


Figure 1.
A simple example of pattern

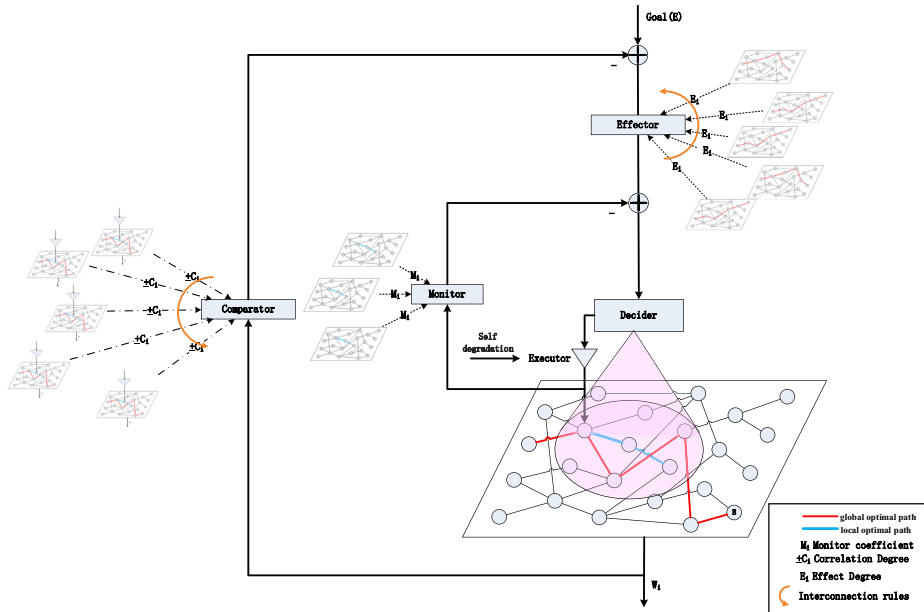


Figure 2.
Primitive unit

pattern to advisors connected with. Advisors would calculate suggestion and send it to primitive unit according to the position received from primitive unit and advisor's own preference path in pattern.

Monitors (Figure 4) are responsible for monitoring unit's consistency of its decisions and pre-actions the unit's self-degeneration occurrence leads to its decision is not consistent with the pre-action. Self-degeneration refers to the degree to which the behavior of a unit deviates toward the decision of least cost. The main body of monitor is comparator and monitoring strength distributor. Monitor dynamically adjusts the external monitoring intensity applied to the unit by comparing the difference between the unit's decision and pre-action.

Advisor and monitor have their upper limit (Figure 5). Advisor's upper limit means its sum of suggestion degree. The stronger the suggestion, the more likely the unit is to adopt its own suggestion and so is monitor, and the greater the degree of monitoring, the more possible the unit is to correct pre-action into the original decision.

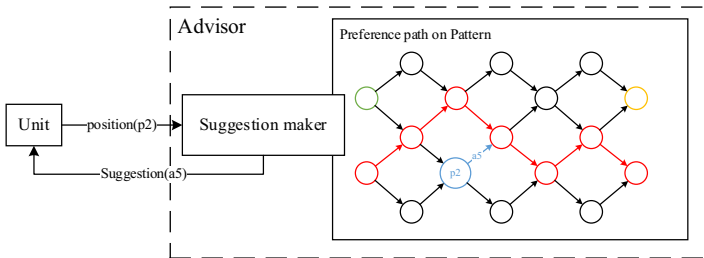


Figure 3. The detail of a unit's advisor

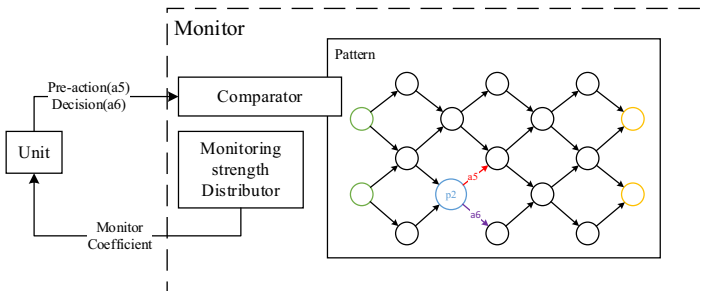


Figure 4. The detail of a unit's monitor

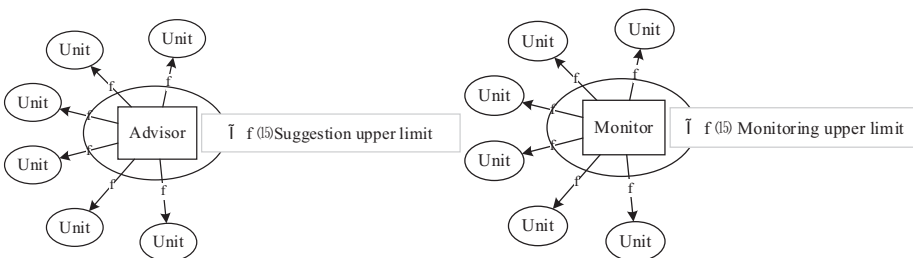


Figure 5. An advisor's and monitor's upper limit

3.3 Networks

There are three networks between primitive units, advisors and monitors: unit-advisor network, unit-monitor network and units network. There is no connection between advisors, monitors or between advisors and monitors. Unit-advisor network is similar to unit-monitor network as shown in Figure 6; their mathematical nature both are a subset of the Cartesian product of all units and all advisors or monitors. Unit network is similar to some traditional networks like little world network. The relationship between units is mutual, and there is no monomial relationship (Figure 7).

3.4 The process of co-crowd simulation

The simulation process of crowd-intelligence network crowd-evolution phenomenon is based on people's practices when facing problems or making choices in general reality. For a primitive unit, the actions of the round in the simulation include the following:

3.4.1 *Broadcasting.* The primitive unit will broadcast its position in the pattern to the advisor through the unit's effector, so that the advisor knows the position of the primitive unit.

3.4.2 *Receiving suggestions and make decision.* These two steps both can be executed in parallel. The primitive unit broadcasts its position in the pattern to the advisor and waits for the advisor's advice information. Meanwhile, the primitive unit makes its decision in the pattern according to its own field of vision and preference.

3.4.3 *Choosing suggestion or decision.* After obtaining the advice and decision, the primitive unit will evaluate each suggestion and decision according to its own confidence level and the influence coefficient of each advisor, and finally choose the most suitable decision or suggestion to implement.

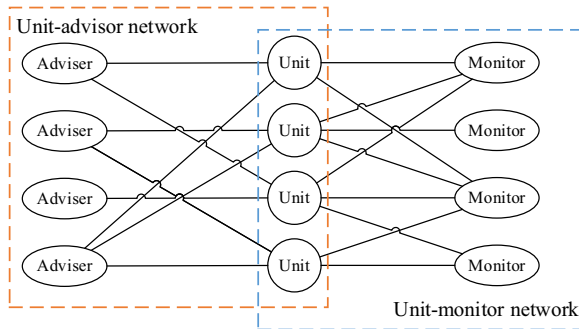


Figure 6.
A network between units and advisors and monitors

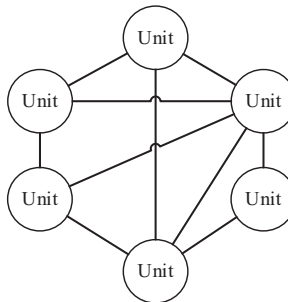


Figure 7.
A unit's little world network

3.4.4 Execution. After confirmed the decision, primitive unit will execute this decision, decision execution would consume primitive unit's resources. Therefore, before implementation, primitive unit shall compare the subjective cost of the decision the lowest cost in the current situation according to its own self-discipline level and self-degradation coefficient. In the process of comparison, the monitor will apply the monitoring intensity between it and the primitive unit to the process of execution, ensuring that the unit will not be affected by its own self-degradation and perform the behavior that is not its own decision by using external force. After the execution, the primitive unit will send a completion signal to all monitors, advisors and other units that have connection relationship with itself, including the decision of execution and the result of execution.

3.4.5 Record. After the execution, the primitive unit will record the cost and harvest of this execution, and then compare the cost and harvest of other primitive units through the connector after recording the sum, and update the connection weight between ontology and other simulation units through the comparison results.

After the a round, the primitive unit will judge whether the current position is a termination node, if not, judge whether the resources owned by the unit can have new action, if not, terminate the simulation process of the unit and record the exhaustion of resources of the unit; continue to simulate if the current position has new action. If the current position is a termination node, then judge whether the current position is the target position; if yes, then the primitive unit's simulation is successful; otherwise, the simulation fails. The flow chart of the simulation process is shown in [Figure 8](#).

4. Iterative advance method

The structure of the connections between members, that is, the network, does not change, but the weight of the connection relationship between members will change. The changing

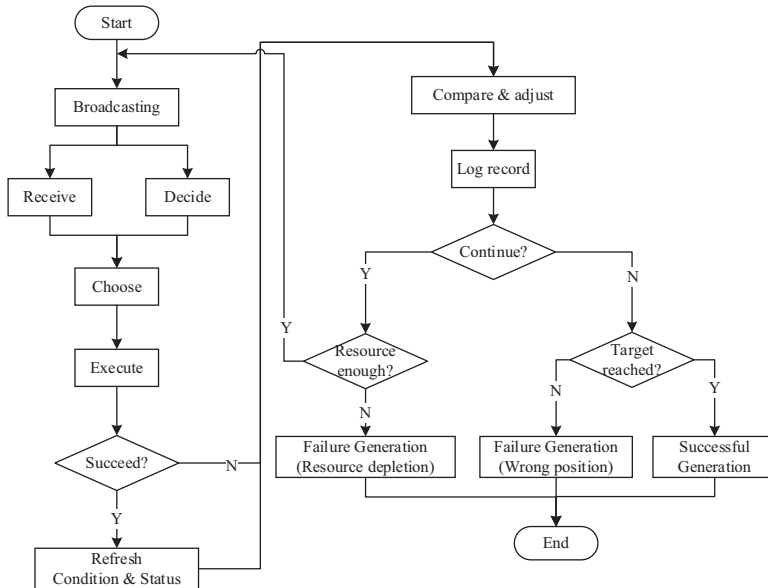


Figure 8. one primitive unit's simulate process in someone's generation

rule of the weight of connection relation between members is based on the old weight and the result of the previous generation.

$$e_{i,j} = (1 - \alpha) \times e_{i,j-1} + \alpha \times IF_{i,j-1} \quad (1)$$

For one primitive unit named U , according to [equation \(1\)](#), influence coefficient e of the advisor i in the generation j can be calculated. Coefficient α is the weight adjustment factor, the value range is $(0, 1)$. It is used to adjust the proportion of the old weight and the previous generation of simulation information in the next generation. IF is the impact factor between primitive unit U and advisor i in generation $j - 1$. The method for calculating IF is not unique, it needs to be defined by user. In generation $j - 1$, all the data between U and i can be used as a raw material for the method.

$$f_j = (1 - \alpha) \times f_{j-1} + \alpha \times IF_{j-1} \quad (2)$$

Primitive unit U has two basic attributes, namely, visual size and confidence coefficient. Visual size is used to simulate a person's vision on the pattern and limit the message from the pattern. Confidence coefficient represents the degree of trust in one's own decisions. It is similar to influence coefficient e in [equation \(1\)](#), the formula used to calculate confidence coefficient is shown in [equation \(2\)](#). In generation j , confidence coefficient f is calculate in the same way as influence coefficient.

How does primitive unit U make decision on pattern? There is no rigid formula to use. Primitive unit U 's method of decision-making is implemented through an external interface. All attributes of primitive unit U can be used in external method.

Primitive unit U has two attributes named self-discipline coefficient and self-degeneration coefficient. These two attributes are used to say primitive unit U degree of compliance with decision. These decisions are selected from U 's advisors' suggestions and the decision made by U . The formula of selection is shown in [equation \(3\)](#). It means that choosing the max of benefits function R on the pattern times influence coefficient or confidence coefficient.

$$d_j = \max \left(\max_{0 < i < n} (e_{i,j}) \times R(\text{sug}_{i,j}), f_j \times R(\text{sug}_j) \right) \quad (3)$$

Then we need to calculate the execution according to [equations \(4\) and \(5\)](#). In [equation \(4\)](#), M means self-discipline coefficient. Function *first* means get the first step. r_1 can be understood as the appeal of d_j . In [equation \(5\)](#), M_0 means self-degeneration coefficient, M_m is external monitoring coefficient from one monitor connected by U . Function W is the cost of one decision on pattern. *now* is the set of all decisions can be made in U 's current position on the pattern. Comparing r_1 with r_0 , if r_1 is higher than r_0 or is equal to r_0 , U would execute the first step of d_j , on the contrary, U would execute one step which have the lowest weight in U 's current position on the pattern, while r_0 is higher than r_1 .

$$r_1 = M \times R(\text{first}(d_j)) \quad (4)$$

$$r_0 = \left(M_0 - \sum M_m \right) \times R(\min(W(\text{first}(\text{now})))) \quad (5)$$

All the primitive units have an attribute named resource. For primitive unit U , execution will consume its resource by weight of arcs on pattern and increase its resource by weight of positions on pattern. At the end of execution, all primitive units arrive at the end of pattern. They exchange their message of execution in last generation across unit's network.

According to these messages, primitive units change their connected weight among them. The way of change weight is also implemented through an external interface as one unit's method of decision.

5. Conclusion

To simulate individual evolution in crowd network, this paper proposes three individual models to simulate individuals and clarifies the network connection relationship among these three individual models. We map real problems to patterns, the decision-making and behavior of individuals in the crowd-intelligence network facing the real problems are represented by solving the path-finding problem in the pattern. Individual decisions are made by themselves and advices given by advisors. Monitors are in charge of individual decision-making instability, helping individuals behaving as their decisions. We can be quickly obtained to get the description file of the simulation process through pre-defined simulation template, a large number of simulation individuals, a large number of individual networks and existing policies and strategies, and the simulation process can be reproduced by description file. The innovation of this paper is to propose that the change of individual relationship in crowd-intelligence network is the embodiment of intelligence in crowd-intelligence network and to design a simulation scheme for this idea.

References

- Barnlund, D.C. (2017), "Communication: the context of change", *Communication Theory*, Routledge, pp. 6-26.
- Boccaro, N. (2010), "Voters' fickleness: a mathematical model", *International Journal of Modern Physics C*, Vol. 21 No. 2, pp. 149-158.
- Brennan, T.J. and Andrew, W.L. (2012), "An evolutionary model of preferences and beliefs", working paper, Sloan School of Management, MIT.
- Chai, Y., Miao, C., Sun, B., Zheng, Y. and Li, Q. (2017), "Crowd science and engineering: concept and research framework", *International Journal of Crowd Science*, Vol. 1 No. 1, pp. 2-8.
- Collie, R.J., Martin, A.J., Papworth, B. and Ginns, P. (2016), "Students' interpersonal relationships, personal best (PB) goals, and academic engagement", *Learning and Individual Differences*, Vol. 45, pp. 65-76.
- Grefenstette, J., Gopal, R., Rosmaita, B. and Van Gucht, D. (1985), "Genetic algorithms for the traveling salesman problem", *Proceedings of the First International Conference on Genetic Algorithms and Their Applications*, Vol. 160 No. 168, pp. 160-168.
- Holland, J.H. (1962), *Concerning Efficient Adaptive Systems, Self organizing Systems*, Spartan Books, Washington, DC, p. 230.
- Janutka, A. and Magnuszewski, P. (2010), "Opinion-structure changes in non-equilibrium model of social impact", *Complexity*, Vol. 15 No. 6, pp. 27-33.
- Lorenz, J., Rauhut, H., Schweitzer, F. and Helbing, D. (2011), "How social influence can undermine the wisdom of crowd effect", *Proceedings of the National Academy of Sciences of Sciences*, Vol. 108 No. 22, pp. 9020-9025.
- Nelson, R.R. (2009), *An Evolutionary Theory of Economic Change*, Harvard University Press.
- Nurmi, T. and Parvinen, K. (2013), "Evolution of specialization under non-equilibrium population dynamics", *Journal of Theoretical Biology*, Vol. 321, pp. 63-77.
- Orehek, E., Forest, A.L. and Barbaro, N. (2018), "A people-as-means approach to interpersonal relationships", *Perspectives on Psychological Science*, Vol. 13 No. 3, pp. 373-389.

- Pohorecki, P. Sienkiewicz, J. Mitrovic, M. Paltoglou, G. and Holyst, J.A. (2012), "Statistical analysis of emotions and opinions at digg website", arXiv preprint arXiv:1201.5484.
- Smith, J.M. (1982), *Evolution and the Theory of Games*, Cambridge University Press.
- Woolley, A.W., Chabris, C.F., Pentland, A., Hashmi, N. and Malone, T.W. (2010), "Evidence for a collective intelligence factor in the performance of human groups", *Science*, Vol. 330 No. 6004, pp. 686-688.
- Yu, C., Chai, Y. and Liu, Y. (2018), "Literature review on collective intelligence: a crowd science perspective", *International Journal of Crowd Science*, Vol. 2 No. 1, pp. 64-73, doi:[10.1108/IJCS-08-2017-0013](https://doi.org/10.1108/IJCS-08-2017-0013).

Corresponding author

Hongbo Sun can be contacted at: hsun@ytu.edu.cn