ON TECHNOLOGY INNOVATION
A Community Succession Model for Software Enterprise

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Abstract: In this paper, we have taken an economic approach of technological innovations to studying the issue of evolution in software enterprise. Based on Lotka–Volterra equations and equilibrium formula, we have built a model for the dynamics of software technological innovations. The model is applied in order to derive the typical succession patterns of communities and a method for optimal co-existence and interactions among the communities. We validate our model by presenting a case study on the development process of the software enterprises.

1 INTRODUCTION

To achieve efficient and sustained innovations of software enterprise, a number of key factors such as effective motives, a complete element market and a tactical technology transfer system, have to evolve to its optimal status ultimately. These factors are implemented by components such as research and development, software production, financial and investment, technology service brokerage, technology administration, and etc. These components co-exist in the software sector and work closely with each other in a collaborative and interactive way. The components and their interactions result in the evolution of software enterprise, which are marked by the continuous innovations created by them.

It is reported in a number of research that technology innovation community can be seen as a social "technology" community that is based on industry associations, characterized by geographical closeness, and composed of interrelated and interaction-al innovative organizations. The theory of ecosystem communities and economics of technology innovation provide several implications that can be used to study technology autonomous innovation community and their organizational patterns and operational mechanisms.

In this paper, we have taken an economic approach of technological innovations to studying the issue of evolution of the software enterprise. The components of the software enterprise innovation are modelled as communities in an ecosystem that evolve over time. Based on Lotka–Volterra equations and equilibrium formula, we have built a model for the dynamics of technology innovation on software enterprise. The model is applied to derive the typical succession pattern of communities and a method for optimal co-existence and interactions among the communities.

2 RELATED WORK

The innovation system of the software enterprise has evolved from a linear, static pattern to a systematic and dynamic pattern with a lot of complex interactions. The earlier innovation pattern can be seen as driven by the technology push and market pull, which is described in the theory of Schumpeter. (Schumpeter., 1990). With an increase of the complexity and scale of software products, this kind of innovation pattern can no longer meet the requirements for software innovation. This has resulted in the emergence of a new innovation pattern that is more adaptive and complex. This new pattern consists of various related software organizations and environments in various geographic regions at certain periods of time. (Weihui Dai, Mingqi Chen, Nan Ye, to be published).

The operational mechanism in natural ecosystem

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gives us inspirations in exploring the complex interactions and evolution rules on innovation system. The study of interrelationships among species and between species and their physical-chemical environments in ecology has defined community as a group of species occurring in a particular area, and ecosystem as assembles of species, communities and the physical and chemical components forming a more or less stable system.

In the early of 1960', some researchers already noticed the similar ecological characteristics in social and economic organization. This lead to successful findings in the evolution mechanism of economic communities by Nelson and Winter in 1982. (Nelson, R.R., Winter, S.G., 1982). Freeman and Hannan gave a systematic summary of the theory, methodology and research experience on organizational ecology. (Hannan, M.T., Freeman, J.H., 1989). Those theory and methodology were also applied to technology innovation. An innovation ecological community can be described as some entities and their inter-relative institutions which jointly and individually contribute to the development and diffusion of new technologies. In 1993, Gerry Martin and John Ziman organized a mult-discipline team to explore the evolution features and rules of technology innovation from philosophy, ecology and behavior science. (Lucheng Huang, 2004). Therefore, ecosystem on technology innovation has been a new hot point. (Lucheng Huang, 2003).

In comparison with other innovation communities, the innovation community of software enterprise has its unique characteristics. (Jianping Wang, 2003). In the startup stage, software enterprises usually infest with universities and hi-tech parks in order to obtain shared talents, capital, and infrastructures. When entering in the mature stage, they appear to be inquilinous with some other industries from a gregarious situation, to avoid excessive competition. (Libing Shen, Weihui Dai, 2006; Nan Ye, 2006). The "food" sources and "species" competition play a leading role in the evolution of software communities. (Weihui Dai, Mingqi Chen, Nan Ye, to be published).

3 LOTKA-VOLTERRA MODEL

The innovation community of the software enterprise contains some innovation populations, supporting populations and their environments. Through the transforming of capital, information and material, these elements build up a complex and open system. (Weihui Dai, Mingqi Chen, Nan Ye, to be published). To study the competition and its mechanism in the evolution of software innovation communities, we used Lotka-Volterra model in this paper. This model was presented by Lotka and Volterra in 1925 (Lotka A. J., 1925), 1926 (Lotka A.J., 1926) and 1931 (Volterra. V., 1931) to describe the quantitative relationship of rival species that in natural ecosystem.

Lotka and Volterra firstly applied the growth Logistic equation to the dynamic process of two competing populations, as shown in (1) and (2) (Volterra. V., 1931), where N_1 and N_2 represent the population size of two species, r_1 and r_2 represent their In-increase rate, K_1 and K_2 represent their maximum size of population restricted by resources, α and β are the competing coefficients of two species. Competing coefficient is used to represent the affect and competence imposed by one species to another. If two species are not in unsolvable conflict, both α and β are zeros. If they request the exact same type of resources, both α and β are ones. If species one consumes a lot more resources than species two, α is much larger than β.

$$\frac{dN}{dt} = rN - \frac{rN^2}{K} - CNN' \tag{1}$$

$$\frac{dN_1}{dt} = r_1 N_1 \left(\frac{K_1 - N_1 - \alpha N_2}{K_1}\right) \tag{2}$$

The Lotka-Volterra competence equation can be use to describe the competitions among populations of software companies that adopt different software technology standards. Let us assume two populations of application software development have different technology innovations or different software technology standards, for example, .NET platform from Microsoft and J2EE platform from Sun, noted by population-.NET and population-J2EE. The sizes of both populations, i.e. N_1 and N_2, can be modelled as (1) and (2). Their sizes are affected by the self-crowd existing among the individuals within the same population as well as competitions among the individuals across different populations. There are three outcomes of the competition: either population survives or both populations survive. Figure 1 shows the density of both two populations, with the vertical axis as the density of population-.NET and the horizontal axis as the density of population-J2EE

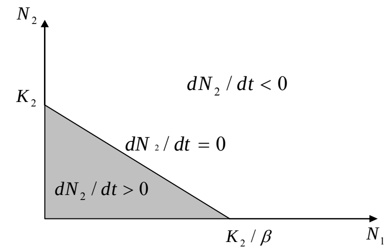

Figure 1: Increase rate of population-.NET.

Similarly, in figure 2, the vertical axis represents the density of population-J2EE and the horizontal axis represents the density of population-.NET.

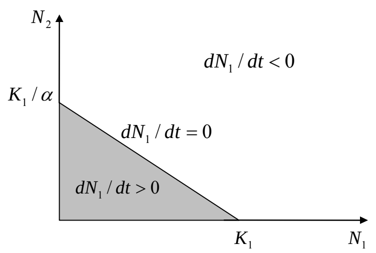

Figure 2: Increase rate of population-J2EE.

Please notice the above model does not consider any situation factors. Therefore, $\alpha \times \beta < 1$ is used to constrain the effect of co-existence and co-beneficial such that the populations will not grow to infinity in the model. When the co-beneficial of the two populations reaches equilibrium, the population sizes are larger. As shown in (3) and (4), as the co-beneficial increases ($\alpha \times \beta$ is larger), the sizes also increase.

$$N_1^* = (K_1 + \alpha K_2)/(1 - \alpha\beta) > K_1 \tag{3}$$

$$N_2^* = (K_2 + \beta K_1)/(1 - \alpha\beta) > K_2 \tag{4}$$

4 EVOLUTION PATTERN

We have defined two evolution dimensions for the innovation community of the software enterprise in terms of the integrity of innovation chain and a rational ratio of different populations. Through the observation on the different trends of software enterprise on two dimensions, we have derived two representative evolution patterns of population succession in the software enterprise on shown as follows:

Type I evolution pattern conforms to the following process: first, companies take up the activities of coding and services at the bottom of innovation ecology chain and accumulate their knowledge of product development, including the knowledge of system software; afterwards they improve the population structure and specialized into multiple populations on all kinds of software products, including system software, support software and application software. Lastly, upon enough accumulation of knowledge on software products, brand and market development, they climb up the chain and forms a new population with an independent brand and IT property.

Type II evolution pattern can be described as the following. Software companies first build up the complete ecology chain in a detailed product field and perform all of the activities ranging from research, design to coding in order to improve the R&D capacity of the population and the individuals; then they spawns new populations and individuals that are capable of performing R&D on higher level of software products via population succession of the software enterprise, which results in the succession of the entire community.

There may be variance to the theoretic patterns above in the real development process of the software enterprise. First, when the innovation ecology community of software enterprise came into being, all of the species may not be at the lower-end of these two dimensions. It is probable that some species exist at the middle of these two dimensions; Second, the ideal state for the innovation ecology community of the software enterprise is at the right-top, which means that all of species in the software enterprise present a better innovation chain and a reasonable product composition. The analysis on the evolving pattern of innovation ecology community in the software enterprise is based on the above framework basically reflects the development process of the software enterprise.

5 CASE STUDY

In the development history of software enterprise originated from the US, which has experienced four stages. Especially from the 1980s, the software enterprise went through rapid development. It is represented by the mergence of numerous new products and even new generations. This is also indicated by the fact that more countries taking their shares in the world software industry and become the large countries of software, such as Indian, Ireland and Israel. They have made great progress in the software industry and the detailed data are listed in the following table, where the development index of software refers to the ratio between the rate of total output value of software industry in the total value of GDT and the personal income of GDP. This table shows the basic situations of different countries' software industries in 2002. The given data tell us that the US takes the most weight in the market of software industry, which takes the dominated place in the world software industry. However, other countries, such as Indian, Ireland, Israel, Brazil and China, are the new members in the software enterprise. In the analysis on these data, it is apparent that the total output value of software enterprise in China approximates those of Indian and Ireland. But there are huge differences in the several inspection data, such as the rate of this total output value compared with GDP. Besides, though the average personal output value is similar with that of Indian, it is in the lowest list. The huge deviations of software industries in Indian, Ireland, Israel and Brazil are resulted from their different evolving patterns in the different environments. The detailed evolving processes for different countries are given as follows in table 1.

Table 1: Evolving processes for different countries.

Country	Software output (billion US dollars)	People involved (10K)	Output per person (10K)	GDP (%)	Software development index
US	2000	102.4	19.53	2	0.05
India	125	25	5.00	2.5	0.96
Ireland	139	2.79	49.82	11.4	0.38
Israel	41	1.5	27.33	3.7	0.17
Brazil	77	16	4.55	1.5	0.22
China	133	19	3.76	1.1	0.23

Account software sub-populations, the first software cluster in Shanghai, China, has experienced the process as Figure 3. From both figures, we can see that the changes of sizes of populations very well inline with our succession model.

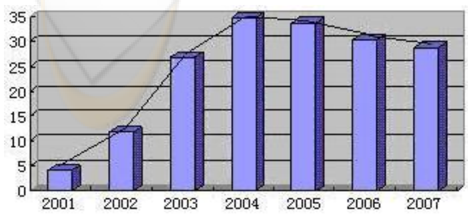

Figure 3: Average numbers of competitors in account software population.

If we consider the two species in this sub-populations: N_1 for domestic account software companies and N_2 for foreign account software companies, the number changes of above two species shown as Table 2 are accorded with the Lotka-Volterra model in equation (1) and (2). The equilibrium point of (3) and (4) are: N_1^* =19.245, N_2^* =6.341.

Table 2: Number change of species in account software population.

	2001	2002	2003	2004	2005	2006	2007
N_1	3	12	17	24	26	22	19
N_2	5	7	9	13	9	7	5

6 CONCLUSIONS

Technology innovation in software enterprise is an adaptive complex system with its special mechanism and evolution patterns. With the ecological theory, we have explored their dynamic mechanism. Based on the research of rival relationship with Lotka-Volterra model, this paper derives two evolution patterns of software innovation community succession model. We are in the process of refining the model and colleting more data for a better validation.

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