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Analysis of Allee effects on spatial distribution of software enterprises*

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Abstract

Software enterprises have been the important components of modern information industry, and play radical promoting roles in social and ecomonic development. Considering the clustering effects of software enterprises, such as benefiting for exchanges of technology and skills, reducing cost through concentrated workforce, and supporting by professional industrial environment, industrial park has been the widely adopted spatial distribution pattern of software enterprises in past practices. However, existing empirical studies argued that the software industrial park made software enterprises gathered homogeneously away from their customers in space, and this situation easily led to the excessive competitions and less efficiency of collaborative innovation with customers. In order to reveal the specialties of software enterprises in their spatial distribution, this article studies the above issue from the perspective of Generalized Ecological Community (GEC). Based on the Allee effect which has been proposed by ecologists and proven in industry analysis, we establish the mathematical model for describing the dynamic development of software enterprises in different spatial distributions, and analyze the factors affecting their survival status. Research findings indicate the underlying ecological laws of software enterprises' spatial distributions, as well as their evolving characteristics influenced by Allee effect, provide new strategies for the spatial distribution of software enterprises.

Keywords: information industry, software enterprise, spatial distribution, Allee effect, Generalized Ecological Community (GEC)

1. Introduction

As people are increasingly connected to the entire world via information technology, the booming of software enterprise has become noticed by a rising number of citizens. The total yearly income of software enterprises has been rising from 14.5 billion CNY in 1995 to 4,900 billion CNY in 2016. In other words, the yearly revenue of software enterprises in 2016 was over 300 times more than that in 1995. The growth of the market encourages developers to establish an increasing number of software enterprises, and administrators of industrial parks are sometimes wondering if they can arrange different software enterprises in a certain region

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with limited space and resource. The main problem discussed in our article is the effect of the spatial arrangement of software enterprises over both software enterprise individuals and the entire software industry. In the progress of social industrialization, the development of industrial ecology, which has been mentioned for the first time in 1989, makes people increasingly clear about the definition of enterprise clusters and encourages them to research related topics. Researchers are gradually aware of the significance of considering individual enterprises as members (or elements) of *populations* from their experience accumulated from daily practice. Through fundamental knowledge of mathematical modeling and differential equations, we are going to discover the intrinsic mechanism of the evolution of individual software enterprises and the ecological dynamics of software enterprises in two different categories with mutually beneficial symbiosis under the Allee effect.

2. Related works

Population and e*cological community* are fundamental concepts of both biology and ecology. In biology, population means all the individuals of the same species occupying a given spatial environment in a period that may exchange genes by mating and feed offspring by providing them with food, water, and hideouts. An ecological community is a combination of populations of different species with relations (predation relationship, competitive relationship, etc.) in a certain spatial environment. The *generalized population* defined in this paper refers to software enterprises located on a given plot that are of the same type. According to the classification method of software industry given by Ye (2016), software enterprise populations can be separated into 4 types, including operating system development population, supporting software development population, application development population and software service population. The populations of different types have the relationship of mutually beneficial symbiosis when they are implemented on the same plot at the same time. Thus, the generalized ecological community defined in this paper indicates the combination of more than one software enterprise population at the same time.

The definition of *metapopulation* is given by Levins in 1969: a metapopulation is a population composed of local populations that consist of a certain group of individuals. Habitually, mathematical models aim at discovering features in generalized ecological communities and only take one of them into consideration. Nonetheless, in the mathematical model constructed in this article, a 10* 1 alignment of blocks with different geographical features are established and analyzed via resolving ordinary differential equations. We assume that the ratio of enterprises that migrate from one block (called block A in this case) to another (called block B) over the total number of enterprises migrating from block A to all other blocks is in inverse proportion to the geographical distance of block A and block B. Since we have 10 different blocks in our model, and each one has a local population composed of software enterprises on its top, all the local populations aggregate into a metapopulation on the 10* 1 alignment.

In the research field of chemistry, ecology and mathematical biology, the tradition of resolving issues by constructing mathematical models and finding numerical solutions of a bundle of ordinary differential equations or partial differential equations can be traced back to around 100 years ago. Lotka (1910) initially proposed a predator-prey model, which is now known as the Volterra-Lotka model, in his research on catalytic chemical reactions, and Volterra (1926) discovered the same differential equation system used to explain his son-in-law, Italian marine biologist Umberto D'Ancona's observation of fish in the Adriatic Sea during the First World War. In 1967, American mathematician and economist Richard M. Goodwin began to publish his research on economic issues by applying the Lotka-Volterra model. Some of his followers in China has already published their researches over economics, management, and sociology applying the Lotka-Volterra model in the recent years. For instance, Li (2008) has used the Lotka-Volterra model to depict the competitive relationship of enterprise clusters. Since the Lotka- Volterra model is designed for the predator-prey relationship between two different species, we need to create a new model to meet our needs of simulating symbiosis between software enterprises based on previous results without omitting essential assumptions and realistic backgrounds.

In the 1970s, Howard E. Aldrich and his co-workers begin to concentrate on related issues of the relationship between organizations and environments. He managed to condense his thoughts in the book *Organizations and Environments* (published in 1979). In this book, he thoroughly illustrated the conditions that make the organizations change, and constructed the fundament of our research based on both organizations (software enterprises) and environments (the spatial distribution of software enterprises). Hannan and Freeman (1977) applied several models including the classic Lotka-Volterra model to provide solutions for organization-environment problems with helpful comments provided by Howard E. Aldrich. As for their followers, Dai (2010) presented the concept of Generalized Ecological Community(GEC) and its theoretical basis. It discusses the common rules and characteristics exsisting in natural communities and socioeconomic communities. Da and Yu (2011) researched and analyzed specific examples of enterprise clusters with the concepts of ecology. Dai (2010, 2012, 2013) applied the theory of GEC to multiple fields such as IT-driven emerging industry, independent scientific innovation, and smart city, etc. He claimed that the software enterprises are not as the "wolves" in gregarious living, but looks more like the "hermit crabs" who prefer to company with their served objects (Dai, 2012; Zhou, et al., 2016). Zhou et al. (2016) studied the evolution of ethnic cultural industry towards a cyberspace from the perspective of generalized ecosystem.

In the year of 1932, W. C. Allee proposed Allee effect to summarize the result in the experiment of recording the lifetime of goldfish in the environment of water containing colloidal silver. This effect may illustrate the phenomenon that the growth rate may reduce or even come to be a negative value when the total number of individuals of a specific species is lower than a given value, which is usually considered as a bottom line, due to the inability of finding spouses and inbreeding. Allee effect may be equipped to research the impacts on biological populations caused by the deterioration of the environment and the protection methods of endangered species. Zhou et al. (2005) mention that considering the Allee effect of populations may make up for some necessary assumptions that have been ignored in Lotka-Volterra system. Chen et al. (2013) managed to analyze the dynamics of the discrete-time predator-prey system with Allee effect supported by plenty of mathematical concepts and propositions.

Innovated by all the related works that are mentioned above, our research managed to regard the spatial distribution problem of software enterprises as an organization-environment problem, construct a creative mathematical model taking the Allee effect and the symbiotic phenomenon into consideration and add the fundamental concepts (e.g., population, ecological community, metapopulation) and traditional methods of ecology into the spatial distribution problem of enterprises (instead of species or animal individuals as traditional research objects of ecology).

3. Analysis of enterprises on one given block

3.1 Dynamic models for the evolution of one isolated enterprise population

The first model in this paper is imported from ecology, which is originally used to depict the relationship between the number of individuals (usually of a specific species of organism in an isolated environment) and time following the Allee effect.

$$\frac{du}{dt} = bu(1 - \frac{u}{R})(\frac{u}{u+a}) - du \qquad (1)$$

u=u(t) denotes the number of individuals in the population (related to the coefficient of time). t denotes the time, b denotes the birth rate of the population, R denotes a constant related to the maximum capacity of the environment, a denotes a constant related to the significance of Allee effect and d denotes the mortality.

We may transform the research object from natural populations to generalized populations of enterprises by changing the meaning of the variables in the following way: u(t) denotes the number of enterprises, t denotes the time, b denotes the increasing rate of software enterprises, R and a are constants with the same meaning as is shown above, d denotes the abstract 'mortality' of software enterprises. In this case, only one generalized population is going to be discussed, and it is isolated with other environmental variables.

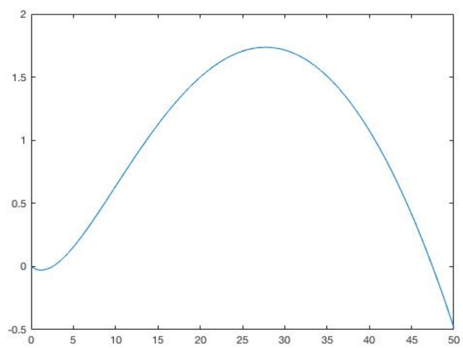
3.2 The relationship between enterprise population evolution and Allee effect

We may find out that the evolutional features of individual enterprise populations may theoretically be compatible with the Allee effect, like software enterprise populations with small volumes may be eliminated by the market when they are not capable of undertaking large orders. On the contrary, a group composed of plenty of software enterprises may undertake large orders to guarantee the growth of their revenue via cooperative manufacture. When the total industrial capacity of software enterprises is higher than the demand of the market, the competition between the enterprises in the same population turns out to be more severe, which may make some enterprises knocked off by their competitors. The deduction mentioned above accounts for the rationality of using differential equation (1) to demonstrate the evolutional behaviors of enterprise population.

We set b=0.3, a=12, R=60, d=0.05 in equation (1) and equipped MATAB_R2017a to generate and visualize its solution in our research. The result is shown in Figure 1. In Figure 1, the x-coordinate indicates u and the y-coordinate indicates u'(t), i.e., the derivative function of u=u(t). We may find out that this function may indicate the characteristics of u'(t) with the effect of Allee effect.

Furthermore, we may find out the zero point of u'(t) in Figure 1. u_1=0, u_2=2.5278, and u_3=47.4722 are all the three zero points that can be found in Figure 1, which indicate three different status of the balance of the dynamic system (1).

Figure 1. The plot of (1) when b=0.3, R=60, a=12, d=0.05



We may directly find out from the figure that software enterprises can hardly survive when their total amount is lower than a threshold defined by the model. When the amount of the enterprises is relatively low, different enterprises may cooperate with each other by sharing technology and large amount orders to make them improve rapidly. The increasing rate of enterprises may gradually descend and ultimately become negative when the market is saturated, and the competition becomes increasingly fierce. The phenomenon extracted from this model may be consistent with the theoretical deduction that has been presented in the paragraphs mentioned above. According to the fundamental theories of the stability of dynamical systems, u_1 and u_3 are two stable fixed points of (1), and u_2 is an unstable fixed point. When the initial value u_0 is larger than u_2, u_3=47.4722 shall become the final fixed point of the system. Otherwise, the population is going to be eliminated irresistibly.

We may adjust the value of a in model (1) to modify the significance of Allee effect. The Allee effect is stronger when a is bigger, and model (1) is exactly the logistic differential equation when a=0.

4. Analysis of enterprise development on multiple blocks

4.1 Model and analysis for a single type of software enterprise on multiple blocks

The model is designed to depict the scenario that an industrial park is a 10* 1 strip of usable blocks. In this case, investors may establish software enterprises in any one of them. The location and number of all the blocks are shown in Figure 2.

Figure 2. Location and number of blocks

Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Block 7	Block 8	Block 9	Block 10

$d_{ij}=|i-j|$ is the geographical distance between two blocks. $u_i=u_i(t)$ is the total number of enterprises on the block of i in the time of t. We assume that we may ignore the environmental difference of the blocks and only one type of software enterprise population is included in the following model.

We define the following ordinary differential equation:

$$\frac{du_i}{dt}=bu_i(1-\frac{u_i}{R})(\frac{u_i}{u_i+a})-su_i-mu_i+km\sum_{j\neq i}\frac{\frac{u_j}{d_{ij}}}{\Sigma_{j\neq i}\frac{1}{d_{ij}}} \tag{2}$$

In (2), t denotes the time, b denotes the increasing rate of software enterprise populations, which is equal among all the blocks from Block 1 to Block 10, R is a constant used to depict the capacity of an individual block, a is a constant used to depict the significance of Allee effect, s denotes the 'mortality' of enterprises in a given block, m denotes the natural migration rate, k denotes the success rate of migration and d_{ij} denotes the geographical distance between Block i and Block j. Model (2) is an autonomous dynamical system with 10 variables. As we can find from (2), those blocks that are closer to a certain block (namely, Block A) are more likely to become the target of emigration from the block (Block A). This tendency is close to reality even though software enterprises are much easier to immigrate than vehicle manufacturers, nuclear power plants or other enterprises with facilities that are not able to move for a long distance in a few days, since a long-distance migration may let the executives on an enterprise pay more in migrating facilities (usually computers and servers) and getting adapted to the new environment.

In our research, we set b=0.3, R=60, a=12, s=0.05, m=0.1 and k=0.7. We use the ode45 algorithm in MATLAB_R2017a to find the numerical solution of (2). In the first situation that we are going to discuss, the initial value is close to the critical point of the survival of populations on all the enterprise populations. We may judge whether the enterprise populations are going to survive in the market by finding whether the solution of the equation reaches 0 as time goes to infinity.

Figure 3. The plot of the solution of dynamical system (2) with the initial value [32,0,0,0,0,0,0,0,0,0]

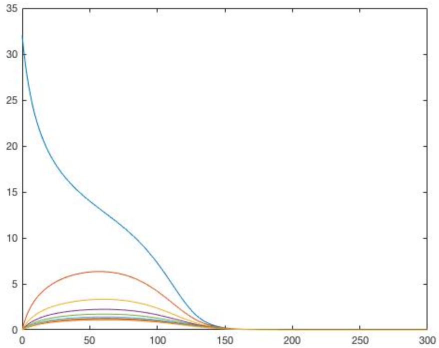
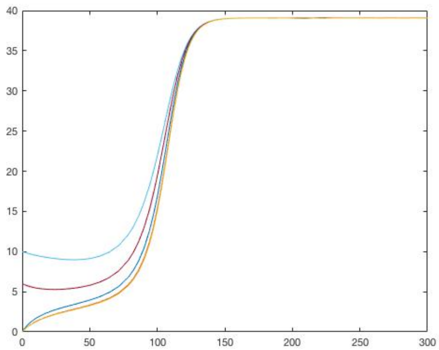


Figure 4. The plot of the solution of dynamical system (2) with the initial value [0,0,0,6,10,10,6,0,0,0]



In Figure 3, the initial value of (2) is all the 32 units of initial resources are arranged in Block 1 (as is shown in Figure 2). We denote this kind of allocation as [32,0,0,0,0,0,0,0,0,0]. According to the plot of the result, we may find that the dynamical system collapses after 150 units of time and ultimately none of the enterprise populations are still able to survive. In comparison, we put 6 units of initial resources on Block 4 and Block 7 and put 10 units of initial resources on Block 5 and Block 6. This pattern of initial allocation is denoted as [0,0,0,6,10,10,6,0,0,0]. Figure 4 shows the solution of (2) with the initial value [0,0,0,6,10,10,6,0,0,0], and we may find out from Figure 4 that the system reaches a steady situation after 140 units of time. The results tell us that the initial conditions referred to in Figure 4 ultimately realized stable survival of all the enterprise populations.

The second issue for discussion is the relationship between results of evolution and initial conditions when the initial investment is sufficient for the survival of enterprise populations on all blocks.

Figure 5 shows the solution of (2) when 200 units of initial investment are entirely located on Block 1. We may denote this initial condition as [200,0,0,0,0,0,0,0,0,0]. In Figure 5, it takes nearly 100 units of time for the system to reach a steady status; the system is vulnerable when the time is close to 50 units as all the lines shown in the plot are incredibly close to the x-axis at that time.

Figure 6 shows the solution of (2) when 20 units of initial investment are located equally on Block 3, Block 4, Block 5, Block 6, Block 7 and Block 8. This condition may be denoted as [0,0,20,20,20,20,20,20,0,0]. Although the total amount of initial investment is 160 units, which is significantly lower than 200 units in the former case, the stable status is reached at around 50 units of time. The comparison between Figure 5 and Figure 6 shows that (2) is more stable with initial condition [0,0,20,20,20,20,20,20,0,0] instead of [200,0,0,0,0,0,0,0,0,0].

Figure 5. The plot of the solution of dynamical system (2) with the initial value [200,0,0,0,0,0,0,0,0,0]

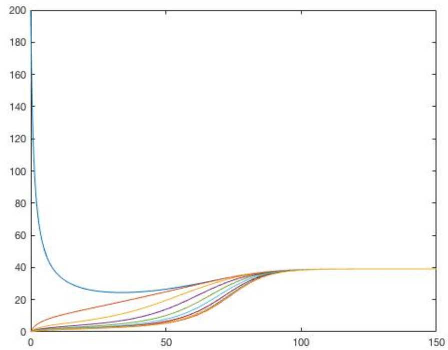
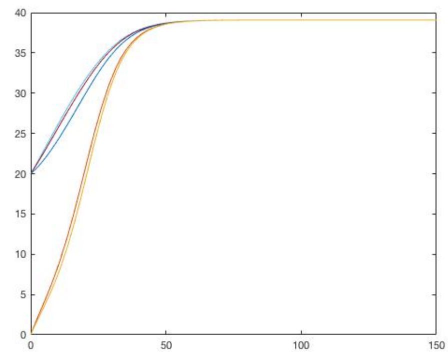


Figure 6. The plot of the solution of dynamical system (2) with the initial value [0,0,20,20,20,20,20,20,0,0]



The results of numerical resolution on (2), which have been shown from Figure 3 to Figure 6, indicate that establishing new software enterprises in the center of the blocks shall be a more proper way than deliberately accumulating all the enterprises on the edge of the blocks in both the two cases. Founding enterprises in the center may increase the probability of their long-term survival when the initial investment is severely limited and may also accelerate the process of reaching a steady status when the initial investment is sufficient.

4.2 Model and analysis for two types of software enterprises on multiple blocks

In this paper, we use differential equations (3) and (4) to refine the characteristics of the problem:

$$\frac{du_i}{dt}=b_1u_i(1-\frac{u_i}{R_1})(\frac{u_i}{u_i+a_1})-s_1u_i+p_1v_i-m_1u_i+k_1m_1\sum_{j\neq i}\frac{\frac{u_j}{d_{ij}}}{\Sigma_{j\neq i}\frac{1}{d_{ij}}} \tag{3}$$

$$\frac{dv_i}{dt}=b_2v_i(1-\frac{v_i}{R_2})(\frac{v_i}{v_i+a_2})-s_2v_i+p_2u_i-m_2v_i+k_2m_2\sum_{j\neq i}\frac{\frac{v_j}{d_{ij}}}{\Sigma_{j\neq i}\frac{1}{d_{ij}}} \tag{4}$$

In ordinary differential equations (3) and (4), b_1 and b_2 are growth rates of software enterprise population 1 (SEP1) and software enterprise population 2 (SEP2). R_1 and R_2 are constants denoting the maximum capacity of SEP1 and SEP2 on all the blocks. a_1 and a_2 are constants denoting the significance of Allee effect of SEP1 and SEP2. s_1 and s_2 are the mortality of SEP1 and SEP2. m_1 and m_2 are immigration rates of SEP1 and SEP2. k_1 and k_2 are success rates of immigration for SEP1 and SEP2. p_1 is a constant estimating the benefit given by SEP2 on SEP1, p_2 is another constant estimating the benefit given by SEP1 on SEP2. d_{ij} is the geographical distance between Block i and Block j. (3) and (4) may be recognized as a dynamical system with 20 variables when considered together. We may notice that SEP1 and SEP2 form a metapopulation in this model.

In our research, we set b_1=0.3, b_2=0.2, R_1=60, R_2=40, a_1=12, a_2=10, s_1=0.1, s_2=0.15, p_1=0.08, p_2=0.1, m_1=0.1, m_2=0.1, k_1=0.7 and k_2=0.65. The same as in 4.1, we first discuss the situation when initial resources are not quite sufficient to guarantee the survival of either SEP1 or SEP2. In Figure 7, we use the initial conditions of putting 20 units of enterprises in SEP1 on Block 1 and 30 units of enterprises in SEP2 on Block 10, which can be denoted as [20,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,30]. We may find out that the system breaks down at around 100 units of time and all initial enterprises are eliminated.

If we change the initial conditions into [0,0,0,0,10,10,0,0,0,0,0,0,0,0,12.5,12.5,0,0,0,0], we may generate Figure 8 as our resolution for (3) and (4). We may find that the system reaches a stable status at around 120 units of time. It is worthy to notice that the initial resource used in this case is less than the former one.

Figure 7. Plots of solutions of (3) and (4) with initial value [20,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,30]

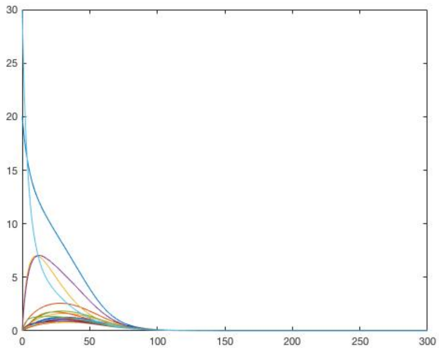
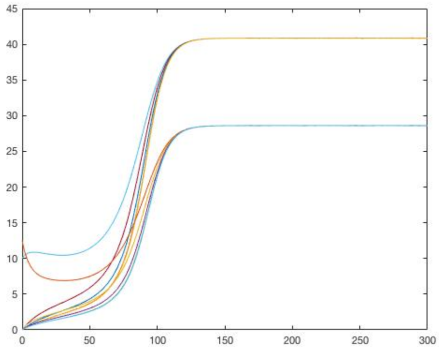


Figure 8. Plots of solutions of (3) and (4) with initial value [0,0,0,0,10,10,0,0,0,0,0,0,0,0,12.5,12.5,0,0,0,0]



Then we need to analyze the situation when initial investment is abundant. First, we set initial conditions as [100,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,100], as 100 units of enterprises in SEP1 are arranged in Block 1 and 100 units of enterprises in SEP2 are arranged in Block 10. We may summarize the results shown in Figure 9 that the final stability is reached at around 80 units of time. In Figure 10, the initial conditions are set as [0,0,0,20,20,20,20,0,0,0,0,0,0,20,20,20,20,0,0,0] and we may find that the stability is reached a nearly 65 units of time with even less initial investments.

Figure 9. Plots of solutions of (3) and (4) with initial value [100,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,100]

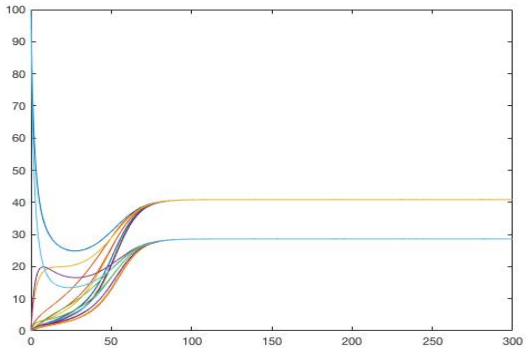
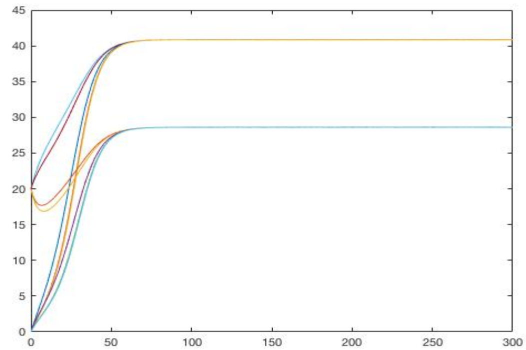


Figure 10. Plots of solutions of (3) and (4) with initial value [0,0,0,20,20,20,20,0,0,0,0,0,0,20,20,20,20,0,0,0]



5. Strategies for spatial distribution of software enterprises

Our research findings indicate the underlying ecological laws of software enterprises' spatial distributions, as well as their evolving characteristics influenced by Allee effect. According to analysis results, marginalized spatial distribution of software enterprises with excessive density is not beneficial for the thriving of the entire software enterprise ecological community. Since the average investment of software enterprises is relatively low in China, we recommend the investors establish complete software enterprise industrial chains in the area with high level of development and traffic convenience. In this way, we may exert the symbiosis effect between different types of software enterprises, enabling the growth of enterprise numbers. Since the ability of diffusion is rather high for software enterprises and the center of the industrial park has advantages of transportation, the surrounding area near the center can be efficiently driven by the rapid development in the park center. As a result, the entire industrial park may reach the upper bound of its capacity in a relatively short time. On the contrary, though the strategy that deliberately separates different types of software enterprise populations and locates them into remote areas with poor transportation condition, which is quite common in China, may reduce the burden of management over industrial park administrators, but it will drastically reduce the symbiotic effect of enterprise populations and thus may result in waste of natural and economic resources.

When the investment of software enterprises is rather abundant in a specific industrial park, we recommend the administrators establish software enterprises in different parts of the industrial chain near the center of the park and ultimately utilize the feature of symbiosis between different categories of software enterprises. This strategy allows enterprises to reach their ecological balance as soon as possible and ensure the robustness of the balance for a long period of time. According to our research, when all the enterprises are located near the boundary, and different categories of software enterprises are artificially isolated, the entire ecological community is kept in instability for a long time. As the software industry renews itself rapidly (usually changing major products and services within 3 years), lots of software enterprises are unstable with a high rate of being eliminated due to lack of revenue or creativity. Once a large part of the enterprises in the industrial park cannot closely follow the innovation of technology, the entire enterprise ecological community in the industrial park may become extremely vulnerable. Besides, the fierce competition happened in some specific regions will contribute to an enormous and meaningless loss of initial investment.

Apart from theoretical deduction, some practical facts in China can be found to support our results. Bi et al. (2011) mention that the city of Shanghai has its software enterprises distributed in around 10 hubs that are close to the center of the city with different types of software enterprises cooperating with each other, and the symbiotic phenomenon is validated in their research as 40% of the enterprises developing financial software are established in Pudong New Area, together with the location of the city's financial center as well as the biggest financial software maintenance center. From Bi et al.'s research, we may find out that the software enterprises of different types form a microcirculation system in Shanghai and the property of symbiotic phenomenon between different types of software enterprises has been shown clearly in this case.

6. Summary and discussion

This paper summarizes relevant theories that are correlated with biology and management and uses mathematical modeling and numerical calculation of differential equations to explore the development laws of software enterprise populations and strategies of spatial arrangement among software enterprises in a specific industry park.

Our results show that the concept of metapopulation is strongly correlated with different types of software enterprise populations with predictable relationships in different places. Some of the evolutional characteristics show that the growth of enterprise populations may be affected by the Allee effect. According to the mathematical modeling and relative analysis over the development situation of enterprises on multiple blocks with different initial values, excessive concentration of initial resource distribution may not only do harm to an economic loss of the entire industrial park but also affect the long-term sustainability of software enterprises. Emphasizing the interdependence among different types of software enterprises and allocating resources in an appropriate way may stabilize the survival of enterprises and then prevent initial investment from being wasted.

As for the practical implication of this research, relative management departments of the government may set up regulations for industry park development based on our research, such as limiting the highest density of software enterprises in the same type, to lower the market instability and avoid unnecessary losses. Those relative departments may also set up regulations to encourage software enterprises of different types to cooperate with each other to reinforce their symbiotic relationship. Zhao et al. (2009) mention that the software industrial park in Dalian was established and supported by the local government, which had played a decisive rule in its development. In fact, it is quite usual in China that the governments offer supporting policies and help the software enterprises construct their infrastructures. Besides, the investors may reconsider their original plans for the spatial arrangement of software industrial parks and make them more stable towards the potential impacts brought by the market. The directors of software enterprises may arrange their locations to the places with a moderate amount of software enterprises in the same type, as we have already shown in this article that both isolating and severely clustering may probably harm the development of software enterprises.

There are some ways to make further insight based on our research, some of which are listed here: at first, the main work of our research in this paper is based on abstract models and solutions of ordinary differential equation systems. Our research may become more empirical when a great deal of data can be extracted and analyzed from real samples of software enterprises and industrial parks in cities that can represent the status of the development of software enterprises in China (e.g., Shanghai and Beijing). Fortunately, we managed to find and quote references that have provided the empirical basis for our research. Second, the geographical shape of an industrial park may be much more complicated than a 10* 1 alignment, which indicates that we need to adjust our model to fit operational demands. For example, the city of Shanghai has 16 districts and over 200 towns and subdistricts with different level of economic development. In this case, we need to construct a much more sophisticated model based on the same idea and method as we demonstrated in this article to predict the development of software enterprises in Shanghai. Finally, our research may be equipped in research fields other than the spatial arrangement of enterprises. In other words, the models and methods explained in this paper may stimulate people’s interest in problems such as the arrangement of workers in wasteland reclaiming.

References

Aldrich, H. E. (1979). *Organizations and Environments.* Stanford, CA: Stanford University Press.

Bi, X. J., Wang, M. F., Li, J. and Ning, Y. M. (2011). Agglomeration and suburbanization: a study on the spatial distribution of software industry and its evolution in metropolitan Shanghai. *Acta Geographica Sinica, 66*(12), 1682-1694.

Chen, X. W., Fu X. L. and Jing Z. J. (2013). Dynamics in a discrete-time predator-prey system with Allee effect. *Acta Mathematicae Applicatae Sinica, English Series, 29*(1), 143-164.

Courchamp, F., Berec, L. and Gascoigne, J. (2008). *Allee Effects in Ecology and Conservation*. Oxford: Oxford University Press.

Da, B. and Yu, Z. (2011). Research on development strategy of Wuhu automobile industrial clustering based on the population model. *Journal of Changsha University, 25*(1), 27-28.

Dai W. H. (2010). Generalized ecological community: theory and application in IT-driven emerging industry. *Advances in Systems Science and Applications, 10*(4), 666-670.

________ (2012). Ecological community pattern and research of independent scientific innovation. *Reseach Report of The National Social Science Fund of China*, Shanghai, China.

_________ (2013). Intelligent city development mode based on Generalized Ecological Community. *Shanghai Urban Management, 2013*(6), 33-37.

Hannan, M. T. and Freeman, J. (1977). The population ecology of organizations. *American Journal of Sociology, 82*(5), 929-964.

Levins, R. (1969). Some demographic and genetic consequences of environmental heterogeneity for biological control. *Bulletin of the Entomological Society of America, 15,* 237-240.

Li, G. (2008). Research on ecological evolution and function mechanism of the industrial cluster. Unpublished master’s thesis, Jilin University, Jilin, China.

Lotka, A. J. (1910). Contribution to the theory of periodic reaction. *The Journal of Physical Chemistry, 14*(3), 271-274.

Volterra, V. (1926). Variazioni e fluttuazioni del numero d'individui in specie animali conviventi. *Mem. Acad. Lincei Roma, 2*, 31-113.

Ye, N. (2006). Research on the ecological community of technological innovation in software industry and its succession model. Unpublished master's thesis, Fudan University, Shanghai, China.

Zhao, W., Watanabe, C. and Griffy-Brown, C. (2009). Competitive advantage in an industry cluster: The case of Dalian Software Park in China. *Technology in Society, 31*(2), 139-149.

Zhou, S. R., Liu, Y. F. and Wang, G. (2005). The stability of predator-prey systems subject to the Allee effects. *Theoretical Population Biology, 67,* 23-31.

Zhou, X., Dai, W., Xu, D. and Chen Y. S. (2016). The evolution of ethnic cultural industry towards a cyberspace: a perspective of generalized ecosystem, In *Proceedings of 2016 IEEE International Conference on Systems, Man, and Cybernetics*, 4756-4761.