An evolution simulation framework for ecological structure of crowd networks

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Abstract

Purpose – This paper aims to obtain optimal specialization mode and level for complex network or system structures. In the e-commerce system, this paper studies the changes of each transaction subject in the process of ecological structure based on the income level of each transaction subject.

Design/methodology/approach – This paper aims to research the change of transaction efficiency evolution process of intermediaries. With the improvement of transaction efficiency, intermediaries interact with other transaction subjects at given modes in e-commerce systems. This paper analyzes the relationship between the factors of production and trade and explains the quantitative relationship between them in the form of mathematical modeling. An evolution simulation framework is established to elaborate the simulation process and method of crowd network in e-commerce ecosystem and then sets up the simulation experiment.

Findings – During simulation processes, the changes of data are observed and analyzed to obtain the optimal evolution paths and specialization modes. Furthermore, this paper provides solid supports for the research of the quantitative analysis of ecological structure evolutions.

Originality/value – Evolution simulation of ecological structure is first proposed in the topic of crowd network. It is with the aid of the concept of ecology, the theory and method, simulation of complex network structure and system structure. This paper analyses and researches the evolution process of optimal specialization modes and intelligent level of crowd networks with transaction efficiency changing. The ecological structure optimal evolution paths can be obtained by trend of simulations.

Keywords Crowd network, Ecological Structure, Evolution Simulation, Mathematical modeling, Evolution simulation framework

Paper type Research paper

1. Introduction

The ecological structure of crowd network refers to the specialized division and collaboration among intelligent agent on macro level, which is an organizational form of future networked industry. Ecological structure is one of the important factors that affect the efficiency of networked co-operations. In given industrial ecology, each intelligent agent continuously reconstructs its specialized division of labor and positioning according to its own state and surrounding environment, and adjusts its relationships with other intelligent agents in real time, so as to maximize its own benefits, thus causing dynamic changes in networked ecological structure (Liu and Li, 2010). According to the ecological theory, the

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concept of ecological structure of crowd network is as follows: the ecological structure of crowd network is the way of crowd unit time and space distribution, information exchange and resource utilization. It is a crowd unit structure network which can be effectively controlled and constructed. In the ecological structure of crowd network, the crowd units are independent and interrelated, and the kinds, quantities, spatial distribution and self-evolution of crowd units have different structural characteristics and functions. From the ecological point of view, crowd network is a complex network ecosystem (Tian and Zhang, 2015; Yang *et al.*, 2008) based on the correlation of crowd units. In crowd ecosystem, each unit continuously establishes or deletes associations to meet the needs of the development of ecological structure, and the relatively unsuitable association structure is gradually eliminated in the development processes. The updated association structure is conducive to the development of ecological structure.

In e-commerce, the core function of intermediaries, service providers and other circulation transaction subjects is to provide necessary transaction services, such as logistics service, payment service, and information service. These services are essential for transactions of commodities. A transaction subject selling commodities must have the transaction necessary service quantity corresponding to the quantity of commodities to complete the sale of commodities. Therefore, the transaction subject needs to make decisions about the amount of transaction necessary service. Given limited total endowment, choosing to produce more types of transaction necessary services means that the lower the output of each service, the less goods are ultimately sold. Choosing to produce fewer kinds of transaction necessary services, the higher the output of each service, the more goods will be sold in the end, but the more transaction necessary services need to be purchased, and the higher the transaction cost may be. Therefore, the core factor of whether the transaction necessary service be specialized or not is the level of transaction efficiency (Wang and Chai, 2018). The higher the transaction efficiency is, the lower the cost of transaction subjects to purchase transaction necessary services, the higher the profit of a single commodity, and the larger the sales volume, the more inclined the transaction subjects are to carry out specialized production.

Crowd network is the main mode of modern service industry and future economic society. Since it is difficult to study by observing the real world in a general way, simulation is a powerful means of research. Compared with other large-scale interactive simulation, the crowd science simulation has the characteristics of dynamic, diversification and strong participation. The study on the structure evolution of crowd network reveals the current development stage of network ecological structure, predicts the future development direction, and provides theoretical guidance for the government and enterprises to formulate development strategies. By controlling and guiding the dissemination of information in the crowd network, it can influence the behavior of each intelligent digital body, realize the controllability of the evolution process of events, and reduce the possibility of negative events or destructive revolutions. In the future, new forms of consumption, production, circulation and social life will emerge, including direct transaction of production and marketing, centralized circulation and personalized products and services. The dynamic evolution process of the specialized division of labor and cooperation among intelligent agents (Tang *et al.*, 2019).

2. Related work

In 1993, James f. Moore first proposed the concept of "business ecosystem" (Moore, 1993), which defined the business ecosystem as an economic complex and an organism of the business world based on the interaction between organizations and individuals. Later, Moore proposed that each individual within the business ecosystem gathers into a mutually supporting organization, which develops in competition and cooperation, and is dynamic and symbiotic. Moore proposed four stages of business ecosystem evolution, including birth, expansion, leadership and renewal, and analyzed the competitive strategies that should be adopted in each stage.

Moore's evolution model has typical characteristics of the general life cycle, and the method of adopting different enterprise strategies at different stages has been widely recognized, which has good practical operability. His four-phase development cycle is also frequently cited as a reference method for identifying system lifecycle and phase strategies. However, the drawback is that the model is too simple. Later, research on evolution based on niche theory gradually became a hot topic. According to Lewin, the business ecosystem consists of interconnected companies occupying different "ecological niche". The change of an enterprise's ecological niche will affect the change of other competitors and partners, and thus affect the composition of the enterprise's value chain and the evolution of the system.

In addition to ecological niche, an important Angle is to apply the system dynamics equation of ecology directly to Business systems. For example, Maure introduced the "predator-prey model" to simulate the dynamic competition process of websites to explain the winner-take-all phenomenon. Research shows that some equilibrium structure will emerge after a long period of time under certain competitive conditions.

He found that under normal conditions, when competition between sites intensifies, it suddenly turns into a "winner-takes-all" situation, in which a few sites gain almost all their users and most others become extinct.

At early stage, domestic research was mainly focused on introducing foreign research, and at the later stage, some research results were gradually obtained in combination with Chinese business practices. Scholars introduce the concept of "business ecosystem" into e-commerce and create the concept of "e-commerce ecosystem" (Jiang *et al.*, 2013). Yanping Yang analyzes the composition of e-commerce ecosystem, studied the ecological niche of different enterprises in e-commerce ecosystem, and take the e-commerce ecosystem cultivated by backbone enterprise Alibaba as an example, and concluded that coevolution is the competitive strategy of enterprises in e-commerce ecosystem. Hu *et al.* (2009) proposed the evolution path of e-commerce ecosystem by referring to Moore's four-stage evolutionary path model. They believe that the e-commerce ecosystem has also gone through four stages of development, expansion, coordination and evolution.

Shuxian Ji constructed the evolution model of individual quantity in the population of China's e-commerce ecosystem by using ecological theory and found that the evolution curve of the quantity presented an *s*-shaped Logistic curve, while the development process of China's e-commerce ecosystem is still at the top of the curve. Liu (2010) summarized several factors that affect the evolution of e-commerce ecosystem, including the diversity of the population, the rationality of e-commerce core enterprises, the layout among communities and the driving role of advanced enterprises.

3. Key technologies

3.1 Simulation model of ecological structure evolution

As shown in the Figure 1, in a community of crowd units, crowd units work in coordination with each other according to the mechanism of division and collaboration of ecological structure and evolve to their optimal specialization mode and level under the given conditions of target/commitment.

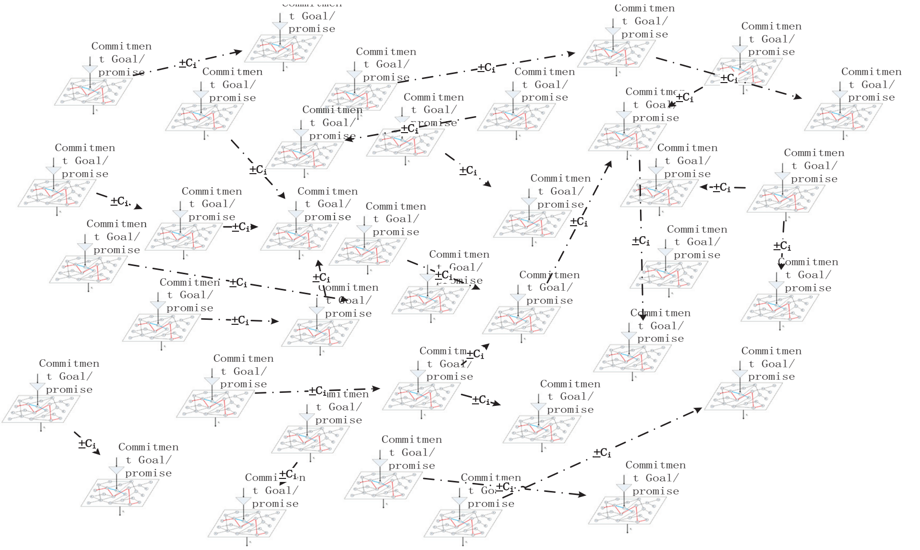

Figure 1.
Ecological structure evolution simulation model diagram

3.2 Crowd machine model

As shown in the Figure 2, an atomic swarm unit consists of pattern, affector, decider, monitor, executor and comparator whose inputs are goals or commitments and whose outputs are the results of actions.

3.3 The structure evolution of ecological in e-commerce

In the e-commerce system, with the improvement of transaction efficiency, the evolution process of intermediaries is as follows:

3.3.1 In e-commerce, each trading entity has three production and management modes to choose from. As shown in the Figure 3, trading entities in the e-commerce system have the above three production and management modes, which are as follows: there is no intermediary or service provider, manufacturers produce transaction necessary services themselves and sell goods directly to consumers; manufacturers produce goods by purchasing the services of service providers, and intermediaries resell the goods of manufacturers by purchasing the transaction necessary services of service providers; and manufacturers sell goods directly to consumers by purchasing transaction necessary services from service providers.

3.3.2 Application of crowd machine model in the structure evolution of ecological. Pattern. As shown in Figure 4, each node W_i is a certain state of a transaction subject, which contains the attributes of producer, service provider and middlemen. The three attributes of the node have the behavior of combine, split and keep. The weight of the node represents the benefit in the current state. Each path Ci represents the behavior to change this state, and the corresponding business strategy (self-production and self-sale, intermediary resale and direct sales of purchasing services for producer) also changes. The weight of the path is the price to pay for the behavior to change the current state.

This graph is a directed acyclic graph with multiple nodes at the beginning, which is artificially set to have multiple initial forms, and then evolves with the change of transaction efficiency, and finally gets the result. The red path is the global optimal path, which represents the change of the evolution mode with the highest income; the shaded area is the

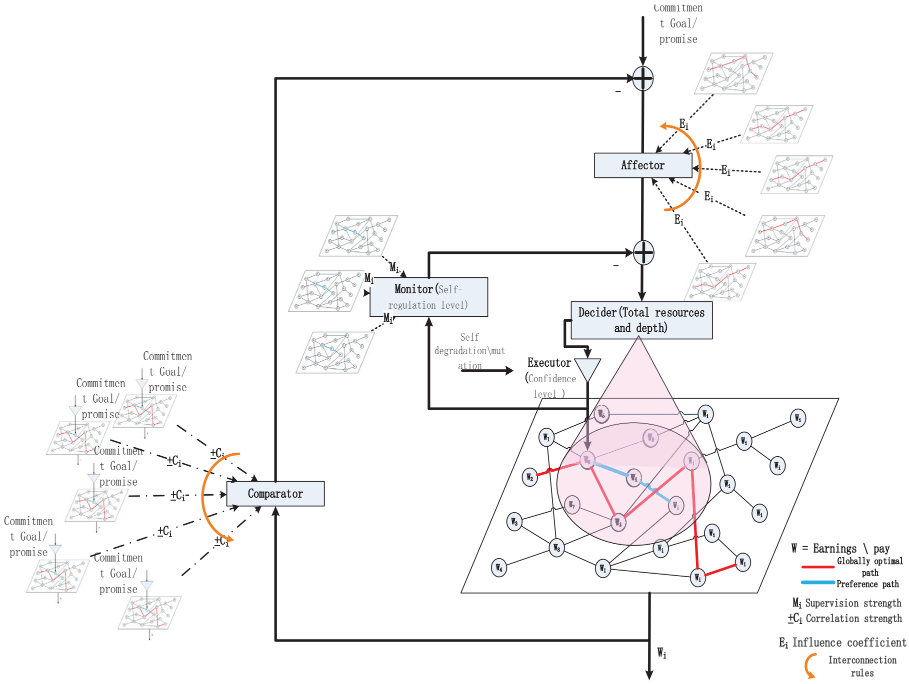

Figure 2.
Crowd machine model for atomic units

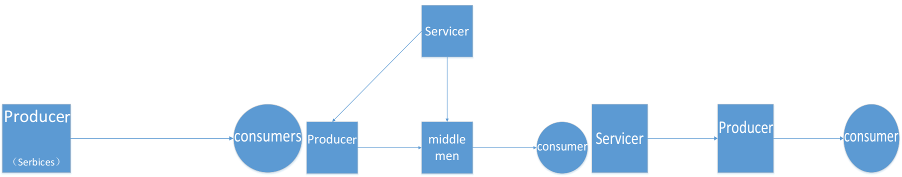

Figure 3.
Structure chart of three production and management modes

scope of view of the decider, so the green path is the judgment made by the decider when the resource and view is limited, and is the local optimal path.

Decider. Before the beginning of each round of iteration, the production and operation mode with the largest benefit is selected from three modes: self-production and self-sale, intermediary resale and direct sales of purchasing services. To make decisions on whom to trade with, on the indicators for the completion of the trade, on the allocation of labor endowments for the production of goods or transaction necessary services, based on the resource situation and capacity; make a decision for the required quantity of transaction necessary services; make decisions about whether to combine, split, or keep:

$$D^c = (\mathrm{k} * \mathrm{M}^n + (1 - \mathrm{k}) * \mathrm{I}^g) * \mathrm{t}^r * \mathrm{d}^t$$

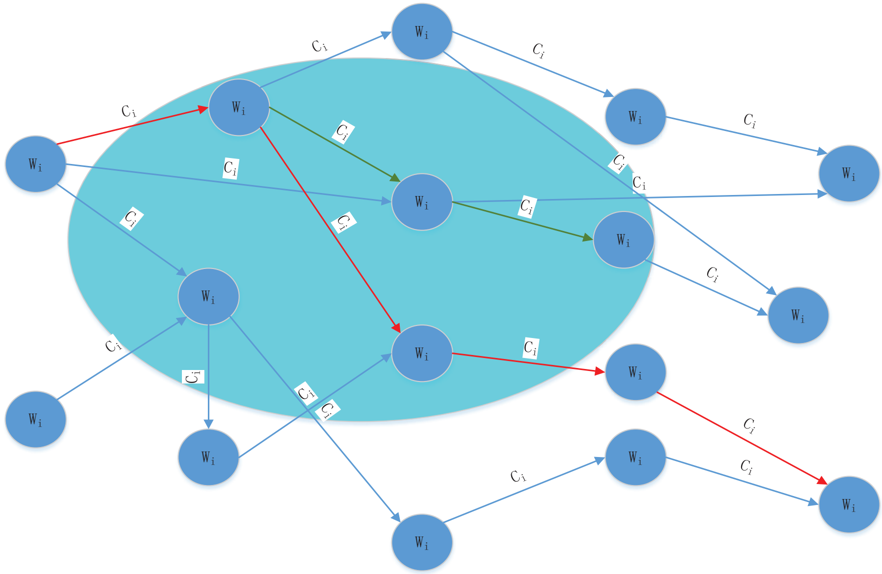

Figure 4.
Pattern

where, D^c represents the Decider, M^n represents the Monitor, I^g represents the Integrator, t^r represents the total resource, d^t represents the depth, and k represents the coefficient between the monitor and the integrator.

Affector. As shown in Figure 5, the advisor takes the suggestions of others according to his own preference and the production and management strategy designated after the previous iteration as the influencing factors; the advisor/advisee stores correlation strength.

As shown in the Figure 6, this is a 0-360 degree polar coordinate system to represent a field; Each ray is a preference (Just the vector direction) in the field; the red arrows represent the preference vector (p,α) of the crowd units; the green arrow represents the advisor's suggestion vector (a,β); The purple arrow is the projection (t,α) of the advisor's suggestion onto the crowd unit preference; $t = a * \cos(\beta - \alpha)$. When the influence t of the advisor on the crowd unit is greater than a certain value, it will have a positive influence on the preference, while when it is less than a certain value, it will have a negative influence. This certain value depends on the situation. Note: the Angle of preference does not change.

Executor. Perform the results of the affector and decider and perform the operation subject to self-degradation/mutations:

$$E^c = \left(k * A^f + (1 - k) * D^c\right) * s^{dm}$$

where E^c represents the executor, A^f represents the affector, s^{dm} represents the self-degradation/mutation, and k represents the effector and decider coefficients.

Comparator. It connects other trading entities, learns from the behavior results of other trading entities, and acts as negative feedback in the next round of evolution. After the completion of the transaction, each trading entity calculates the return of this round respectively and formulates the strategy for the next round according to its own and other

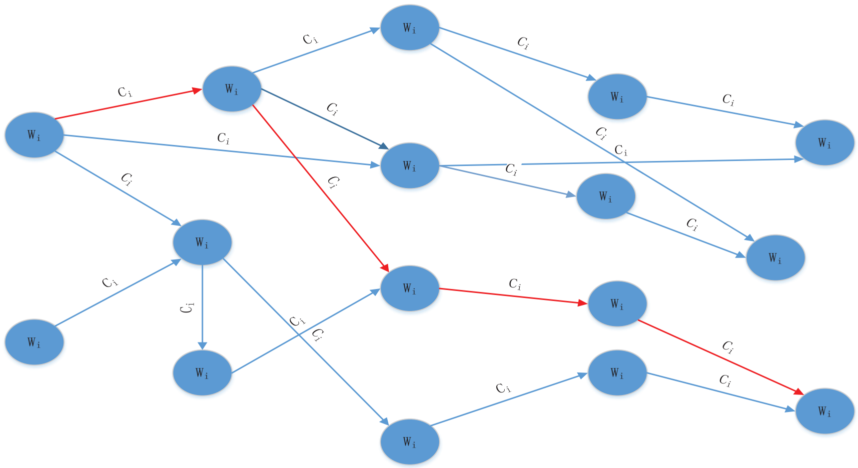

Figure 5. Proposed path diagram

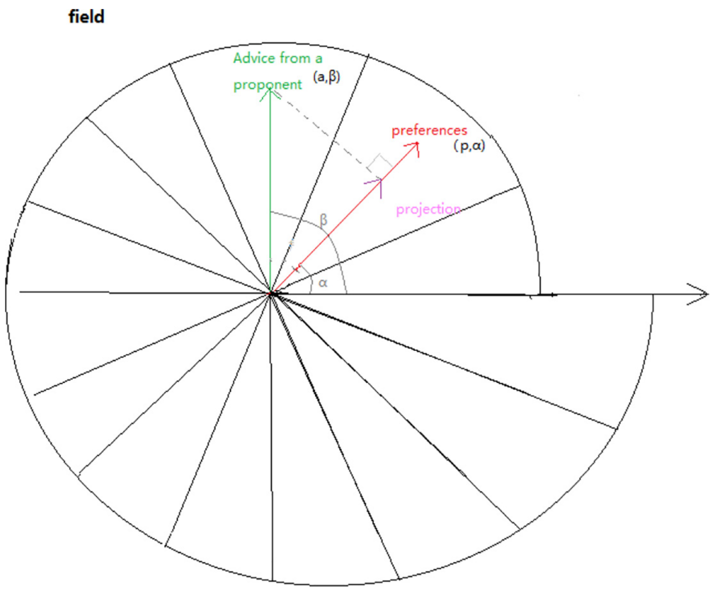

Figure 6. Preferences influence diagram in the field

entities' returns (random selection in field of view). A random selection of a number of other producers compares the returns, and then replicates at probability the production and business mode of producers with higher returns and their acceptance prices for transaction necessary services:

$$P_i^p = \frac{I_i^p}{\sum_{i=1}^{n} I_i^p} \quad P_i^s = \frac{I_i^s}{\sum_{i=1}^{n} I_i^s} \quad P_i^m = \frac{I_i^m}{\sum_{i=1}^{n} I_i^m}$$

$$M = f\left(\max\left\{P_1^p, P_2^p \ldots P_n^p\right\}\right)$$

I_i^p represents the revenue of producer *i*, I_i^s represents the revenue of service provider *i*, I_i^m represents the revenue of intermediary *i*, P_i^p represents the revenue ratio probability of producer *i*, P_i^s represents the revenue ratio probability of service provider i, P_i^m represents the revenue ratio probability of intermediary *i*; *M* represents the production and business mode corresponding to the producer with the highest revenue. The function of $f(x)$ is to calculate the production and business mode *M* corresponding to the highest revenue P_n^p.

4. An evolution simulation framework for ecological structure of crowd networks

4.1 Design framework

As mentioned above, we know that crowd network is a very complex and huge system with dynamic, diversification and large-scale characteristics. Taking e-commerce system as an example for evolution simulation for ecological structure, we first need to establish an evolution simulation framework (Zhang and Sun, 2017) that is most suitable for such characteristics, as shown in the Figure 7.

To solve the dynamic and diversification characteristics of e-commerce system, this paper uses a two-level simulation framework, which is system level and application level respectively. The system level defines the semantic environment of physical aspects and the application level defines the semantic environment of logical aspects. The individual members of the system level are projected from real system, and the individual members generated in the level will first build the network structure and then join in the application level for simulation.

To solve the problem of outside agreement, this paper adopts the method of simulation definition to improve the framework. Simulation definition is to define conditional related parameters, simulation related parameters and interaction-related parameters. Conditional related parameters are the initialization of the simulation environment, such as members of the scale, member distribution, product sales/purchase price, sales/purchase price of necessary services for transaction, various endowment prices and specialized economic degree. Simulation-related parameters are defined how the simulation runs, such as simulation wheel, income threshold setting, trading efficiency change rule and simulation algebra setting.

To solve the systematic and scale problems, this paper uses the concept of shared resources pool in the framework. The shared resources pool stores all the individual members of different types for use by the application level.

5. Implementation

5.1 Simulation member definition and generation

5.1.1 Trading entity. Intermediaries: $\text{Middlemen}_{i,}$ purchase transaction necessary services, purchase and sale of goods.

Service providers: Servicer_i, buy | sell transaction necessary services.

Producers: Producer_i, sell goods, buy transaction necessary services.

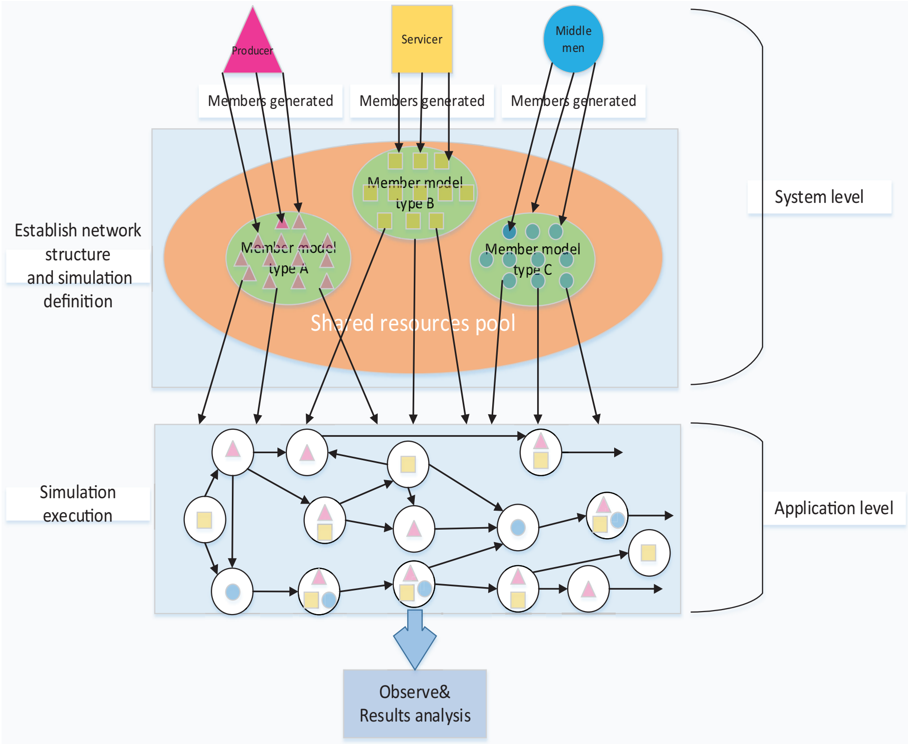

Figure 7.
E-commerce system simulation framework

5.1.2 Formal language description.

Algorithm1 pattern

algorithm 1. Generate_pattern(NUM, beginnode, endnode)

Input: NUM number of nodes
beginnode starting node
endnode termination of the node

Output: no

1 **foreach** (NUM, beginnode, endnode)
2 Start at starting node and end at termination of the node, NUM nodes are generated , labeled with ID respectively;
3 Assign weights to each node , weightnode;
4 Records the edges between adjacent nodes, and assign weights to the edges , weightedge;
5 Generates a list of node adjacencies , {CL};
6 **end**

Algorithm2 affector

algorithm 2. Affector (ID, {SL}, compar)

Input: ID The ID of the node on the pattern
{ SL} the advisor list (the ID of the advisor, influence coefficient [0,1], connection strength)

```
compar Comparator compares the results of other simulation units
Output: impastrth impact strength
foreach(ID, {SL})
        Find the corresponding relationship between simulation unit and advisor from
        the advisor list {SL};
        m.strength=m.strength *connection_strength;
        impastrth= m.strength;
end
return   impastrth
```

The decider is influenced by the monitor (self-regulation level), the comparator, and the affector (preference of the advisor), and has two attributes of confidence level and field of vision.

```
Algorithm3 decider
algorithm 3. Decider(ID, mode, impastrth, Em)
Input:   ID The ID of the node on the pattern
         mode Three production and management modes A, B and C
         impastrth impact strength of the advisor
         Em      Monitor(Self-regulation level)
Output: D      decision D
foreach(ID, mode , impastrth, Em)
        confilevel;
        D = impastrth * k1 + Em * k2 + confilevel * k3 (0< = k3, k2, k1< = 1 AND
        k1 + k2+ k3 = 1);
end
return Di;
```

```
Algorithm4 executor
algorithm 4. Executor(ID, Di , degralevel)
Input:  ID      The ID of the node on the pattern
        Di      decisionDi
       degralevel self degradation level
Output:   ID      node code on pattern (note the next generation node location)
foreach (ID, Di , degralevel)
        The execution result is calculated according to the decision Di of the Executor,
        and is affected by the degralevel;
end
return ID;
```

```
Algorithm5 monitor
algorithm 5. Monitor(ID, ML )
Input:  ID       The ID of the node on the pattern
        {ML}   List of monitors for simulation units (customize the monitoring strength)
Output: Em      Acting on the decider
foreach (ID, {ML})
        The objective of the monitor's own Self-regulation level is compared with the
        execution result;
        Self-correcting off-target execution results;
        Feedback to the next round of decider;
end
return Em;
```

By comparing the operating strategy income of adjacent simulation unit, the operating strategy with the largest income is selected to further influence the next round of decision of simulation unit, The influence on the decider is expressed by the influence coefficient (impastrth); Calculate your own return W_i and save it in the {CL} adjacency list.

Algorithm6 comparator

algorithm 6. Comparator (ID, { CL})

Input: ID The ID of the node on the pattern
{ CL} List of adjacency for simulation units(contains the revenue Wi for each adjacency)

Output: compar the results of Comparator compares with other simulation unit revenue

```
Cal_myEarn(ID)
    Calculate your own revenue Wi ;
    Store in the adjacency list {CL};
end
foreach (ID, { CL})
        Compare the revenue of adjacent units to obtain the Maximum gainer;
        Make choices about the three behaviors of your function;
        And get the maximum gainer of the corresponding business strategy;
        Quantize to get compar;
end
return compar;
```

5.2 The assignment of simulation experiment variables and parameters

5.2.1 Calculation of three production and management modes

(1) Self-production and self-marketing mode:

$$I^p = pQ - \sum_{j=0}^{z} l_j$$

I^p is the producer's income; l_j is the labor endowment for producing the j good. Because the producers have the labor endowments to put in the right kind of labor to produce the right kind of goods.

(2) Intermediary resale:

$$I^m = pQ - wQ + \sum_{i=1}^{m} p_{si}s_{si} - \sum_{i=1}^{n} p_{bi}s_{bi}$$

I^m is the profit of intermediaries; p is the retail price, w is the wholesale price, Q is the wholesale sales quantity, p_{si} is the sales price of transaction necessary service i, s_{si} is the sales quantity of transaction necessary service i, p_{bi} is the purchase price of transaction necessary service i, and s_{bi} is the purchase quantity of transaction necessary services.

(3) Producers purchase transactions necessary services for direct sale:

$$I^p = pQ - \sum_{j=0}^{z} l_j - \sum_{i=1}^{n} p_{bi}s_{bi}$$

I^p is the producer's revenue:

$$I^s = \sum_{i=1}^{m} p_{si}s_{si} - \sum_{i=1}^{n} p_{bi}s_{bi}$$

I^s is the revenue of the service provider

5.2.2 Define parameters and variables. Simulation parameters are as shown in Table I.

5.3 Simulation execution and validation

5.3.1 Simulation initial state setting. Simulation initial state, environmental variables generate X = 100 producers, intermediaries, service providers and X = 100 total market demands;There are n = 10 transaction necessary services on the market. Each producer has a labor endowment of l_j =10; Economic degree of specialization a = 1.8.

In the simulation experiment, the Transaction efficiency k is increased from 0 to 1, each time by 0.01. After the end of each iteration, subjects whose income is lower than the threshold M = 20 will be eliminated. For each transaction efficiency, the simulation experiment will iterate 100 times. Simulation wheel R records an information log for every five generations.

5.3.2 The evolution from state i to state i + 1. The evolution simulation of ecological structure is based on the transaction efficiency as the evolutionary power to move forward into the next generation of iterative evolution. First, a certain number of trading entities with single attribute (producer attribute, service provider attribute, intermediary attribute) are generated. Meanwhile, simulation environment parameters, global variable parameters, generation method and wheel method are set. In the process of simulation, the trading subject will have the behaviors and states of combine, split and keep. The behaviors will consume the endowments. Decider will select the production and operation mode according to the current state and calculate the revenue. Choose other trading subjects to compare their revenue within the scope of decider view, and choose the production and operation mode with the highest revenue to act on the next decision, so as to affect the behavior of trading subjects in the pattern. At the same time, the number, status and selected production and operation mode of each trading subjects are recorded:

- **Step 1**: initialize the e-commerce ecosystem and generate x simulation members with a single attribute (producer attribute, service provider attribute, intermediary attribute);

Table I.
Table of simulation parameters

No.	The parameter types	The parameter types	Value range	The set value	Note
1	total market demand N	Integer	+	100	
2	Producers P	Integer	+	100	
3	Intermediaries M	Integer	+	50	
4	Service providers S	Integer	+	10	
5	Transaction necessary services n	Integer	+	10	
6	Labor endowment l	Integer	+	10	
7	Degree of specialized economy a	Double	+	1.8	
8	Revenue threshold M	Integer	+	20	
9	Transaction efficiency k	Double	(0,1)	0.01	
10	Simulation of wheel R	Integer	+	5	

- **Step 2**: set the parameters of simulation environment, global variable, generation method and wheel method, and generate the network connection relationship among simulation members;
- **Step 3**: calculate the revenue of the production and operation mode adopted by each simulation member under the current state, eliminate the simulation member whose revenue is lower than the threshold value M and record the data;
- **Step 4**: select a certain number of other simulation members within the scope of decider view, compare their revenues, and select the production and operation mode with the highest revenues to act on the decision of the next generation; and
- **Step 5**: repeat Steps 3 and 4 until the end of simulation.

6. Conclusion

Through the research and analysis of the relevant literatures in the field of ecological structure evolution, this paper provides a lot of meaningful references and guidance for the research of this paper in the aspects of system structure, ecological composition, system implementation and algorithm.

Existing studies combine the business ecosystem theory with the Internet to explain the static and dynamic evolution process of the internal structure of the Internet business ecosystem. Theoretically and deeply explored the internal mechanism and operation mechanism of ecological development within the Internet business ecosystem. And using the computer simulation (Lv *et al.*, 2011) method to simulate the internal evolution process of Internet business ecosystem. However, this study is only limited to the qualitative research and analysis on the overall level of the ecosystem, and does not further discuss the change process of the internal structure evolution of the system. The method adopted in this paper is to observe and analyze the changes of other simulation factors by controlling the changes of variables (Dong *et al.*, 2001) according to the internal components of the ecosystem structure, and quantitatively analyze and study the evolution process of the ecological structure, so as to achieve the optimal level of specialization mode. And the two-level evolution simulation framework for ecological structure is established to support the orderly and efficient operation of the simulation.

This research is based on the crowd machine model, and the theoretical principle is closely related to the crowd machine model. In this study, how the evolution for ecological structure is carried out step by step, and how the division and cooperation of each device are all the results of my study under the guidance of my tutor. The results show that the evolution simulation of ecological structure is the most effective and best evolutionary method for studying complex network and complex system problems.

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