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An empirical study on classification of patent life patterns①

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Abstract

With the theoretical framework of patent information life cycle, this research studies the relationship between patents' life patterns and technological development stages of the relevant field, using life status in patent information life cycle as the research dimension. Data of patents issued in the field of wireless charging are retrieved from the United States Patent and Trademark Office Library. Citation information about these patents is also collected. By analyzing the temporal citation count data of patent information, the patents' life patterns using the RSD/P classification method are classified. This study found that the emergence of different life patterns of patent information has strong connection with the technological stage in which the patent information is located, and sleeping beauty patents have high hidden values. In the stage of technological development, attention should be paid to the identification of non-stationary patents. Rapid identification of high-value patents, i.e., patents with certain life pattern, is instrumental to accelerate the development of technologies. This study provides a viable approach for identifying high-value patents of emerging technologies through empirical research.

Key words: patent information, life cycle, wireless charging, life pattern, high-value patent

0 Introduction

With the development of science and technology, intellectual property has been widely valued in the world. Protection of intellectual property helps to promote social development in a positive and orderly manner. The vast amount of patent information generated in this process, like other scientific literature, web information and documentary information, is governed by the law of aging. In the process of aging, some information is paid close attention to, while others are seldom used; some information gets recognized quickly, while others attract attention much later only after being triggered by some factors. Patent information shows different life patterns during the process of being exploited. Identification and classification of these patterns help people understand the status of the patents in a field from a new perspective. This article adopts a specific classification method to classify the life patterns of patent information in the field of wireless charging, explores the distribution of various life patterns and further analyzes the field.

1 Research review on life patterns of patent information

1.1 Life cycle theory of patents

The concept of life cycle originates from the biological field and refers to the whole process of a living being from birth to death. Many scholars believe that information in various forms, such as literature information, web information, and patent information, has a process of continuous loss of value and aging, which is called the life cycle of information. Gosnell[1,2], based on the study of the selection of library literature, proposed a law of aging of the literature. He believed that the use of library literature would have a process of the use number of new published books which would increase to a maximum and return to the baseline gradually after a few years of fluctuations, and creatively proposed a life cycle exponential model of literature information to accurately describe the rate of change of this process. Indicators such as the half-life period and rate of obsolescence were used to measure document

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aging. In 1976, for the first time, Clark[3] studied the age and aging of patent information from the perspective of citations, and found the characteristics of the distribution of patents being referred by scientific literature and other patents over time after 1836. Caballero and Jaffe[4] pioneered studying the life cycle of patents with citation data by proposing the dual-index model from the innovative perspective of patent being cited, and used the model to explain the process of patent information dissemination and the law of patent information ageing.

1.2 Life patterns theory of patents

Life pattern is the trend of citations to a literature changing over time during its life cycle. A common approach used by many scholars to identify the life patterns of literature information is to collect the citation data of literatures in a field and then draw citation-time series curves to distinguish different life patterns of literature information based on the citation profiles in the dividing time periods.

In 1979, Avramescu[5] combined curve fitting and qualitative interpretation methodologies to describe the citation-time series curves of literature information and divided its life patterns into five types. 1) Initially much praised articles, the literature was used quickly after publication, then was forgotten at once, and the peak in the citation curve was relatively high. 2) Basic recognized work, the literature was quickly recognized after publication, then the degree of citation gradually decreased, the peak in the citation curve was lower than the first type. 3) Scarcely reflected work, the literature attracted attention gradually after publication and then the degree of attention faded out gradually, with a lower overall degree of recognition and very low peak of citation curve. 4) Genial work, the literature was well recognized and had been cited frequently after publication, the citation curve grew in exponential form. 5) Well-received but later erroneous qualified work, the literature attracted constant attention after publication, but then suddenly lost it for some reasons. In the research process, Avramescu's method represented life status of the entire literature and could not explain the life pattern of individual literature information.

In 1985, Aversa[6] used quantitative methods to classify life patterns of 400 highly cited articles. Considering both the external and internal features of the literature information, the author determined the features of the citation patterns through the K-means clustering method. In addition, a discriminant analysis method was used to classify the literature information into two types: the delayed rise-slow decline type, which received the largest fraction of total citations in the sixth year following publication, with a gradual drop-off in citations; and the early rise-rapid decline type, which showed a citation peak in the third year followed by a rapid decline in citations. However, the implementation of this method is cumbersome and is not suitable for the processing of big data. In 1989, Mccain and Turner[7] used a method similar to Aversa's to divided 11 highly cited articles into two types: slowly aging and quickly aging, by using an aggregate citation context measure and the mean utility index, and believed that the slowly aging paper representing important theoretical concept could not be distinguished from quickly aging papers using citation context alone. In 1991, Cano and Lind[8] considered the field of literature and divided the classic and common literature from medical and biological categories into two types: rapid growth-gradual decline and steady growth-rapid growth, by using the citation-time series curve.

In 2003, Aksnes[9] studied the life pattern of high-cited papers. The author used a relative standard method to define highly cited documents and established the theoretical basis for highly-cited to some extent. The author used 5 years as the paper cited time window, to count the citations of each document within 5 years after publication, and then used the relative standard method to determinethe citation of other documents, to classify their types. The authors finally divided the literature information into three types: early rise-rapid decline, medium rise-slow decline, delayed rise-no decline. However, selection of the time window was rather subjective and lacked strong theoretical basis.

In 2005, Dalen and Henkens[10] selected literature published from 1990 to 1992 to track their times of being cited within 10 years and divided them into four types: rarely cited, short-lived, standard, and sleep-beauty. The author integrated the quality of the literature into the selection of literature and evaluated the quality of the literature in terms of the author's reputation, the journal's influence, and the zero-cited state of the literature.

In 2010, Costas et al.[11] proposed the quartile statistics method to classify the life pattern of literature information. According to the half-life of each document and the relationship between P_{25} and P_{75} of the group in which the document was located, the life style of the document was divided into three types: flashes in the pan, which received citations immediately after their publication but were not cited in the long term; delayed documents, which received the main part of their citations later than normal documents; and normal documents, which with a typical distribution of citations over time. This method solved the problem of the cited frequency in Aversa's research. It was not only suitable for high-cited papers but also for low-indexed ones. However, the author did not consider the problem of living conditions of document such as the aging of document.

2 Introduction of RSD/P method

2.1 Evaluation of classfication method

Comparing with earlier methods used for classification of life patterns of patent information, Aversa standardized the citation data within 8 years after highly cited paper were published, and used the K-means clustering method to classify the patterns. This approach is rigorous but the process is cumbersome. At the same time, the highly cited documents come from the same period, and the observation time of the cited records is also the same, which is not conducive to multiple periods nor a large number of patent data processing. Aksnes uses relatively standard method that is, a paper has been considered as highly cited if it has received more than a certain multiple of the citations of the average paper within the scientific subfield instead of a fixed threshold, i. e. 400 citations, to expand the number of samples in the study. There will be errors due to the presence of singular values in the selection of the time window and error classification occurred in article with a very slow or 'delayed' citation growth. The quartile statistics method is more universal than the aforementioned two, because it can be applied to both highly-cited documents and rarely-cited documents, and it takes into account both the type of literature and the domain issues of the literature during the patterning process. The method is relatively simple and adaptable, but it uses the average life length in different field and literature type as the index, ignoring the individuality between the documents.

In the division of the life pattern, most studies follow the Avramescu's citation-time series curves fitting method, and simplify or enrich the five types of curves. Dalen and Henkens's[10] classification has become the more mainstream division, namely, the flash-in-the-pan type, noted early and receiving few citations, the standard type, noted early and receiving many citations, and sleeping beauty type, noted late and receiving many citations.

2.2 The RSD/P method

In this study, the quartile statistical method is drawn on. Inspired by Dalen and Henkens's[10] classification of life patterns, RSD/P method is used to classify the life patterns of patent information into epiphyllum type, standard S type, sleeping beauty type and smooth type, of which the first three types are non-stationary life pattern.

The RSD/P method draws lessons from Wang's[12] life pattern classification of network information which combines the advantages of the relative standard method and the quartile statistic method, using the relative standard deviation (RSD) as an important index, and combining the reference points of the half-life T_{50} with the reference ratios P_{25} and P_{75} to classify the life pattern. In early stage, patents and citation database are conducted, then the life length of patent is calculated for each patent, not as a whole. The selection of relative indicators P_{25} and P_{75} improves the applicability of the method. Meanwhile, the stationary type is distinguished, that is, the number of citations in each observation interval after publication of the article is within the acceptable range of small fluctuations, and there is no obvious citation peak, which had not been clearly differentiated and scattered among other types in previous studies, resulting in a certain amount of research error. The RSD/P method is a creative improvement of existing methods.

The core steps of this method are as follows.

- Calculate the RSD value for each sample patent. The calculation formula is as below, where z_i is the number of citations of each sample patent in the ith period, S is the standard deviation of z_i, $\bar{z}$ the average number of citations in each sample patent life cycle and sample patent life-cycle refers to the length of time from the approval of an authorization to its expiration or the end of the observation, n is the number of groups in which the patent is located.

$$RSD = \frac{S}{\bar{z}} - \frac{\sqrt{\sum_{i=1}^{n}(z_i - \bar{z})^2}}{\bar{z}} / n \qquad (1)$$

- Calculate the RSD value of each patent, and determine threshold C according to the 80/20 rule. The RSD value and the C value of each patent are divided into two groups; when RSD value is less than C, it is stable, and when RSD value is greater than C, it is non-stationary.

- For non-stationary patents, calculate the reference half-life T_{50}, which is the first reference time to reach 50% of the time.

- For non-stationary patents, the groups are grouped according to the same public audit year, and

P_{25} and P_{75} of each group are calculated respectively, that is, the time when the group's citation count reaches 25% and 75% for the first time.

- For the non-stationary patent, T_{50} of each piece of information is compared with the pieces of P_{25} and P_{75} of the group which it belongs to, and if $T_{50} < P_{25}$, then it is the epiphyllum type, if $P_{25} < T_{50} < P_{75}$, then it is the standard S type, if $T_{50} > P_{75}$, then it is the sleeping beauty type.

3 Empirical study on wireless charging based on RSD/P method

3.1 Data set acquisition and preprocessing

This paper selects U.S. Patent and Trademark Office (USPTO) issued patent library (Issued Patents) as data source and uses (CCL/307/104 OR CCL/191/10 OR CCL/455/573 OR CCL/320/108) OR ((CCL/455/41.2 OR CCL/320/$ OR CCL/D13/108 OR CCL/455/41.1) AND (TTL/Wireless OR TTL/Contactless OR TTL/Non-contact OR TTL/Noncontact OR TTL/Inductive OR TTL/Resonant OR TTL/Charge OR TTL/Charging OR TTL/Transmit)) as the search formula. A total of 7 272 patents related to wireless charging were obtained from the search of wireless charging domain by using the search formula. The search time was December 10, 2015. The data was cleaned by excluding patents with missing metadata, zero cited patents, and merging equivalent patents issued in the same country. After the cleaning step, there were 5 240 valid sample patents, involving a total of 30 031 cited records and 91 936 reference records to form the Patent Data Sets. Then a total of 4 541 patents were selected from January 1995 to December 2015. According to the relationship between patents, the patent authorization time was used as a starting point to calculate the cited time, citation frequency, the cumulative number of citing times and cited percentage of each patent in the month to form 'Cited Times-Time Series' database.

The authorization time of the patent is treated as the beginning of the patent life cycle. If the patent is not cited for a period of time T, it is considered that its probability of being noticed in the future is not high, i.e. the patent has lost its value. This point in terms of time represents the end of the patent life cycle. The determination of time T uses the 'double-proportion' method[13]. The method works as follows. Say for the first time, the sample patent does not obtain any other patent reference in a unit of time T, and the cumulative number of the patent being referred from its authorization time to the moment reaches P1. Now when the ratio of the number of patents to the sample patent portfolio reaches P2, the minimum T value satisfying the dual ratio of P1 and P2 is considered as the effective value, which is then used as the judgment criterion of the failure time and life length of the sample patent portfolio. The effective T value 16 is calculated when P1-P2 is the standard 60% – 60%. Using this value, 3 811 sample patents have been selected with valid ends in their life cycles to do the life pattern analysis.

3.2 Wireless charging patents' life patterns classification

According to the citation data of the patent, patent citations fluctuate over time. The fluctuation of the citations of some patents always stays within a relatively stable range after being authorized. Which is called 'stationary patents'. Some patents, after being authorized, have many fluctuations in the number of citations of patents, such as rapid increase or rapid decline over time, which are called 'non-stationary patents'. To directly reflect the fluctuation of the citation quantity of patent, the RSD value is used to quantitatively describe the degree of patent citation fluctuation. The calculation procedure of the RSD value is described in detail with the patent '5675627' as an example, shown in Table 1.

Table 1 Cited timing distribution of patent No. 5675627

Period (year)	Citation frequency	Cumulative proportion	Period (year)	Citation frequency	Cumulative proportion
1	0	0.00	10	6	0.57
2	0	0.00	11	5	0.66
3	1	0.02	12	2	0.69
4	3	0.07	13	2	0.72
5	8	0.20	14	3	0.77
6	6	0.30	15	2	0.80
7	4	0.36	16	7	0.92
8	4	0.43	17	4	0.98
9	3	0.48	18	1	1.00

The patent information has a life span of 195 months, and was cited 61 times during the life cycle. The patent life length is divided into time segments by year. According to the data in Table 2, the average citation frequency, standard deviation and other related indicators are calculated. According to Eq. (1), the RSD value of the patent is calculated to be 1.49.

According to the influence of patent conversion rate on patent classification, the author believes that the citation data of patents indicates the degree of patent attention, the transformation of patent results is related to many external and complicated factors, and the patent literature itself is weak. Therefore, when classifying patent documents, the conversion of patents is considered as a weak correlation factor.

Table 2 Various indicators statistics of patent No. 5675627

Patent No.	Length of life	Total cited times	Average citations $\bar{z}$	Standard deviation S	RSD
5675627	195	61	0.31	0.46	1.49

According to the above operation method, the RSD values of all the patents in the patent group are calculated, and the RSD threshold C is determined to be 1.735 according to 80/20 rule. According to the relationship between the RSD value and threshold value C, the patent information of the sample is divided into two types. When RSD > C, it is non-stationary patent, and RSD < C, it is a stationary patent. For example, patent 5675627's RSD value is less than the C value of 1.735, therefore it is a stationary patent.

For non-stationary patents, further pattern division is needed. On a monthly basis, the non-stationary patents are grouped according to their authorization approval time to calculate the cited half-life of the patent T_{50} and the patents P_{25} and P_{75}. Cited half-life T_{50} refers that the time interval of the patent's citation exceeds 50% for the first time. For example, the sample patent '5 532 526' authorized in July 1996 has been cited 20 times within the valid life span. In November 2000, the cumulative number of cited citations in the total number of citations exceeded 50% for the first time, and the cited half-life value T_{50} of the patent was 52 months. P_{25} and P_{75} refer to the time interval that the number of citations in the same group reaches 25% and 75% of the total number of citations respectively. Take the 8 patent samples authorized in July 1996 as an example, the total citation frequency of the 8 sample patents within the valid life span is 68 times. When the citing patents to the eight patents are arranged according to the order of approval time, the upper and lower quartiles, i.e. the time interval between the approval time of this group of patents and time when the 17th and 51st citation happened, can be calculated respectively. It is concluded that P_{25} and P_{25} of this group of samples are 34 months and 57 months respectively.

The life model of each non-stationary patent is determined by comparing the T_{50} with P_{25} and P_{75}. July 1996 group classification results are shown in Table 3.

Table 3 Life patent for sample group in July 1996

No	Patent No.	Authorization time	Cited times	RSD	P_{25}	P_{75}	T_{50}	Life pattern
1	5532526	199607	20	1.7386	34	57	52	Standard S
2	5536979	199607	8	1.7903	34	57	37	Standard S
3	5537023	199607	1	2.111	34	57	10	Epiphyllum
4	5539296	199607	1	2.0588	34	57	18	Epiphyllum
5	5539297	199607	10	1.7424	34	57	36	Standard S
6	5541491	199607	8	1.7451	34	57	30	Epiphyllum
7	5541492	199607	8	1.8167	34	57	41	Standard S
8	5541496	199607	12	1.7595	34	57	54	Standard S

3.3 Distribution and discipline of four life patterns

According to the RSD/P classification method, the sample patents are divided into four life patterns, and the distribution rules of life patterns are shown in Fig. 1. Smooth patents' curve is almost in parallel with the X axis; the patent received a steady amount of attention since the date of authorization, with less fluctuation over time. Epiphany patents receive a great deal of attention within a short period of time from the date of authorization and reach their peak of citation early, then followed by then are followed by a rapid decrease till they are no longer cited. Standard Stype patents' curve is similar to the normal distribution curve, which gradually reaches the cited peak and then gradually decreases with the lapse of time since the authorization day, which is the most ideal time distribution curve. Sleeping beauty patents seldom gain the attention at the beginning of the authorization for a relatively long period of time and then receive sudden recognition while the number of being cited increases rapidly.

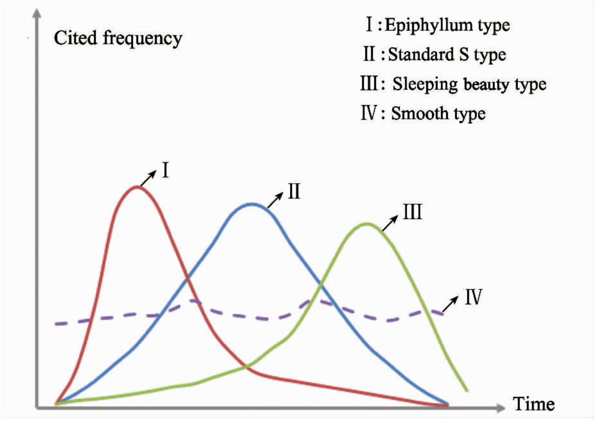

Fig. 1 Four types of life Pattern curves

Meanwhile, the distribution of patent life patterns mainly depends on the fluctuations of the quantity of patent being cited over time, which has nothing to do with the total number of citations of patents. Fig. 2 shows the citation distribution of the two patents licensed in 2010, i. e. patent '7741734' and '7647024'. The RSDs of the two patents were 0.91 and 0.92 respectively. Though the fluctuations of the cited times were similar, the total cited frequencies of the two patents were quite different. Patent '7741734' has been cited in total of 231 times since its authorization. Since 2012, the total number of citations per year has remained at around 70, while patent '7647024' granted in the same year has been cited 86 times and the annual number remained at about 20 times. This shows that there is almost no direct relationship between the citation quantity of RSD and the total citation number of cited patents, and the RSD value can reflect the fluctuation of citation quantity without being affected by cited times patents.

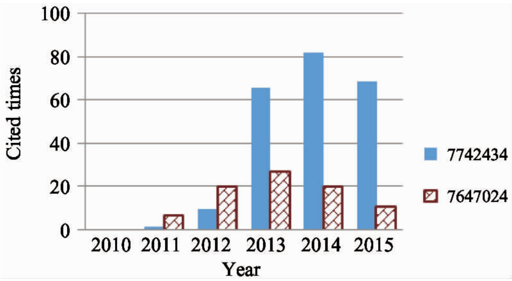

Fig. 2 Cited times distribution of two smooth types patents

3.4 Analysis of patent life patterns classification

The patent life pattern of the 3 811 patents in the field of wireless charging is determined by RSD/P classification method, and the results are shown in Table 4. Among the samples, the standard Stype patents accounted for the highest proportion of 45.03% and the sleeping beauty patents accounted for the least amount of 13.36%, while the epiphyllum and smooth patents accounted for about 20%. The proportions of only non-stationary patents, i. e. three types ratio, were examined in Table 4, and standard Stype was found to be still accounted for the highest proportion of 56.28%, while sleeping beauty patents accounted for the least proportion of 16.69%.

Table 4 Life pattern distribution of sample patents

Life pattern	Smooth	Epiphyllum	Standard S	Sleeping beauty
Number of sample patents	762	824	1716	509
Ratio of four types (%)	19.99	21.62	45.03	13.36
Ratio of three types (%)	--	27.03	56.28	16.69

To further understand the distribution of patent information patterns in the field of wireless charging, the distribution of life patterns in each year from 1995 to 2014 was statistically analyzed in units of years. Table 5 shows the statistical results. As can be seen from the chart, the average annual percentage of stationary patents is between 20% and 30%, and the distribution is relatively stable. Among the non-stationary patents, the highest proportion of standard S patents is followed by the proportion of epiphyllum type patents, and sleeping beauty type patents accounted for the least.

From the overall perspective of changing, the trend of the four types of patents and the trend of the total number of sample patents are basically the same, but the number of sleeping beauty patents shows completely different trend in the later stage, which increased or even exceeded the number of smooth patents and epiphyllum patents after 2012. The reason for this phenomenon is mainly attributed to the relatively low timeliness of the patents, as the sample patents authorized from 2012 to the present are more likely to be cited after 2014, in other words, the patents are still in the early stage of life, and the number of the patents being cited is relatively low and the cited time occurs mostly after the half-life, as a result, some of them are classified as sleeping beauty type.

Table 5 The yearly distribution of life patterns

Authorized year	Smooth	Standard S	Epiphyllum	Sleeping beauty	Sum
1995	20	27	14	7	68
1996	29	41	16	8	94
1997	31	69	34	14	148
1998	19	66	21	17	123
1999	29	76	34	16	155
2000	29	71	33	14	147
2001	26	53	30	15	124
2002	26	51	33	15	125
2003	17	41	27	18	103
2004	14	32	13	13	72
2005	28	37	21	13	99
2006	34	51	32	7	124
2007	33	52	42	11	138
2008	42	67	40	19	168
2009	47	90	54	15	206
2010	61	120	91	20	292
2011	73	167	80	30	350
2012	77	226	101	76	480
2013	94	238	59	59	450
2014	30	119	49	106	304

The emergence of this phenomenon also reflects the classification method used in this article has some limitations. In view of the patent authorized in recent years which is in the early stage of life, our study has difficulties in distinguishing its life pattern from the perspective of complete failure, instead its life pattern is divided according to the cited situation of patents from the authorized time to the end of observation time. This is theoretically feasible, however, in the actual operation some of the recent patents will likely be falsely classified.

It can be seen from Fig. 3 that between 1995 and 2000, the numbers of all four types of patents were relatively small and increased only minimally. The invention of wireless charging first appeared in 1985, but at that time, the shortage of technological funds and other aspects caused the development of wireless charging technology to be stagnant and the subsequent development was also at a slow stage. Therefore, the patents in this period were only at a slow growth speed. From 2001 to 2004, there was a slight decrease in the number of smooth, standard Stype and epiphyllum patents, indicating that innovation in wireless charging technologies was weak during this period, and sleeping beauty patents were still in a relatively stable state, while its large proportion means this period made a large proportion of core patents for the latter development of wireless charging. Between 2005 and 2012, the four types of patents all showed an upward trend and the ephemeral growth rate at this stage was larger than the smooth type, and the difference in the number of patents between them was widened. Many patent technologies continued to emerge and got cited in a short period of time shows that there has been more researches in the field of wireless charging at this stage and the innovation vitality has been enhanced, most of the technology in sleeping is awakened.

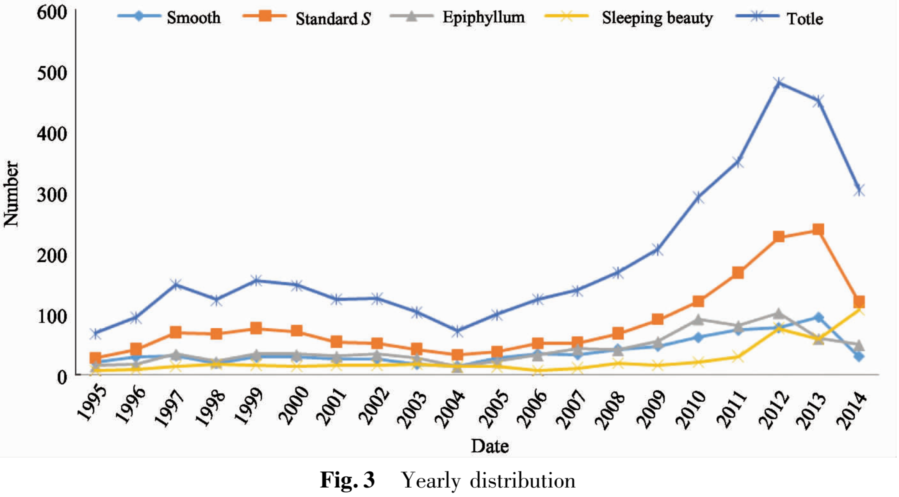

Fig. 3 Yearly distribution

4 Conclusion

To a certain extent, the variation of life patterns of patents reflects the development stage of technology in a certain field and also reflects the variation of patent value. With the classification of life patterns in the paper, conclusions are made as follows.

1) From the perspective of classification methods, the "RSD/P" classification method is adequate in classifying the life pattern of patents in the field of wireless charging. However, since the time range selected in this paper is the date of data download, citation information of some patents in recent years cannot be fully collected, and therefore it may be not precise enough to determine the patent mode at the early stage of the life cycle.

2) According to the classification results, the standard Stype patents in the field of wireless charging accounted for the highest proportion and greatest fluctuating with time; the smooth type and the epiphyllum type accounted for the second highest, and the sleeping beauty type accounted for less, and the development was relatively stable. In general, the percentage of epiphyllum type patents accounts for about one-fifth, which is relatively small compared to other fields. The other three types of patents with higher value are still the focus of the current researches. Although there is some rapid development in this field, it is still at an exploratory stage. Related research patents still focus on intrinsic high value and R&D is stable.

3) From the perspective of the development of technology and the life pattern of patent information, the research focus has shifted from the core technology researches to the broadened multi-field researches as technologies progress. Specifically, the early core technologies were gradually accepted by people after a period of exploration and the number of stationary patents and sleeping beauty patents increased slightly, then the technological fields were continuously expanded, resulting in a large number of standard Stype and epiphyllum patents, as the technological development has matured.

4) From the viewpoint of the value of patents, the average value of the smooth patents is relatively higher, and the sleeping beauty patents have higher hidden value. The stationary patents witness little fluctuations in citation frequency over time and receive constant amount of attention. The value they bring is relatively stable. The sleeping beauty type was seldom paid attention to in the early days, and the time they were suddenly cited was mostly in the period when wireless charging technology was actively developing and it also drived the growth of other types of patent information. After the sleeping beauty type patents are generated, they need to wait for being discovered by late-stage researchers and have a large potential value to drive the development of technology.

5) According to the life cycle theory, the patent literature is divided and evaluated, and the value changes of different types of patent documents in their life cycle are discussed in depth. The following is some assumptions about the changes in the internal value of the patent document life cycle. The residual value of the patent document reaches its peak at the time of its publication. Over time, the value of patent documents is converted, and the residual value tends to zero. Different patent documents have different value conversion modes in their life cycle, and the initial value of value is different. Patent documents are in the degree of value conversion in its life cycle is related to the emergence of alternative patents. The value conversion of different patent models in their life cycle will be introduced in the next article.

This paper conducts an empirical study on life pattern of patents in wireless charging domain based on the RSD/P method. The field of wireless charging is an emerging field. Its development time is short, and the characterization of the life pattern of patents may not be perfect yet. In the follow-up study, a more mature field can be an alternative choice. In addition, the scope of the sample selection still needs further expansion. This paper selects the data of USPTO, which limits the patents of wireless charging to only those licensed in the United States; incompleteness of the sample may also cause biases in the classification and description of life patterns.

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