A new simulation framework for crowd collaborations

Rui Yang and Hongbo Sun
School of Computer and Control Engineering, Yantai University, Yantai, China

Received 25 February 2020
Revised 16 May 2020
Accepted 17 May 2020

Abstract

Purpose – Collaboration is a common phenomenon in human society. The best way of collaborations can make the group achieve the best interests. Because of the low cost and high repeatability of simulation, it is a good method to explore the best way of collaborations by means of simulation. The traditional simulation is difficult to adapt to the crowd intelligence network simulation, so the crowd collaborations simulation is proposed.

Design/methodology/approach – In this paper, the atomic swarm intelligence unit and collective swarm intelligence unit are proposed to represent the behavior of individuals and groups in physical space and the interaction between them.

Findings – To explore the best collaboration mode of the group, a framework of crowd collaborations simulation is proposed, which decomposes the big goal into the small goals by constructing the cooperation chain and analyzes the cooperation results and feeds them back to the next simulation.

Originality/value – Two kinds of swarm intelligence units are used to represent the simulated individuals in the group, and the pattern is used to represent individual behavior. It is suitable for the simulation of collaboration problems in various types and situations.

Keywords Simulation, Cooperation chain, Crowd collaborations, Swarm intelligence unit

Paper type Technical paper

1. Introduction

As human beings enter the network era, big data and artificial intelligence continue to improve the intelligence of people, machines and objects. Internet, internet of things and cloud computing continue to enhance the depth, breadth and mode of connection between human, enterprise, government and other institutions, intelligent robots and intelligent objects. The phenomenon of wisdom is more extensive and complex. The physical space of natural people, enterprises, governments, intelligent equipment and goods is becoming more and more intelligent. The depth, breadth and way of connection between these many intelligent agents are constantly expanding, forming a large number of crowd network systems (Chai *et al.*, 2017; such as e-commerce platform, networked manufacturing supply chain, Wikipedia, online election, etc.). The crowd network is the idea of the intelligent agent and its consciousness space in the physical space, which is mapped to the intelligent agents in the information space and the intelligent agents form the crowd network through interconnection (Ikediego *et al.*, 2018).

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

International Journal of Crowd Science
Vol. 5 No. 1, 2021
pp. 2-16
Emerald Publishing Limited
2398-7294
DOI 10.1108/IJCS-02-2020-0006

The crowd network has the characteristics of deep integration of physical space, consciousness space and information space. The deep integration of three elements creates a new generation of the social model and promotes social development. Compared with the traditional wisdom phenomenon, the wisdom phenomenon under the network environment is not only large-scale but also closely connected.

Crowd network system is the main form of the modern service industry and future economy and society. In the crowd network system, it is difficult to accomplish too complex tasks because of the limited ability of individuals. For large tasks, individuals can establish mutually beneficial and win–win relationships through cooperation, but the results are not necessarily the same due to different ways of cooperation. As the saying goes, "three bad cobblers are better than Zhuge Liang," and of course, "three monks have no water to drink". They reveal that different collaboration results may be produced under the same collaboration condition. Crowd collaborations is a new mode of collaboration. Taking a supply chain as an example, the organizer selects and organizes the supply chain according to the overall goal. Different enterprises in the supply chain play different roles in the supply chain because of different functions. Different enterprises influence and restrict each other. In the enterprise itself, there are self-degradation and other phenomena that tend to maximize the interests of the enterprise. Crowd collaborations simulation is an essential abstraction of the three-dimensional space of physics, consciousness and information. It aims to achieve more effective, more human and more sustainable economic, social and government governance activities, and to avoid possible chaos, turbulence and mutation to the greatest extent. It takes the crowd network as the research object and the means of simulation to explore the best way of collaboration for the whole group.

2. Related work

Since the 1980s, as a new field, group intelligence has attracted people's attention. Group intelligence is a kind of intelligence form based on people's observation of social creatures in nature. It has the characteristics that the wisdom emerging from groups surpasses the wisdom of individuals. Swarm intelligence originates from the research on the group behavior of social insects represented by ants and bees, and a series of swarm intelligence algorithms are proposed, such as ant colony optimization algorithm (Colorni *et al.*, 1991), ant clustering algorithm (Chu *et al.*, 2004), particle swarm optimization algorithm (Kennedy and Eberhart, 1995) and so on Zhao *et al.* (2019).

Intelligence in swarm intelligence is the macro-ordered behavior of a large number of individuals without central control. This kind of macro ordered behavior is called emergence phenomenon. Without emergence, intelligence cannot be embodied (Kennedy and Eberhart, 2001).

Swarm intelligence was first used in the description of the cellular robot system, which has the following characteristics:

- The control is distributed and there is no central control. Therefore, it can better adapt to the current network environment and has strong robustness, that is, it will not affect the group's solution to the whole problem because of the failure of one or several individuals.
- Each individual in the group can change the environment, which is a way of indirect communication between individuals. Because group intelligence can transmit information and cooperate through indirect communication, with the increase in the number of individuals, the increase in communication cost is small, so it has better expansibility.
- The ability or behavior rules of each individual in a group are very simple. So, the realization of group intelligence is more convenient and simple.

- The complex behavior of a group is the intelligence that emerges through the interaction of simple individuals. Therefore, a group has self-organization. Self-organization is a kind of dynamic mechanism, which presents the whole system by the interaction of the underlying units. The rules of interaction only depend on local information, not on the global pattern (Wang *et al.*, 2005). Self-organization is not a kind of nature that external influence exerts on the system but a kind of nature emerging from the system itself.

In the June 2006 issue of *WIRED* magazine, Jeff Howe, a reporter of *WIRED* magazine, introduced the concept of crowdsourcing for the first time. Crowdsourcing, also known as network social production, has the advantages of low cost, high efficiency and meeting the personalized needs of users. It is characterized by open production, dynamic organization structure, distribution of physical scope and autonomy of participants (Tan *et al.*, 2011). Crowdsourcing is a process of everyone's participation, joint innovation and production. In 2004, Surowiecki put forward the view that "the masses are smarter than the few." He believed that the information collected in a group is often conducive to making decisions much better than the decisions made by each member alone (Xia *et al.*, 2015).

The idea of crowdsourcing is to use the internet to gather group wisdom to solve problems. The so-called "crowdsourcing" is actually a mass contracting mode in which an organization publishes specific tasks to external audiences through a designated website, and pays agreed remuneration to the volunteer who completes the organization's tasks as required. From the perspective of contract economics, crowdsourcing is a kind of public entrustment contract that uses the wisdom, strength and resources of people outside the organization to complete specific tasks of the organization without specific contract awarding objects (Ni, 2009). The task of crowdsourcing is usually undertaken by individuals, but if it involves tasks that need to be completed by more than one person, the complex tasks need to be divided into microtasks. The platform displays the task list. Workers choose according to their interests and preferences. The platform collects workers' answers to microtasks, and finally integrates workers' answers to complete their initial tasks. To decompose complex tasks, it is necessary to combine the characteristics of tasks to build the dependency relationship between each subtask, so as to maximize the independence of each subtask (Feng *et al.*, 2015).

Since the 1990s, scholars and practitioners have been promoting the development of supply chain cooperation. Supply chain collaboration deepens supply chain management from the side. In addition to better control and management of procurement, warehousing, transportation, sales and other aspects, it also emphasizes the benefits brought by cooperation between enterprises. Because it is difficult for supply chain enterprises to coordinate with each other in information technology, operation process, competition mechanism and benefit distribution, it is very complex. In today's economic situation, every enterprise is seeking its own long-term partners. Because the supply chain involves suppliers, manufacturers, distribution centers, retailers, consumers and other business entities, as well as a series of related business activities, it presents a complex network structure (Yu *et al.*, 2009). Generally speaking, supply chain cooperation can be divided into two categories: the first is process-centered, and supply chain cooperation is regarded as a business process by which supply chain partners work for a common goal. The second is relationship-centered. Supply chain cooperation is defined as a close and long-term cooperative relationship, through which supply chain members work together to share information, resources and risks to achieve common goals (Zhang, 2015). The core of supply chain management is to optimize supply chain operations through supply chain collaboration. Supply chain collaboration means that under the guidance of common goals, two or more companies in the supply chain can achieve greater benefits than the company's individual actions by establishing long-term relationships and cooperating closely to complete the planning and implementation of the supply chain operation. When supply chain members pursue their own local interest optimization, the overall interests and objectives of the supply chain will be difficult to achieve (Xie and Zhang, 2014).

3. Simulation framework for crowd collaborations

In the traditional multi-agent simulation frame, according to the existence of management and service organizations, the group organization structure is divided into three types: distributed, centralized and hybrid. In the simulation group, each member is autonomous and independent, and they cooperate with each other to serve each other and complete a task together. Management and service organizations assign tasks to individuals. The process of task allocation is to achieve local and global goals at the same time while ensuring that the cost of execution and communication is as small as possible when the system completes a task without conflicts between individuals. Individuals have certain knowledge, intelligence, thinking ability and autonomy ability, and their behaviors include perception, thinking and action (Xie, 2005).

Different from the traditional simulation framework, there are various behaviors such as suggestion and supervision among individuals in the crowd collaboration simulation, and the behaviors of individuals have a certain willingness and tend to their own interests. Therefore, the collaborative simulation framework is more suitable for the interaction between members in the simulation process.

In the environment of industrial interconnection, because of the existence of the supply chain, the supplier may also be the demander, and the supplier may also need the semi-finished products of other suppliers. The collaborative chain is longer and the relationship is more complex. There are both rational and irrational behaviors among individuals in crowd collaborations simulation. The behaviors of individuals are constrained by each other. The number of individuals in the simulation group is very large. The traditional simulation framework is difficult to realize the crowd collaborations simulation. So, we propose a crowd collaborations simulation framework. Figure 1 shows the interaction between individuals in a group.

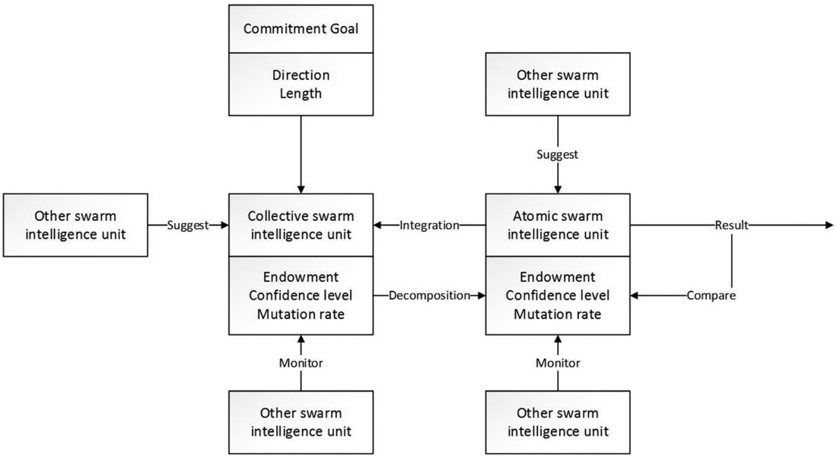

Figure 1. Simulation framework

In the crowd collaborative simulation group, we call the simulation individual as the swarm intelligence unit and set it to have two kinds of roles. One is the collective swarm intelligence unit, which is the organizer and participant of the group. It is mainly responsible for the integrator of individuals in the group, as well as the decomposition and distribution of the overall goal. The other is the atomic swarm intelligence unit, which is the participant of the group only, which is mainly responsible for the completion of the assigned sub-goals. Because of the large number of individuals participating in the simulation, and the complexity, uneven, it is difficult to use computer language to express one by one. So, we propose a general simulation model. Because the individuals in the simulation group are not independent, we add the affector, decider, monitor, executor, decompositor, integrator, comparator and other devices to the general simulation model to represent the interaction between individuals. The swarm intelligence unit itself has the attributes of self-confidence level, endowment, mutation rate and so on. Its behavior is also suggested and monitored by other swarm intelligence units. The influence coefficient and supervision strength are related to the relationship between individuals. The relationship is the degree of connection between swarm intelligence units.

Because of the uncertainty of individual behavior in nature, it is difficult to express *these behaviors*. For the generality of the crowd collaboration simulation framework, we propose the concept of pattern. The pattern is a directed acyclic graph, and the edges and points have their own weights to represent the income and consumption of behavior. In this way, the selection of individual behavior and the results of behavior can be shown on the pattern.

In the simulation, we use T (D, L) to represent the whole task. T has two attributes: direction and length. Direction represents a corresponding field and length represents consumption, which are represented by D and L, respectively. N(D) represents the requirement, and N has the direction property. $A\ (T(D_1,\ L),\ N(D_2))$ is used to represent the ability of a swarm intelligence unit. The consumption L is generated when it completes the target T in the direction of D1 and the demand in the direction of D_2 it needs.

The collective swarm intelligence unit perceives the swarm intelligence units existing in the group to decompose T (D, L), according to the capacity and quantity of the existing swarm intelligence units, and is recommended by other swarm intelligence units:

$$T(D,L) = T_1(D_1,L_1) + T_2(D_2,L_2) + T_3(D_3,L_3) .... + T_n(D_n,L_n)$$

Because of the existence of adviser, monitor and mutation rate, the results are not necessarily the same even when swarm intelligence units achieve the same goal, and because the number of individuals in the group is large and their abilities are different, there are many schemes of decomposition and distribution.

Number the scheme of decomposition and distribution. The collective swarm intelligence unit has a certain tendency to the choice of scheme, and it is also influenced by the suggestions of the advisers. The lower the confidence level of swarm intelligence units, the greater the influence of the adviser. Under the joint influence of the two, there is a certain probability for the selection of each scheme.

After multiple rounds of simulation for a scheme, the probability of selecting the scheme will decrease, and the simulation scheme will be reselected. After getting the corresponding goal, the atomic swarm intelligence unit forms a decision under the joint action of the adviser and self-confidence level and starts to implement. Because of the mutation rate and the tendency to individual interests and other factors, the implementation process cannot be fully implemented according to the established plan, and the implementation process is also monitored by other swarm intelligence unit.

We use R for the final result, G for the income and R for the ratio of income to consumption, we get the relationship:

$$R = (G_1 + G_2 + \ldots + G_n) / (L_1 + L_2 + \ldots + L_n)$$

After the task is completed, the evaluation results will affect the next round of the simulation, and the optimal solution will be obtained after the finite round of simulation. Each scheme carries out multiple rounds of simulation to get the optimal solution and finally gets the best scheme.

4. Key technologies

With the popularization and application of big data technology and intelligent technology, the natural people, enterprises, government departments and other institutions, all kinds of intelligent equipment and articles in physical space become more and more intelligent. We call these people, enterprises, institutions and articles in physical space as intelligent agents. With the help of network and data, many intelligent agents, together with their own ideas of consciousness space, can be mapped to their own images in the information space. We call the mapping of these intelligent agents as intelligent agents in the information space. The agents in these information spaces reflect the behaviors of agents in physical space and their respective psychological consciousness in real time, and realize accurate, timely and dynamic interconnection through network interconnection, intelligent search, interactive interaction, transaction matching and other operations (with the help of intelligent software algorithm), and generate various interactive behaviors. It is characterized by personalized and active consumption, centralized and direct circulation, intelligent and decentralized production, personalized and convenient life, forming networked wisdom-based economic and social form of the internet of all things, which indicates that human beings are entering the wisdom network era of wisdom interconnection.

4.1 Pattern

We use a pattern to express the behavior choice of an individual, as well as the consumption and income of behavior. The pattern is a directed acyclic graph composed of decisions on time series. Arc represents behavior, and weight on arc represents the cost of behavior; the node represents the result of behavior, and weight on the node represents the benefit of behavior. There is a global optimal path in the pattern, but because of the limitation of resources or judgment, the swarm intelligence unit itself can only find the local optimal path.

As shown in Figure 2, the initial and end states of an atomic swarm intelligence unit are represented by capital letters, and the transition from the initial state to the end state is represented by two capital letters. If there is a path between the capital letters on the left and right sides, it means that the atomic swarm intelligence unit can achieve this goal. If there are multiple paths, there are many ways to achieve this goal, and each way consumes different resources.

4.2 General model of simulation members

We use swarm intelligence units to represent the intelligent entities in the information space. Figure 1 shows the interaction between the collective swarm intelligence units, the atomic swarm intelligence units and other swarm intelligence units. In the actual group, each swarm intelligence unit has a certain relationship. The collective swarm intelligence units gather the atomic swarm intelligence units, which are connected with each other. The structure among the swarm intelligence units in the group is shown in Figure 3.

The atomic swarm intelligence unit corresponds to the atomic intelligence subject that cannot be decomposed, such as people, goods, or enterprises (when discussing as

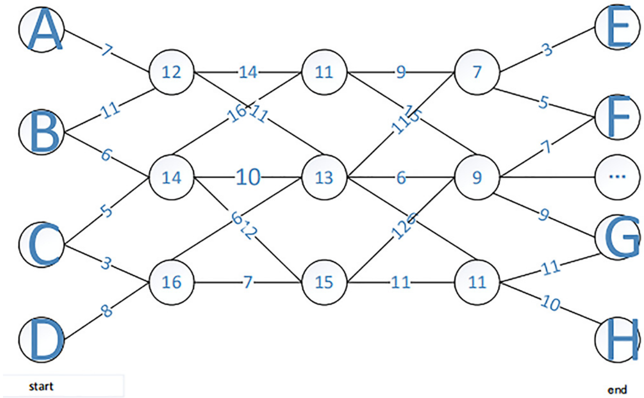

Figure 2.
Pattern

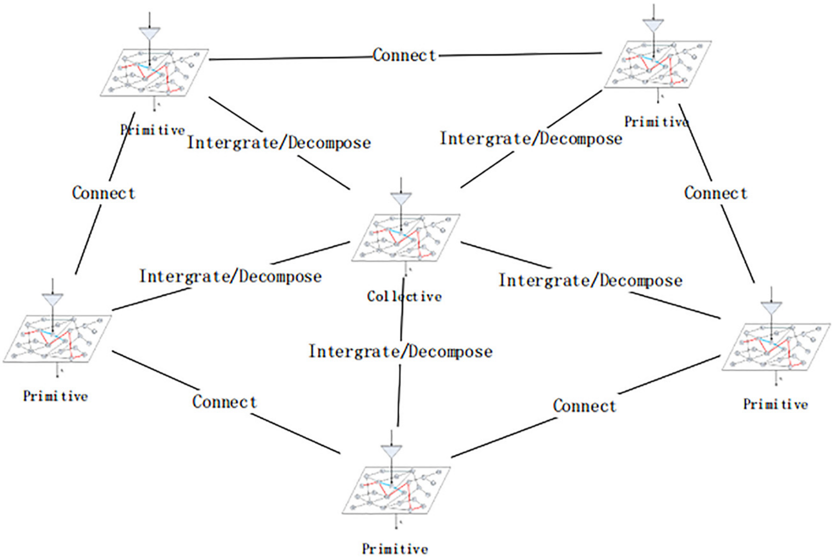

Figure 3.
Structure of swarm intelligence unit

the minimum unit). The atomic swarm intelligence unit is shown in Figure 4. The affector is influenced by several advisers. The decider and executor are the behaviors of the swarm intelligence unit. The monitor corrects the deviation, and the comparator represents the process of evaluation and learning.

As the organizer, participant, and manager of a group, the difference between collective swarm intelligence unit and atomic swarm intelligence unit lies in its unique decompositor/selector and integrator, mainly responsible for the decomposition and distribution of objectives. The collective swarm intelligence unit is shown in Figure 5.

The swarm intelligence units with various devices can fully map the behaviors of an individual in a group and the interaction between individuals.

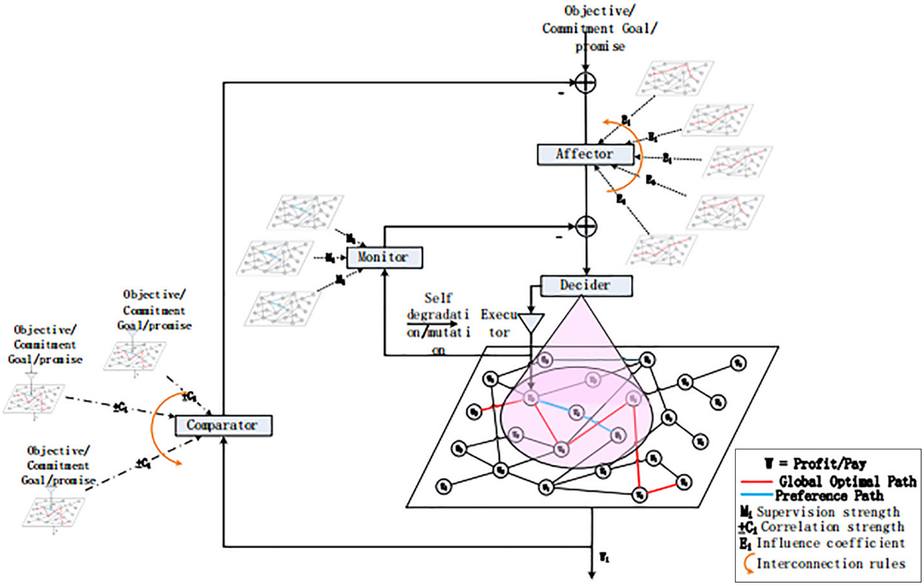

Figure 4.
Atomic swarm intelligence unit

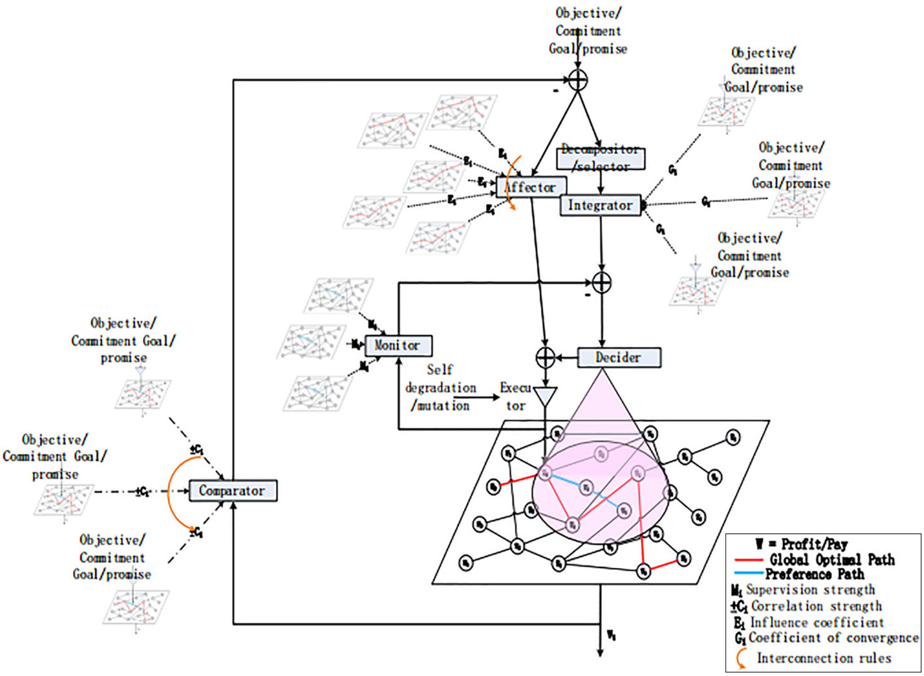

Figure 5.
Collective swarm intelligence unit

4.3 Construction of collaborative chain

Different from the traditional collaborative simulation framework, a vector represents a task. The completion of the task requires certain preconditions, which are also some vectors. The completion process of the task is to generate new vectors after several vectors complete some operations.

In a supply system, the demand side generally has a general intention, whereas the supply side is difficult to express its ability against several fixed intentions. Its ability often has strong advantages in several directions, whereas the advantages in other directions are not obvious. As shown in Figure 6, for a supplier, the cost advantage of manufacturing formed products A and B is the most obvious, but the cost of manufacturing-related products is not particularly advantageous. Of course, manufacturing completely unrelated products has almost no cost advantage. For the sake of simplification, the left figure is often simplified to the right figure.

Because of the existence of the supply chain, the seller may need to purchase semi-finished products from other suppliers at the same time. The collaboration chain is longer and the relationship is more complex. It is necessary to comprehensively consider all suppliers related to the supply chain and the collaboration system formed by supplying specific products, as shown in Figure 7.

Demand has a certain direction. A certain direction represents the demand for a field. Supply is represented by vectors. Different vectors represent the different services provided. In the collaboration system shown in Figure 7, the following relationships can be obtained:

$$n_1 + n_2 \to W, n_1 + n_3 \to W, n_1 + n_4 \to W$$
$$n_5 + n_6 \to n_3, n_{10} + n_{11} \to n_1, n_{10} + n_{12} \to n_4, n_9 \to n_2$$
$$n_{10} + n_3 \to n_4, n_7 + n_8 \to n_3$$
$$\dots$$

So many different kinds of collaborative chains can be constructed. The ultimate goal of the collaborative simulation is to explore the best collaborative chain.

5. Implementation

In crowd collaborations simulation, a certain number of swarm intelligence units are generated first, and each swarm intelligence unit is closely connected according to the

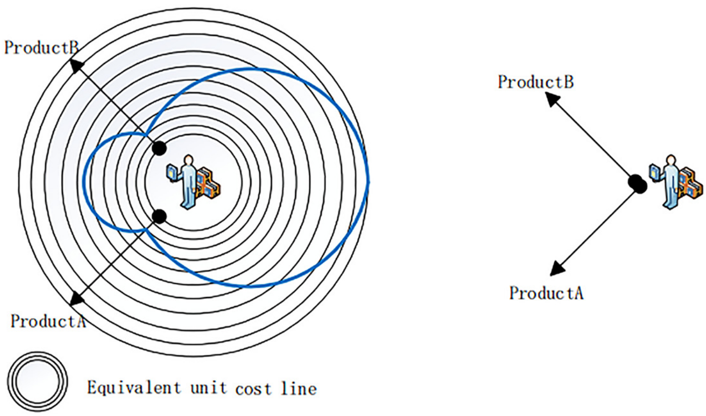

Figure 6.
Supply capacity chart

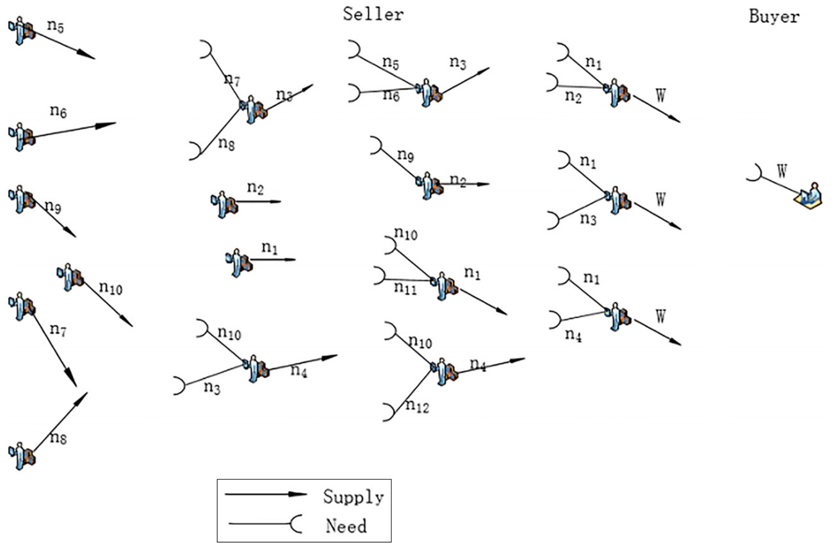

Figure 7.
Supply and demand matching chart

connection relationship to form a certain network structure. *As the organization and manager of the group, the collective swarm intelligence unit is mainly responsible for the decomposition and distribution of tasks.* Then set the overall goal, that is, the direction of demand. After the collective swarm intelligence unit obtains the overall goal, its decompositor and integrator establish multiple collaborative chains for selection according to the overall goal, the atomic swarm intelligence unit in the group and the collaborative relationship.

The collective swarm wisdom unit summarizes all the feasible cooperative chain schemes. The collective intelligence unit monitors the progress of subtasks at all times during the simulation process and summarizes the completion of subtasks. The feasible cooperative chain schemes are numbered from 1 to n. The collective swarm intelligence unit has a certain tendency to choose the cooperative chain, and the value of scheme n is an. The selection of schemes is also influenced by the adviser. The adviser has different suggestions for each scheme. If the confidence level of swarm intelligence units is C, the larger the C is, the more willing the swarm intelligence units are to believe in themselves and reduce the influence of the adviser. Set the suggestion as S, S_n (i_1, i_2... i_n) indicates the suggestion of the adviser n for each scheme, $i_n \in [0,1]$, 0 indicates no suggestion. Sum the influence coefficient of all advisers for every scheme to get In. After one round of the simulation, after comparator evaluation, it will have a certain impact on the selection of schemes. In the next round of the simulation, it will be regarded as an adviser. Set the selection of collective swarm intelligence unit as probability P, then:

$$P_n = C * a_n + I_n$$

So, there is a certain selection probability for each scheme. After the coordination chain is determined, each sub-goal will be distributed to the corresponding atomic swarm intelligence unit according to the coordination chain. After the atomic swarm intelligence unit obtains the sub-goal, because of psychological and other factors, it cannot complete the goal in strict accordance with the planned way. The process of accomplishing the goal of the swarm intelligence unit corresponds to a path in the pattern, and there can be multiple paths from the starting point to the endpoint in the pattern. Therefore, there are many ways to accomplish the goal, and the consumption and the profit of each are different.

5.1 Affector

After getting the assigned sub-goals, the atomic swarm intelligence unit plans how to complete the sub-goals, that is, to explore all feasible paths from the starting point to the endpoint in the pattern. There may be many ways for the atomic swarm intelligence unit to complete the sub-goals, but the tendency of each method is different. The advisers who are connected with the atomic swarm intelligence units will also make their own suggestions according to their own preferences. Because the relationship between the advisers and the atomic swarm intelligence units is different, the influence of their suggestions will be different.

When the simulation population is generated, a value – influence coefficient corresponding to each adviser is set. The influence coefficient is used to express the influence of the adviser on the individual.

At the beginning of the simulation, influence coefficient $I_1, I_2, I_3 \ldots I_n$ ($I \in (0, 1)$ is set to represent the influence of other multiple intelligence units and set the interconnection rules. The influence coefficient is positively correlated with the interconnection rules. The affector summarizes the suggestions of the adviser. If the suggestions are the same, the influence coefficient is added:

Algorithm 1. Suggest

```
Algorithm 1. Suggest ({Ic},{Su})
Input:    {Ic }   Influence coefficient set
          {Sa}    Suggestion of adviser list
Output:   {Ir}    Influence result list
          {S}     Suggestion list
1   foreach S1 in {Sa} do
2     foreach S2 in {S} do
        if (S1 = S2)
3         I in {Ir} + = I in {Ic} (match with S1);
        else
4         I in {Ir} = I in {Ic} (match with S1);
5     end
6   end
7   return {Ir},{S};
```

5.2 Decider

After the decider gets the suggestions from the affector, it makes a decision by considering the resource situation and ability and set the confidence level of the swarm intelligence unit as *C*, which determines whether the swarm intelligence unit is more willing to believe itself or the advisers. The swarm intelligence unit has a certain tendency to each method of achieving the goal, and under the joint action of this tendency and the suggestion of the adviser, the final plan is drawn.

Algorithm 2. Decide

```
Algorithm 2. Decide ({Ir},{S}, c, {A}, {W})
Input: {Ir}  Influence result list
       {S}  Suggestion list
       C  Confidence level
       {A}  Prefer
       {W}  Way
```

```
Output: Dr  Decided result
p, q = 0
foreach i in {Ir} do
  foreach s in {S} do
    foreach a in {A} do
      foreach w in {W} do
          p = a(match with w)*c + i(match with s, s match with w);
        if(p > q)
          q = p;
      end
    end
  end
end
return Dr(match with q);
```

5.3 Executor

The work of the executor is to walk on the pattern, indicating the behavior of the swarm intelligence unit. The executor operates according to the decision of the decider, and it will also be affected by the self-degradation phenomenon (the swarm intelligence unit always tends to degenerate in the most favorable direction for itself, which is a major aspect of the disturbance). The executor of the simulation unit has an attribute self-discipline level. The self-discipline level is the ability to execute according to its own decider and not change its own decision for short-term interests. The opposite of the self-discipline level is the degree of self-degradation.

5.4 Monitor

The monitor corrects the deviation according to the specific goal/commitment, in which the self-discipline level represents the self-correction ability of the swarm intelligence unit, whereas the interference of the monitor represents the external correction ability, and the supervision strength is determined by the correlation strength; the supervision strength is in [0, 1]. The higher the supervision strength is, the less the actuator will deviate during execution.

```
Algorithm 3. Execute and Monitor
Algorithm 3. Execute and Monitor({p}, ML, DL, Np, Dr, Ep)
Input:  {p}   Pattern
        {ML}  Monitor level
        DL    Self-discipline level
        Np    Nowpoint
        Dr    Decided result
        Ep    Executive preference
Output: R     Result
foreach Np.nextline in pattern do
  if(Np.nextline!=null)
    if (Np.nextline=Dr)
      P = Ep + Dr;
    else
      P = Ep;
end
 Np.nextline = random * P;
 R = R + Np.nextline.number − Np.number;
 Execute and Monitor({p}, ML, DL, Np, Dr, Ep);
return R;
```

In addition, set the mutation rate is M, there is a probability of random execution of M.

Completing tasks under the supervision of other swarm intelligence units is the core behavior of swarm intelligence units. For the crowd network simulation, it is a typical kind of continuous and discrete event hybrid simulation. These behaviors can be expressed in the pattern. The path from the beginning to the end of the pattern is the various behaviors of individuals in the time series.

5.5 Comparator

After arriving at the end node, it represents the end of a round of simulation. The ratio of income to expenditure is obtained, and the scheme with the highest ratio is selected to act as an adviser in the next round of simulation.

Algorithm 4. Comparator

```
Algorithm 4. Comparator(R, E)
Input:    R  Results of execute
          E  Expect
Output:   Ic  Influence coefficient
    if(R > E)
        Ic = 0.1;
    else
        Ic = −0.1;
    return Ic;
```

5.6 Next scheme

After the atomic swarm intelligence units complete their respective tasks, the collective swarm intelligence units summarize and evaluate the results. After multiple rounds of simulation, make $P_n = P_n - 0.1$ to reselect the collaborative chain for simulation, and finally get the best collaborative chain and the best solution.

5.7 Result

As shown in Figure 8, the simulation results are listed in the reverse order of revenue and show the specific participants of each collaborative chain, the tasks involved, the way to complete the tasks and the revenue. At the bottom of the results display page, we show the relationship between each individual in the form of a matrix, that is, the size of the influence intensity.

6. Conclusion

Collaboration refers to labor collaboration, in which many people work in a planned way in the same production process or in different but interrelated production processes. Collaboration refers to a means used to coordinate the relations among participants, between acts and between participants and acts to achieve the desired objectives. Collaboration can create a greater benefit than a simple sum of the benefits of a single strategic business unit, that is, to achieve synergy. The advantage of collaboration is that it can make full use of organizational resources, expand the scope of business, shorten the working time and concentrate on accomplishing tasks that are difficult for individuals in a short time. In this paper, a framework of crowd collaborations simulation is proposed, which decomposes the overall goal by building a collaborative chain, and simulates the collaborative group by using collective and

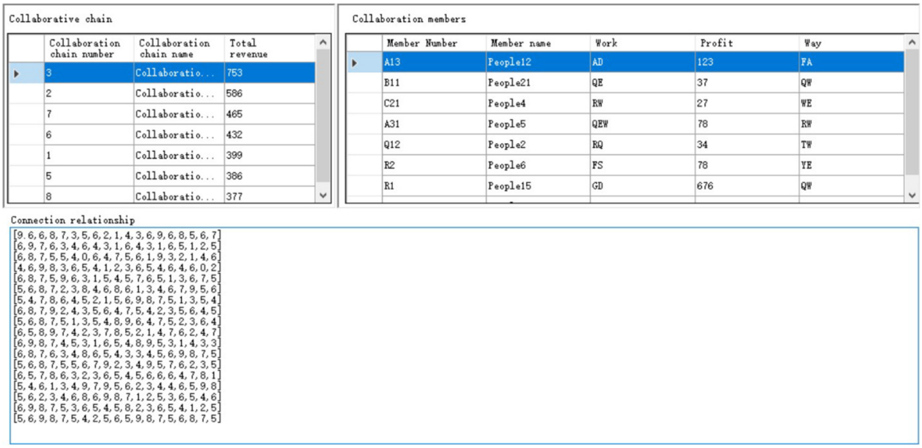

Figure 8. Simulation results

atomic swarm intelligence units, which provides a feasible method for the simulation of crowd collaborations problems.

References

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.

Chu, S.-C., Roddick, J.F. and Su, C.-J. (2004), "Constrained ant colony optimization for data clustering", *J. Artif.Intell*, pp. 534-554.

Colorni, A., Dorigo, M. and Maniezzo, V. (1991), "Distributed optimization by ant colonies", *Proceedings of ECAL91 European Conference on Artificial Life*, *Paris*, pp. 134-142.

Feng, J., Li, G. and Feng, J. (2015), "Review of crowdsourcing technology research", *Journal of Computer Science*, Vol. 38 No. 9, pp. 1713-1726.

Ikediego, H.O., İlkan, M., Abubakar, A.M. and Bekun, F.V. (2018), "Crowd-sourcing (who, why and what)", *International Journal of Crowd Science*, Vol. 2 No. 1.

Kennedy, J. and Eberhart, R.C. (1995), "Particle swarm optimization", *IEEE International Conference on Neural Network*, Vol. 4, *IEEE Service Center*, *Piscataway, NJ*, pp. 1942-1948.

Kennedy, J. and Eberhart, R.C. (2001), *Swarm Intelligence*, Academic Press.

Ni, N. (2009), "'Crowdsourcing' – a new model of enterprise HR management with the help of external forces", New Capital.

Tan, T., Cai, S. and Hu, M. (2011), "Research status of crowdsourcing abroad", *Journal of Wuhan University of Technology (Information and Management Engineering Edition)*, Vol. 2, pp. 97-100.

Wang, M., Zhu, Y. and He, X. (2005), "Review of group intelligence research", *Computer Engineering*, Vol. 22, pp. 204-206.

Xia, E., Zhao, X. and Li, S. (2015), "Current situation and trend of overseas crowdsourcing research", *Technology and Economy*, Vol. 34 No. 1, pp. 28-36.

Xie, X. (2005), *Multi Agent Interactive Cooperation Research and System Simulation*, Northwestern University of technology, pp. 10-21.

Xie, H. and Zhang, Z. (2014), "Review of supply chain collaboration research and theoretical model construction", *Journal of Shandong University of Business and Industry*, Vol. 28 No. 2, pp. 71-77.

Yu, S., Li, J. and Lv, X. (2009), “Collaborative optimization of supply chain based on simulation”, *Microcomputer Application*, Vol. 10, pp. 76-82.

Zhang, H. (2015), “Analysis of supply chain cooperation research”, *Logistics Technology*, Vol. 38 No. 3, pp. 48-49.

Zhao, J., Zhang, X., Li, J., *et al.* (2019), “Group intelligence two research review”, *Computer Engineering*, Vol. 12.

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