TL 015

BIOLOGICAL DESCRIPTION OF PATENT TECHNOLOGY

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Abstract Understanding the evolution path and dynamics of technology evolution—whether for the purposes of forecasting technology trend ,identifying key points and development phases or studying relationships among technology, society, culture, sports and so on—is a key challenge for innovators and policymakers. This paper presents concept of technology population under framework of population ecology and evolutionary biology, and interprets hierarchic relationship among technology population, technology individual (technology integration) and technology community; identifies status of patent technology population through several parameters, like density of patent technology population, nasality and mortality; age structure and spatial distribution structure; explores growth rules of patent technology population; finally, describes evolution process of technology population with patent technology evolution map, and made an evolution map for optical lithography patent technology population based on analysis from patents retrieved from USPTO in optical lithography domain to locate aberration points and phases of technology population.

Keywords Biology, Patent Technology, Technology Population

1 Introduction

Innovative ecology as a new research direction of technology innovation was first proposed by Nelson and winter in their book An Evolutionary Theory of Economic Change in 1970s, according to theory of biological evolution [1]. Tong Wu brought forward concept of technological ecology, an emerging literature working on technical activities, technical composition, and correlation among inner technical system, external environment, technological activity and human life. Lucheng Huang has ever studied on hypothesis of application ecological theory and methods on technology management, and then further analyzed technological innovation behavior in different hierarchies, like individual behavior, population behavior and community behavior and discussed rules on regional technological innovation behavior [2]. John Ziman researched evolutionary characters on knowledge, invention and technological innovation system from perspective of creature's evolution [3]. Jianqi Mao worked on components and characteristics of technological innovation system, and analyzed power source of technological innovation evolution from market choice, factor interactions, innovation individual and innovation environment, competition and collaboration, and then proposed evolutionary model of technological innovation, and finally discussed principle of co-evolutionary on technological innovation and external environment [4]. Gediminas Adomavicius interpreted patterns of technological evolution in framework of Ecosystem, and illustrated technological development with status paragraph [5].

In the recent few years, there have been many attempts to interpret technological innovation problems with ecological theories. However, few achievements resulted from patent technology population. Patents as one of the most important technological innovation achievements take significant role on development of society. And its quantity change and evolutionary path exhibit salient characteristics of population. According to this, the present paper strives to apply theories of population ecology and evolutionary biology on patent technology analysis, proposes concept of patent technology population and expounds its rules of development. Though study on characteristics and evolutionary laws of patent technology, we could receive some meaningful revelations.

2 Technology Populations

2.1 Technology Population and Technology Community

The concept of population on ecology is based on individual creature, while the concept of technology population is based on technology individual that is single operable programs used for transferring from input set to objective set in certain social and human environment [6]. In most cases, individual exists in technology population as single technology or technology integration, which is a

technology carrier, conformed by interaction among certain single technologies. For instance, CT machine for medical includes precision machinery manufacturing technology, electronic control technology, X-ray technology, computer technology, imaging technology etc, most of which contains many technology individuals. And all of them combined through complicated interactions into an integration that is computed tomography. The technology set of every kind of computed tomography builds up CT population. The difference between technology integration and technology population is mostly relative and several subpopulations can be arranged if necessary.

Tab.1 Technology Individual, Technology Population and Technology Community

Community	technology Community
Population	Patent technology population, non-patent technology population; emerging technology population, traditional technology population; etc.
Individual	Technology individual (technology integration)

Generally speaking, technology innovation problems cannot be solved by only considering technology individuals. It is important for researchers to put technology and relative technology together as a whole to study rules of technology development [6]. Technology population is a collection of specific technology individuals. And different scopes of individuals consist of different technology population. Ta.1 shows that technology population can be divided into patent technology population and non-patent technology population classified by whether technology is recorded in patent document or not; technology population can also be divided into emerging technology population and traditional technology population. As collections of relevant technology individuals, each of them has particular age structure and spatial distribution and quantity change.

Technology community is described as a group of two or more populations occurring in a particular area and technology ecosystems. These populations connect with domain and social requirement community through knowledge and information flows, and produce many complicated dynamic and static relationships [7]. A natural and stable community can utilize energy adequately to correspond connections inside populations and between populations and outside environment.

2.2 Characteristics of Technology Population and Technology Community

A technology population contains certain number of individuals in unit domain or space, and quantity of individuals is changing every time. In history of technology, birth and growth of one technology population is measured by quantity of population members. The boom of knowledge and human demand promote increase of solutions, namely growth of technology population; if nobody utilizes this kind of technology, it could be determined to death [3]. Then, technology population usually distributes unevenly in certain regions with strong technology innovation capability. Last, technology population is a self-organized, self-regulated system, in which relationships among inner factors, environmental factors and population quantity variation are studied and mechanism of quantity variation is discovered [8].

Main characteristics are as follows.

(1) The structure of technology community can be divided into two layers, technology population and technology individual or more according to practical need. Multilayer structure of community just exhibits technology evolution path occurred from basic to advanced, from imperceptibility to intricacy, from original to mature. Different levels have different property, structure and quantity variation rules. High level contains low level and could dominate low level [9]. Generally speaking, structure of technology community is increasingly diversified, number of population boosts steadily and relationships between populations and communities are complicated significantly.

(2) Status of technology community is changing from time to time. In the process of evolution, hierarchy and complexity of technology community enhanced, and structure and function of overall system is regulating along with change. The evolution power of technology population originated from inside and outside of system. Interconnections and interactions among various technology individuals and technology populations form intrinsic evolution power of technology community. Such close relationships among various populations are not occasional, and will create self-expansion of modern technology, because each innovation will simultaneously lead to direct and indirect results [6].

Interactions between technology community and other community or environment factors are extrinsic agent of community evolution, for instance selective action from economics community, culture community and sport community to technology community often restricted speed, scale and direction of technology community evolution [10, 11].

(3) Although every technology individual and technology population contained by technology community has unique function and composition, all of them interrelate and interact as an organic integrity. Overall structure, function and character of technology community cannot display in technology individual level and population level.

3 Patent Technology Population And Patent Technology Community

3.1 Concepts

Patent technology population refers to collection of all patent technology individuals in certain domain. Table 2 shows that patent technology population can be divided into information communication patent technology population, patent biotechnology, new material patent technology population and so on, according to different research domains. Patented technology community refers to integrity of patent technology formed by close relation among patent technology population and interaction with other communities and the environment factors. Description on technology population and technology community with patents is significant in theory research and practice. First, patent documents, one of the most important achievements obtained from technology innovation behaviors, have clearly recorded progressions human being has ever made in technology domains. It is an extension on technology innovation study to study development laws with patent analysis method. Second, with ecological characteristics of patent document, it is convenient to determine population parameters, like nasality, mortality and age structure and discover dynamic change laws of technology population with math formula, considering interactions among patent technology populations, patent technology communities and environment factors and other communities. This study could provide novel perspective to interpret relationship between technology and society, culture, sport etc.

Table 2 Patent Technology Individual, Patent Technology Population and Community

Patent technology community	Patent technology community
Patent technology population	information communication patent technology population, patent biotechnology population, new material patent technology population etc.
Patent technology individual	Single patent technology (technology integrity)

3.2 Characteristics of Patent Technology Population

3.2.1 Density of patent technology population

Density of patent technology population, a parameter changing with environment and control time means number of patents in unit technology domain. Density investigated set in particular time and space, reflects correlation between technology and environment. A boom in density of patent technology population in a short period indicates a breakthrough of technology innovation in this domain.

3.2.2 Nasality and mortality of patent technology population

Nasality of patent technology population refers to number of patent authorized recently in unit time, including nasality of issued and reissued patents.

Mortality of patent technology population means number of patent out of authorization in unit time. As well as nasality, there are two kinds of mortality. One is for patents out of protection deadline; the other is for patents without payment.

Thus, size of population is decided by four basic parameters.

Population change = nasality – mortality = (nasality of issued + reissued patents) – (mortality of patents out of protection deadline + mortality of patents without paying annual fee)

3.2.3 Age structure of patent technology population

Age structure of technology population, a important parameter also known as age distribution, refers to categorization of the population of communities by age groups, allowing researchers to make analysis for the growth or decline of the particular population, status of population structure and development trend, which would help governors make full use of technology innovation resources.

Jingwen Li used age structure method to illuminate dynamic trend, and than determine stability of community [12]. Pyramid shape structure suggests an expanding population; cone shape structure means a steady population; upside-down pyramid shape indicates a declining population.

Figure 1 shows an age structure of technology population made by patents collected from USPTO with 'wide viewing angle' as keyword. The USPTO patent database has been the principal data source used in the development technology population age structure method because it attracts inventors and innovators from all over the world, and patents from it could reflect evolution process of technologies exactly. On 6~14 age, age structure of population exhibits pyramid shape, suggesting old age individuals are more than young age individuals, nasality of population is higher than mortality, and technology is on growing-up stage; on 1~5 age, age structure shows upside-down pyramid, reflecting high mortality and low nasality of the technology population and the technology is on declining stage.

3.2.4 Spatial distribution structure of patent technology population

Intricate interaction among technology populations, communities and other environment factors, such as overall level of market development in regional cities, R&D investment, foreign investment, and proportion of research personnel in population distributed region has generated corresponding style of proliferation distribution in specific space. Individual spatial distribution structure in population can be classified into four types: random distribution, uniform distribution, accumulation distribution and sporadic distribution. Usually, technology population distributes in cluster in certain enterprises, institutions and cities particularly with strong technology innovation capability. Accumulation distribution is one of the most widespread kinds of distributed structure.

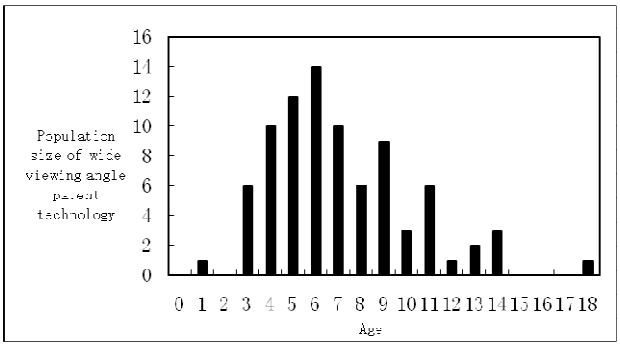

Figure 1 Age structure of wide viewing angle patent technology population

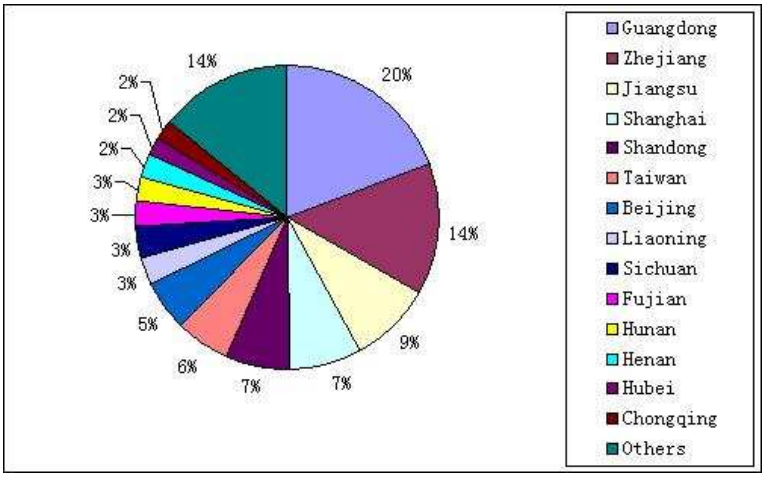

Figure 2 Spatial distribution situation patented technology population in Chinese various provinces and cities in 2007

Chinese spatial distribution of approved patent technology population in 2007 is described as Figure 2, based on China statistic yearbook 2007. Quantity of patent technology population grew rapidly in coastal cities, especially Guangdong, Zhejiang, Jiangsu and Shanghai, while in western areas like Inner Mongolia, Shaanxi and Xinjiang quantity of patent technology population increased steadily. That is because there are massive funds and intelligence resources investment, good economic basis, science and culture foundation as well as ability to take risks in coastal area, and also developed manufacturing

industry in coastal area has huge demand of technology innovation, all of which are advantageous to stimulate proliferation of patent technology population in these regions. However, growth rate in other areas is still slow [13].

4 Growth Laws on Patent Technology Population Quantity

Under influence from internal and external factors, quantity of patent technology population always maintains dynamic balance and variation over time. Internal factors include intrinsic nasality and mortality of patent technology population; external factors contain competition, prey and other conditions. In order to understand influence on patent technology population suffered from technology community and environmental factors, mathematical model is generated to study growth rule of patent technology population. In view of intraspecific growth model of ecology population, quantitative formula in patent technology population could be build up to analyze behavior type and development law of patent technology population.

4.1 Characteristics of Patent Technology Population

The increase in a patent technology population occurs when birth rate is higher than the death rate. A growth curve, obtained by plotting population size against time, is typically S-shaped or J-shaped [14]. A J-shaped growth curve shows an initial phase of exponential growth that ceases abruptly, with a sudden decrease in population numbers. This decrease may be caused by a number of factors, such as the end of the life cycle of the prey or any other factor contributing to environmental resistance that may suddenly take effect. This kind of growth curve is on the assumption that endless resources and space could support individual's endless propagation, which is not possible in nature. A sigmoid growth curve shows an initial phase of exponential growth. The curve levels off when the environment has reached its carrying capacity, i.e. when food, space, and other conditions can support a given number of individuals without an increase in population numbers.

In a circumstance with limited technology innovation resources, growth of technology is closely related to R&D investment in this domain with an S-shaped curve. On a typical technology development path, patent technology population increase steadily on initial R&D stage, because scarce resources invested lead to small number of patents. When R&D investment is injected gradually, the population starts to grow, the curve does go through an exponential growth phase, but as it gets closer to the carrying capacity, then the growth slows down and it reaches a stable level. There are many examples in nature that show that when the environment is stable the maximum number of individuals in a population fluctuates near the carrying capacity of environment. Generally speaking, replacement of emerging patent technology population will not occur before existing patent technology population reaches climax. This is because when incessancy improvement generated from investment, companies favors to continuously invest on the existing technology population rather than emerging technology population on their first choice list [15]. After technology becomes mature, improvement achieved on existing technology path declines due to competition from emerging technology population or application domain restriction of existing technology [16].

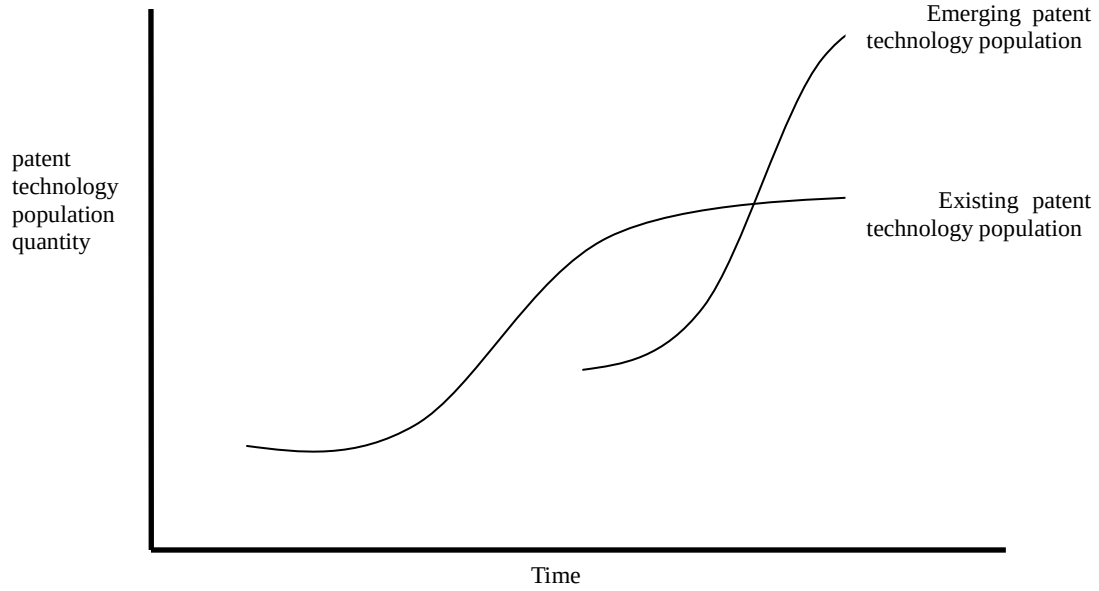

Table 3 Growth and evolution of patent technology population

4.1.1 Assumptions of patent technology population model

Application of patent technology population model should satisfy several assumptions:

(1) Per capita birth and death rates are assumed to be constant regardless of age structure.

(2) Carrying capacity of technology domains with finite R&D resources, modeled by parameter K, is also assumed to be constant;

(3) Instantaneous responses are assumed;

(4) Linear relationship between growth rate of patent technology population and density of population, i.e. f(*N*)=(K-*N*)/K;

4.1.2 Logistic model of patent technology population

$$dN/dt = N(r\text{-}cN) \quad (1)$$

$N \rightarrow K$, $dN/dt=0$, $r\text{-}cN=0$,

$$c=r/K$$

$$dN/dt = rN(1\text{-}N/K) = rN(K\text{-}N)/K \quad (2)$$

N represents the population size at time t. The units of time could be hours, days, years, etc;

K represents carrying capacity of technology domains with limited R&D resources, the maximum population size that a given domain can support;

R referred to as the Malthusian factor, is the multiple that determines the growth rate;

(K-*N*)/K is logistic coefficient, reflects how far patent technology population is from its maximum limit.

If patent technology population size N is far below K, it would tend to grow rapidly because resources of technology innovation are not absorbed adequately; as it approaches K, the growth would slow down; when N reaches K, population size becomes stable and balanced; if the population size would exceed its upper limit K, the growth would actually be negative due to overlarge scale of patent technology population competes for relatively scarce resources of technology innovation.

The growth of patent technology population typically follows an S-shaped curve that can be divided into four stages. Namely the construction stage, the development stage, the stability stage and the decline stage, The first is slow initial growth phase, as new technology is being explored with small number of patents output, leading to few individuals in technology population and steady increase on density. Once a breakthrough occurs, a period of rapid growth phase follows and density of patent technology rises exponentially as patent technology individual's rocket. Finally, its growth is limited by technological or socioeconomic factors and levels off toward some upper limit, and reaches stationary phase in carrying ability and then goes to decelerating phase.

4.1.3 Logistic growth model with time lag

Actually, time lag exists between the change in patent technology population size caused by mutative technology innovation environment and its effect on patent technology population growth,

which will change logistic coefficient finally. Logistic equation incorporated time lag.

$$dN / dt = rN[1-(Nt-w /K)] \quad (3)$$

Nt-w= population size in the past, the population growth at time t is controlled by its size at some time in the past, t-**w**.

Ratio of time lag to response time controls population growth. When r**w** is small, population increases smoothly to carrying capacity; r**w** is large, population enters into a stable oscillation called a limit cycle, will rise and fall around K and never reach equilibrium; r**w** is intermediate, populations undergo oscillations that dampen with time until K is reached.

4.2 Studies On Principles Of Technology Evolution Based On Patent Technology Population

Technology evolution roadmap tool is employed to describe evolution path of technology population. It consists of two parts. One is aberrance point, also known as key technology point in technology evolution process; the other is technology development path joining two adjacent aberrance points [17]. In terms of technology individual, technology development, as an important and indispensable R&D process without aberrance points, exhibits as a specific form in a period of time. We consider key technology points in technology roadmap tool which often used in technology foresight as marks of technology evolution, and then draw technology evolution roadmap to describe overall evolution process.

Figure 4 provides an evolution roadmap of optical lithography patent technology population drawn from almost 300 patents retrieved in USPTO. In 1980s, the I-line (365 nm) light source was filtered from mercury lamps. As phase-shift masks (PSM), off-axis illumination (OAI), optical proximity effect correction (OPC) and pupil filtering (PF) technologies were widely used to improve performance of optical lithography system, resolution limit was increasingly ameliorated in early 1990s [18, 19, 20]. Optical lithography system with KrF and ArF light source was originated from the end of 1990s, then improved by adopting several technologies leading to rapid proliferation of patent technology population of optical lithography, and has located in optical lithography technology mainstream successively. Observed from evolution map, fierce competition occurred between I-line optical lithography technology population and KrF optical lithography technology population in late 90's and latter population replaced former one finally; since immerging system was introduced in 2002, relative technologies on ArF optical system were broken through and became one of the most compelling patent optical lithography technology population.

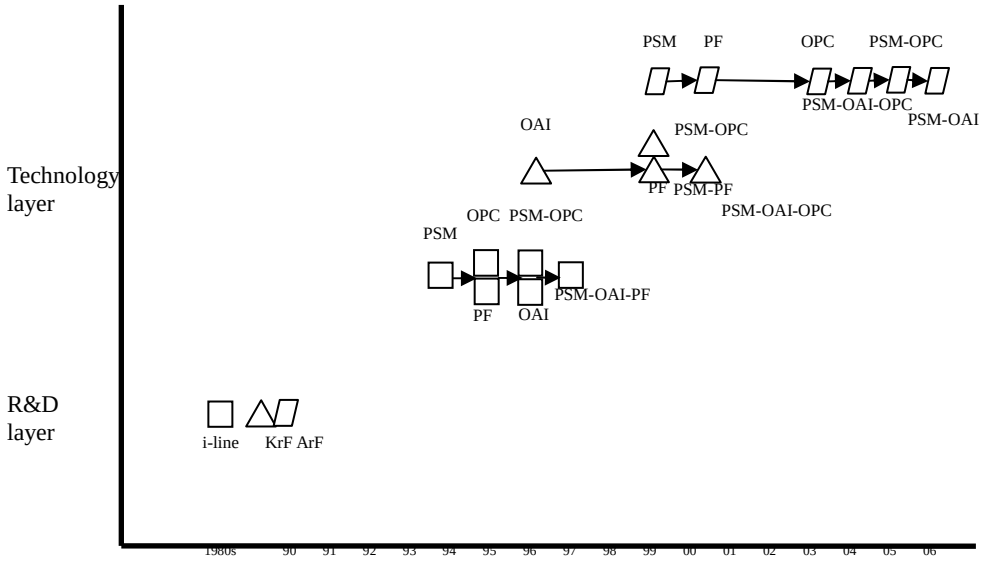

Figure 4 evolution map of optical lithography patent technology population

5 Conclusions

Patent documents, as one of the most important achievements obtained from technology innovation behaviors, have clearly recorded progressions human being has ever made in technology domains. Then,

on discuss of technology innovation problems, researchers can not solved them by only considering technology individuals. It is important that researchers put technology and relative technology together as a technology population to study the rules of technology development. According to ecological characteristic of patent document, status of patent technology population and evolution principles of technology could be identified to discover that evolution process of patent technology population conforms to principles of population biology and evolution process of technology could be studied with relative theories and methods of evolution biology and population ecology. In addition, influencing factors of population quantity variation and stages of technology development could be found out and located through exploring on growth model of patent population quantity. Finally, evolution map of patent technology population drawn according to analysis on patents retrieved in relative domain is a utilized approach to describe overall evolution process of technology population. In this paper we interpreted that the only way for study on evolution of patent technology population is to hold aberration points and corresponding phases of technology population evolution build up technology development path thoroughly.

In this article the concept of patent technology population is proposed and could be further extended to technology population in communities, with which could facilitate to solve technology development problems. Next, we are planning to consider more influential variables in Logistic model of patent technology population to investigate various forces and internal and external institutions controlling population quantity variation. In addition, technology evolution roadmap tool provides an approach to visualize technology development path, which could be used to technology foresight domain and explore primary impetus behind evolution. Furthermore, our current model focused on single technology population. We plan to extend to study interaction and co-evolution process among multi-populations and even technical, social, economic, athletic and other communities.

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