Research on the New Method and Example of Patent Analysis—the Perspective of Patentees

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Abstract: In recent years there have been an increasing number of studies adopt the method of patent analysis to analyze the development and trend of technology. However, this kind of patent analysis increasingly fails to meet the needs of the technological competition between enterprises due to the dynamic development of competition and the trend of technology integration. Technology is changing so fast, if just analyze technology itself, it's hard to position the enterprises themselves as well as measure the development of an enterprise's competitors only with patents. In order to overcome the disadvantages of the traditional patent analyzing method, this paper adopts patent analysis with the technological subject, namely the patentee, as the research unit. For this study, firstly, we use the patentee co-citation method combined with MDS method to derive the coordinates of each patentee. Secondly, we cluster the patentees into several groups. Thirdly, according to the coordinates and the clustering results, we mimic the centroid calculating method in physics to calculate the centroid of each patentee groups and the centroid of the whole network. Finally, we calculate the distance from several typical patentees to the centroids in different time windows to judge the future development direction of the enterprise.

1. Introduction

With the rapid development of science and technology, industries with high-tech technologies are constantly showing the phenomenon of convergence and crossover (Takano et al., 2016), and technology itself shows the characteristics of shortened cycle, accelerated reform and dynamic development (Park et al., 2015). To adapt to the fierce competition and occupy an invincible position, it is necessary for enterprises to have a clear understanding about the technological development level and future technological endeavoring direction of the whole industry, competitors and their own company.

In recent years there have been an increasing number of studies adopt the method of patent analysis to analyze the development and trend of technology because patent data is publically available (Daim et al., 2006) and full of valuable information (Park et al., 2005; Park et al.,2015). Besides, according to the report of World Intellectual Property Organization, patent publications covers nearly 90–95% of the world's R&D outcomes (Takano et al., 2016), indicating that patent is an important data source for research. However, prior researches are almost all take technology represented by the patent itself as the research unit no matter at the technological level or at the enterprise level. However, this kind of patent analysis increasingly fails to meet the needs of the technological competition between enterprises due to the dynamic development of competition and the trend of technology integration. Technology is changing so fast, if just analyze technology itself, it's hard to position the enterprises themselves as well as measure the development of an enterprise's competitors only with patents.

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In order to overcome the disadvantages of the traditional patent analyzing method, this paper adopts patent analysis with the technological subject, namely the patentee, as the research unit. Focusing on patentee can not only help us grasp development trend of the whole technology in the industry, identify technology subject's position in the industry, but also help us effectively measure competitors' technological level and future endeavoring direction, thus helping managers to make reasonable strategic decisions.

For this study, firstly, we use the patentee co-citation method combined with MDS method to derive the coordinates of each patentee. Secondly, we cluster the patentees into several groups. Thirdly, according to the coordinates and the clustering results, we mimic the centroid calculating method in physics to calculate the centroid of each patentee groups and the centroid of the whole network. Finally, we calculate the distance from several typical patentees to the centroids in different time windows to judge the future development direction of the enterprise.

Our paper contributes to three aspects. Firstly, we propose an analytical method that takes the patentee as the unit of analysis. It effectively solves the drawbacks of patent analysis with technology as the unit. Secondly, through the proposed analysis, the structure of patentees in the display screen can be identified and the whole technology direction of an industry can be tracked, so practitioners can have a good understanding of the technological development and direction of industry and enterprises. Thirdly, in terms of method, we introduce the concepts and algorithms in physics into our patentee co-citation analysis and give an example case to explain the operation process of the new approach.

2. Methodology

2.1. Overall research framework

The overall process of our proposed approach consists of the following two modules—establishing an industrial technological reference system and positioning enterprises (See Fig. 1). In order to establish an industrial technological reference system, this paper mimic the concept of centroid reference in classical physics. This requires us to determine the origin and the axis of the frame of reference. After the establishment of the industry technological reference system, the technological position of enterprises can be determined by the technology distance of the enterprise to the reference system's axis.

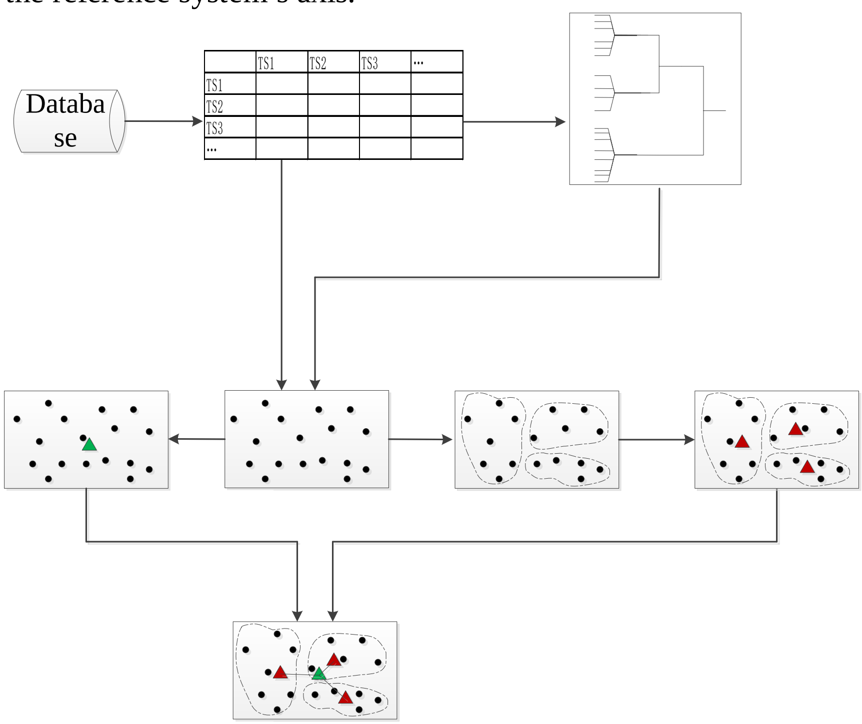

Fig.1. Operation procedures of the new method

2.2. Detailed procedures

2.2.1. Locating the patentee centroid of the entire network

The application of the concept of centroid has played a very important role in the development of physics. After introducing the concept of centroid into physics, many theorems are easily obtained (e.g. the momentum conservation theorem of multi-body system and the parallel axis theorem of the inertia of rigid body). At the same time, the concept of the centroid makes the related concepts in physics more accurate. Centroid in physics refers to an imaginary point where the mass is considered to be concentrated. It is an ideal model which is obtained by scientific abstraction to represent the overall particle system for simplifying the complex problems in mechanics. Here, a particle which is also an idealized model of physics is a point with mass but no volume or shape. As we all know that the object itself, in fact, have a certain size. However, if the size of the object is extremely small compared to the other dimensions of the problem studied and can be ignored, then the object can be approximately regarded as a particle. The particle system is a mechanical system of many particles that interact with each other. Suppose that a particle system is composed by n particles whose masses are denoted as $m_1, m_2, \dots m_n$, then the position of centroid can be determined by the following formulas.

$$m_c = \sum_{i=1}^{n} m_i \tag{1}$$

$$x_c = \frac{\sum_{i=1}^{n} m_i x_i}{\sum_{i=1}^{n} m_i} \quad y_c = \frac{\sum_{i=1}^{n} m_i y_i}{\sum_{i=1}^{n} m_i} \tag{2}$$

Here m_c is the mass of the whole object, m_i is the mass of part i. x_i ,y_i are the horizontal and vertical coordinate of part i ,respectively. x_c,y_c are the horizontal and vertical coordinate of centroid, respectively. n is the number of the patentees in the particle system.

Through the above calculation, the position of centroid can be clearly determined on the coordinate system.

To analyze the overall industrial technology development and trends in a more concise and accurate way, we mimic the concept and calculating formulas of centroid. Since the centroid is an imaginary point that represents the whole particle system, so we use this concept for reference to establish the industrial centroid (IC) for the whole industrial technology. The IC represents the concentration of technology in the entire industry.

It takes three steps to realize the localization of IC:

(1) Constructing a co-citation matrix of patentees. Wwe build a co-citation matrix of patentees. This step is equivalent to establishing a particle system in physics. In physics, it is generally believed that an infinite number of massive particles consist of an object. Similarly, an industry is also composed by numerous technological subjects. To calculate the centroid in physics, we need to locate the position coordinates of each particle. Similarly, in order to calculate the industrial centroid, we first need to build the patentee network and then locate every patentee's position coordinates in the network. So we use co-citation to build an industrial patentee network.

(2) Mapping the patentees. After constructing the co-citation matrix of the patentees, we need to position every patentee's coordinates. We use Multidimensional Scaling Analysis (MDS) to map the patentees. Multidimensional scaling (MDS) is a set of mathematical techniques used to reduce data dimensions. It shows hidden structures in the data through visualizing them (Rangarajan and Raich et al., 2008). MDS algorithm inputs the distances between each pair of object and outputs 2D-points or 3Dpoints (Stojkoska, 2014). It works by measuring the proximity between objects. If the proximity is high, these objects are close to each other .If the proximity is low, they are far away (Sagarra and Mar-Molinero et al., 2017).

(3) Locating the industrial technological Centroid. In this paper, we mimic the algorithm of irregular objects in physics to determine the position of industrial centroid. The calculating formulas are as follows:

$$e_c = \sum_{i=1}^{n} e_i \tag{3}$$

$$x_c' = \frac{\sum_{i=1}^{n} e_i x_i'}{\sum_{i=1}^{n} e_i} \quad y_c' = \frac{\sum_{i=1}^{n} e_i y_i'}{\sum_{i=1}^{n} e_i} \tag{4}$$

here e_c is patent number of all the patentees in a field, e_i is the patent number of patentee i, x_i',y_i' are the horizontal and vertical coordinate of patentee i ,respectively. x_c',y_c' are the horizontal and vertical coordinate of patentee, respectively, n is the total patentee number in the entire industry. Table 1 is the comparison between the calculated variables of IC and the those of centroid in physics.

Table 1 Comparison of the correlation factors between centroid and IC

Related concepts of centroid	Related concepts of CIT
m_c: the mass of the whole object	e_c: the number of all patents in an industry
m_i: the mass of particle i	e_i: the number of patents held by patentee i
x_c: horizontal coordinate of centroid	x_c': horizontal coordinate of CIT
y_c: vertical coordinate of centroid	y_c': vertical coordinate of CIT
x_i: horizontal coordinate of particle i	x_i': horizontal coordinate of patentee i
y_i: vertical coordinate of particle i	y_i': vertical coordinate of patentee i

2.2.2. Establishing a frame of reference

In order to accurately locate the positions of patentees, we need to resort to other reference standards in addition to the IC. Here we use the centroids of different patentee groups as the reference points. There are two processes for solving the centroid of industrial technology group:

(1) Classifying the network into several patentee groups. After constructing the co-citation matrix of patentees, we cluster the patentees by using hierarchical clustering. Cluster analysis, whose results are intuitive and concise, can objectively reflect the internal composition of the study object. One of the popular method of cluster analysis is hierarchical clustering. Hierarchical clustering is often described as a good clustering method (Steinbach and Karypis et al., 2000). Hierarchical clustering procedures are characterized by the tree-like structure established in the course of the analysis. There are several methods in hierarchical clustering, here we choose CONCOR .CONCOR is a kind of hierarchical clustering method, suggested by Breiger (Breiger and Boorman et al., 1975).It begins by forming a square matrix and then iterates on the matrix, eventually forms a blocked form. As CONCOR is based on the equivalence of structure, it is helpful to reveal the relationship position or roles of technologies in patent network (Jin and Kyung et al., 2016).

(2) Locating the centroid of the patentee groups. After the patentee groups are sorted, we calculate the centroid of each patentee group with a method the same as positioning the industrial centroid. The patentee group centroid (PGC) represents the concentration of technology in a group. The formulas are as follows:

$$e_f = \sum_{i=1}^{m} e_i \tag{5}$$

$$x_f' = \frac{\sum_{i=1}^{m} e_i x_i'}{\sum_{i=1}^{m} e_i} \quad y_f' = \frac{\sum_{i=1}^{m} e_i y_i'}{\sum_{i=1}^{m} e_i} \tag{6}$$

here e_z is patent number of all the patentees in a field, e_i is the patent number of patentee i, x_i',y_i' are the horizontal and vertical coordinate of patentee i, respectively. x_c',y_c' are the horizontal and vertical coordinate of patentee, respectively, m is the patentee number of a patentee group.

2.3. Technological distance's calculation

One method to characterize the technological environment and the technological position of a firm is the technological distance analysis (Jaffe 1986; Peretto and Smulders 2002). This article expends the technology distance calculation method to calculate the distance between patentees and GTCs. The concept of technological distance was first proposed by Jaffe in 1986, and he believed that the technological distance was the degree of similarity between the two enterprises in the technological space. In cluster analysis the degree of similarity between data points is generally (but not exclusively) computed in terms of Euclidean distance, based on the assumption that measurements are at least on an interval scale(Perrotta and Williamson, 2018).We used Euclidean distance formula to measure the technological distance. The formula is:

$$d = \sqrt{(x_i - x_t)^2 + (y_i - y_t)^2} \quad (7)$$

Here, d denotes the technological distance. x_i, y_i represent the horizontal and vertical coordinates of Patentee i in the multidimensional scale diagram, respectively. x_t, y_t represent the horizontal and vertical coordinates of GTCs in the multidimensional scale diagram.

3. An example of approach implementation: the case of display screen technology

In this case study, we select display screen industry, one of the most competitive peripherals in the market, as our research object. The selecting reasons are based on the following two aspects. Firstly, the technological classification of the display screen is numerous, containing the technology of optics, physics, chemistry, etc, and the display screen technology increasingly showing the phenomenon of integration with different fields of technology. Secondly, the number of relevant patents has likewise been steeply increased since the year 1995, indicating the display screen technology is changing rapidly. We choose Derwent World Patent Index (DWPI) database, the largest patent database in the world, to conduct patent search.

3.1. Constructing the co-citation matrix of patentees

First of all, through sorting and screening the previous literature and web pages, we ascertain the keywords that can represent the display technology. Then we input the keywords into the DWPI database and retrieve the number of applications for patents from 1975 to 2017. Fig. 2 shows the number change of the patents. Through the picture we can see that there are two inflection points around 1995 and 2005,respectively, indicating the display screen field has experienced two major technological changes in its development. In order to reveal the technological changes well and shorten the time interval as much as possible, we choose the patent of over the 1995-2017 period which contain two inflection points as the research data. We select the top 38 patentees which hold patents that account for more than 0.5% of the total patents in the display screen industry during this period. The number of patentees and the percentage of total patents held by these 38 patentees are presented in table 2.

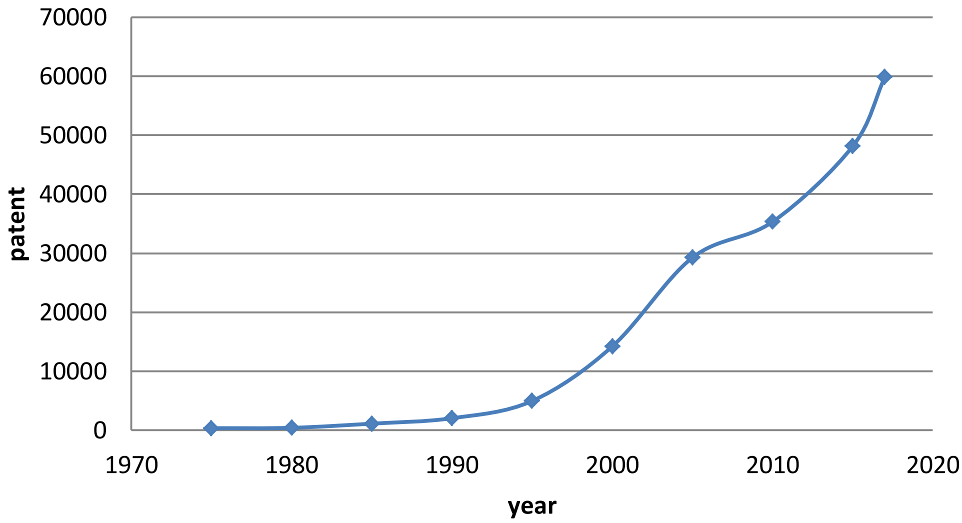

Fig.2. Number curve of patent applications over time

Table 2 Top 38 patentees in 1995-2007

Number	Patentee cord	Patents	Total patents %	Number	Patentee cord	Patents	Total patents %
1	GLDS-C	37265	5.625	20	SEME-C	5025	0.758
2	SMSU-C	34909	5.269	21	CHEN-I	4907	0.741
3	SHAF-C	18264	2.757	22	NIKR-C	4871	0.735
4	SHIH-C	17896	2.701	23	TIAN-N	4676	0.706
5	MATU-C	14688	2.217	24	WANG-I	4592	0.693
6	SHEN-N	12105	1.827	25	SUMO-C	4520	0.682
7	SONY-C	10397	1.569	26	TOPP-C	4360	0.658
8	FUJF-C	9191	1.387	27	DNIS-C	4343	0.656
9	CANO-C	8134	1.228	28	KONS-C	4333	0.654
10	SHAN-N	7865	1.187	29	CASK-C	4305	0.65
11	TOKE-C	7731	1.167	30	BEIJ-N	4181	0.631
12	BOEG-C	6902	1.042	31	JIAN-N	4109	0.62
13	HITA-C	6015	0.908	32	MITQ-C	3937	0.594
14	NIDE-C	5930	0.895	33	ZHAN-I	3860	0.583
15	TCLC-C	5723	0.864	34	INLX-C	3570	0.539
16	GUAN-N	5338	0.806	35	ARUZ-C	3414	0.515
17	NIPQ-C	5329	0.804	36	SUZH-N	3358	0.507
18	AUOP-C	5284	0.798	37	FUIT-C	3342	0.504
19	HDIS-C	5049	0.762	38	PARK-I	3310	0.5

Then we use 3 years as a time window to construct the co-citation metrics. After the co-cited number of patentees are retrieved by entering the keyword in DWPI, nine 38x38 matrix, each including 1444 cells, are constructed by calculating the co-cited times of the patentee pairs. After that, we use the jaccard formula which is considered more suitable for analyzing co-citation strength (Leydesdorff, 2009) to convert the former matrix into the jaccard coefficient matrix. The jaccard formula is shown below.

$$S_J(\mathrm{i},\mathrm{j}) = \frac{\mathrm{coc(i,j)}}{\mathrm{cit(i)+cit(j)-coc(i,j)}} \tag{8}$$

Here $\mathrm{S_J(i,j)}$ denotes the coefficient of Patentee i and Patentee j, $\mathrm{coc(i,j)}$ denotes the co-citation frequency of Patentee i and Patentee j, $\mathrm{cit(i)}$ and $\mathrm{cit(j)}$ are the cited frequency of Patentee i and Patentee j, respectively. The partial results after standardization are shown in the table 3.

Table 3 Example of normalized matrix

	SHEN-N	GLDS-C	SMSU-C	GUAN-N	TIAN-N	TCLC-C	SHAN-N	JIAN-N	BOEG-C
SHEN-N	1	0.010842	0.011264	0.042469	0.021816	0.041822	0.061010	0.026869	0.035265
GLDS-C	0.010842	1	0.186601	0.002528	0.001175	0.022959	0.006832	0.000735	0.038685
SMSU-C	0.011264	0.186601	1	0.003321	0.001978	0.019182	0.005824	0.000947	0.030956
GUAN-N	0.042469	0.002528	0.003321	1	0.021422	0.014133	0.045853	0.024861	0.011048
TIAN-N	0.021816	0.001175	0.001978	0.021422	1	0.007386	0.028849	0.019529	0.004600
TCLC-C	0.041822	0.022959	0.019182	0.014133	0.007286	1	0.022021	0.006555	0.127489
SHAN-N	0.06101	0.006832	0.005824	0.045853	0.028849	0.022021	1	0.034855	0.024950
JIAN-N	0.026869	0.000735	0.000947	0.024861	0.019529	0.006555	0.034855	1	0.004903
BOEG-C	0.035265	0.038685	0.030956	0.011048	0.004600	0.127489	0.024950	0.004903	1

3.2. Mapping two-dimensional scale analysis

After normalizing the raw matrix, we import the new matrix into SPSS 22.0 to do the two-dimensional scaling. We choose the square Euclidean distance as the measurement standard (Deutsch, 2011), and select “ordinal” in the approximate value conversion column. After reliability and validity testing, the values obtained in the statistical analyses that exhibit goodness of fit (stress of Kruskal’s formula all less than 0.2) and the estimated variance percentage (RSQ all greater than 0.8) show good fitness and meet the test requirements. The testing results are shown in table 4.

Table 4 Test results of Multidimensional Scaling

	1995-1997	1996-1998	1997-1999	1998-2000	1999-2001	2000-2002	2001-2003
Stress	0.00097	0.14400	0.16095	0.12835	0.16393	0.11564	0.12521
RSQ	1.0000	0.94345	0.92724	0.95164	0.91706	0.96188	0.94716
	2002-2004	2003-2005	2004-2006	2005-2007	2006-2008	2007-2009	2008-2010
Stress	0.13198	0.14068	0.17497	0.15321	0.16252	0.16368	0.02009
RSQ	0.93975	0.93013	0.88793	0.91195	0.92348	0.89803	0.99963
	2009-2011	2010-2012	2011-2013	2012-2014	2013-2015	2014-2016	2015-2017
Stress	0.00029	0.00025	0.18242	0.14845	0.14287	0.00039	0.15198
RSQ	1.00000	1.00000	0.84462	0.89855	0.90343	1.00000	0.88405

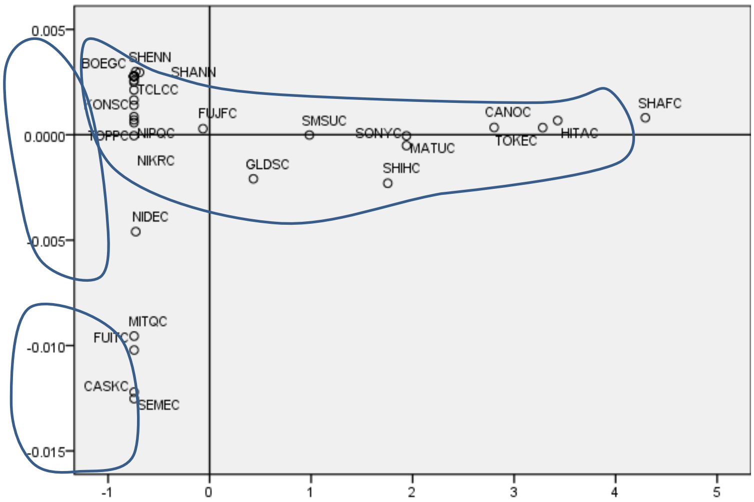

Fig.3. The coordinates of each patentee

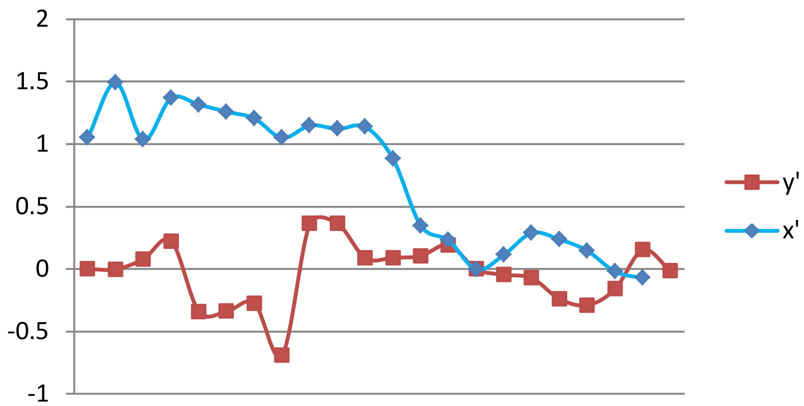

Fig. 4.Coordinate diagram of Centroid over time

According to the two-dimensional scale analysis, we get the coordinates of each patentee (Fig. 3). Calculated by formula (6), we get the change graph of the industry's centroid over time (Fig. 4).

3.3. Clustering the patentee groups

Fig. 5 shows the number of patents held of the top 38 patentees at different time Windows, which is one of the time windows we study. Then we put the standardized matrix into UCINET 6.0 to do the hierarchical clustering. After the CONCOR clustering, we get the tree diagrams (Fig. 6). It is clear that 38 patentees are clustered into several groups.

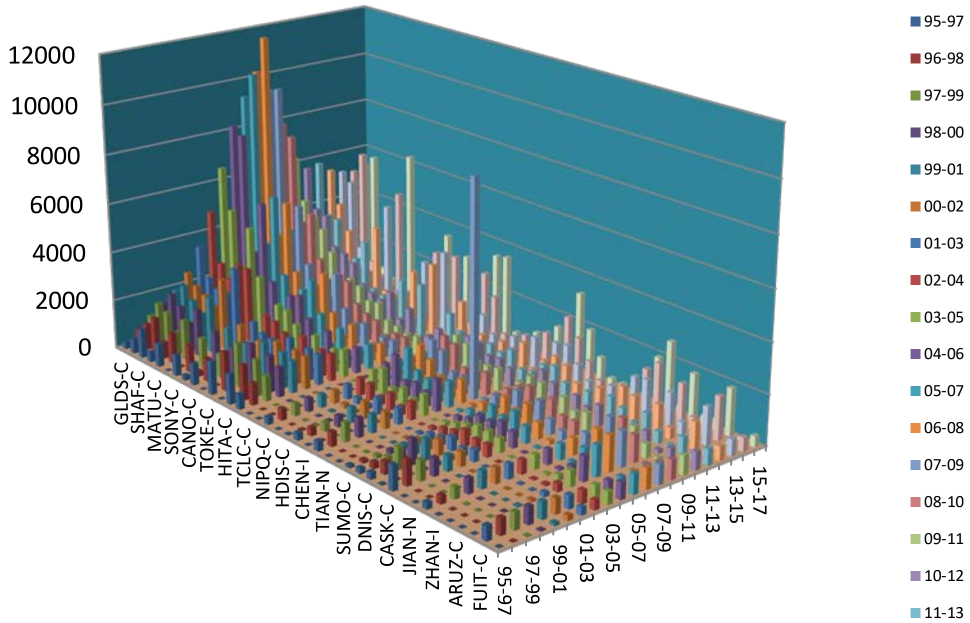

Fig. 5. The number of patents held of the top 38 patentees at different time Windows

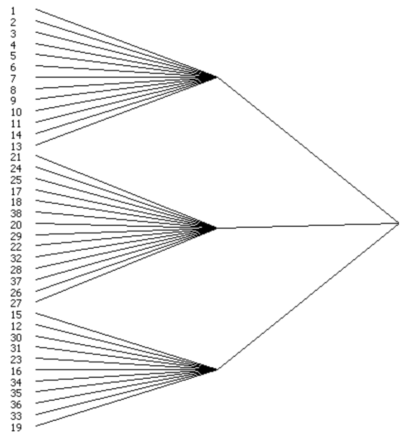

Fig. 6. Cluster diagram by CONCOR

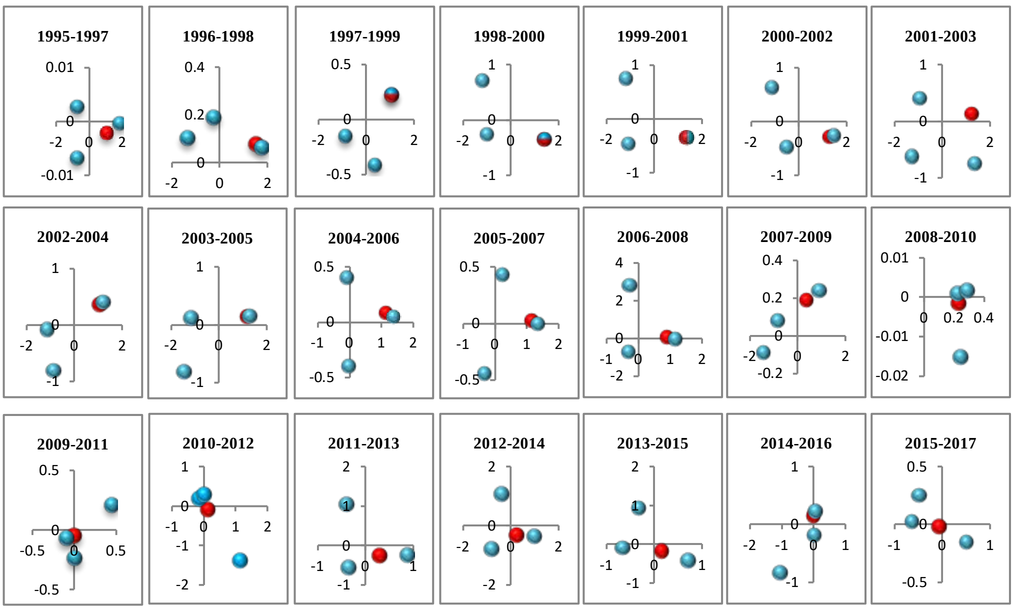

Fig 7. The distribution results of the IC and the TGCs over time window.

3.4. Calculating the technological distance

According to the quantity of patents granted, we choose three patentees SMSU-C, SHAN-N, HITA-C, which represent granted patents of patentee have been stable, have been growing, have declined, respectively. Then we calculate the distance between them and the centroid of each patentee group with formula (7). Fig. 7 shows the distribution results of the IC and that of the TGCs in each time window.

4. Discussion

Fig.8 shows the horizontal and vertical coordinate changes of the whole industry's centroid over the year 1995-2017. It can be seen that the vertical coordinates of industrial centroid fluctuate up and down in a small range near the axis, while the horizontal coordinate shows a decreasing trend after the year 1996, especially decreases sharply between 2005 and 2007. After 2008, the horizontal coordinates tend to fluctuate in a small range near the axis. This indicates that the development of Y-axis technology owned by the patentees is relatively stable, while that of X-axis technology owned by the patentees is greatly changed over time. By studying the development history of display technology, we find the screen technology, one of the main technologies of display screen, mostly use plasma technology before 2005. After 2005, liquid crystal technology (LCD) is widely used, which made a big breakthrough in display technology. Until now, LCD still dominate the display industry. This indicates that the X-axis has a high probability to represents the technological direction of screen technology.

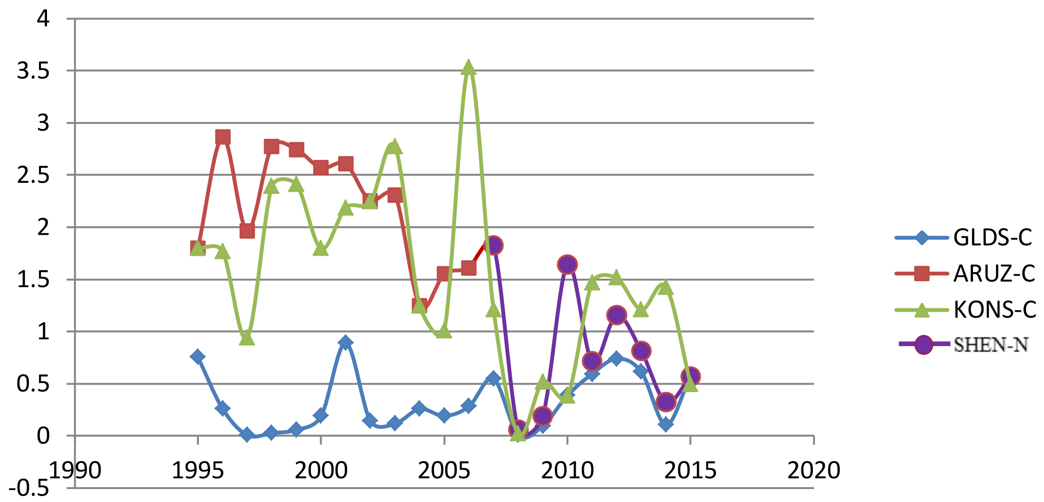

Fig.8. The distance from three TGCs to IC over time window

5. Conclusion

Although prior scholars mostly used the technology itself as the analysis unit. However, with the increasing of technology complexity and growing technology convergence, the previous approach which takes patents as the object of analysis has been unable to guide the development of enterprises. However, the technological subject remains unchanged, and the research capability and direction of the technical subject will not change easily. Therefore, the analysis of the technology subject can bring more guiding suggestions for the development of enterprises. This paper takes the patentee as the object of analysis, combines with the concept and calculating formulas of centroid in physics to build the patentee coordinate system, so as to locate the technological position of the patentee, i.e. the enterprise, and predict the technical effort direction of the industry and the enterprise.

Theoretically, this paper draws lessons from the idea of ACA method and takes the patentee as the analyzing unit. This unique perspective helps address the shortcomings of the traditional approach that take the patent as analysis unit. It can identify the technological structure of a specific field. Methodologically, this paper construct a coordinate system based on the concept of centroid in classical physics, so as to analyze the technological development trend of the whole industry, speculate the technological development directions of each sub-group in the industry and position the technological position of the patentee in the frame.

In practice, by constructing the centroid coordinate system for the technological subject of a certain industry, we can clarify the development sequence of the whole industry and the subgroup of the main technological subjects and predict their development directions. At the same time, this approach are also able to locate the technological position of the enterprise and its competitors in the dynamic and integrated industrial environment, so as to predict the future direction of the enterprise's technological efforts and guide the enterprise's strategy formulation.

Although the proposed method improves upon conventional patent analysis techniques, some limitations remain. First, only one case study is conducted in this paper. Although this case can confirm the validity and practicability of this method, it still needs a large number of cases to prove it. Therefore, for future work, several case studies in different fields are needed to verify the method's validity. And it is best to construct an evaluation model for the proposed method.

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