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Improvement of Technological Innovation of SMEs Using Patent Knowledge

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Abstract. Small and medium-sized enterprises (SMEs) play an important role in economic development. Due to the limited internal resources of SMEs, the introduction of technical knowledge in other fields is very important to improve its innovation level. In addition, highly innovative technical features can effectively stimulate designers' innovation inspiration. Therefore, in the process of introducing cross-domain technical knowledge, it is necessary to judge its innovation. However, due to a large number of patents in the industry, the operating efficiency based on the existing innovative evaluation methods is too low. Therefore, we propose a highly innovative technology feature screening method based on cross-domain technical knowledge. The method improves the evaluation efficiency of radical innovation (RI). At the same time, the improved method is conducive to deeply stimulating the generation of RI. The data supporting the realization of this method comes from public patent information, so this method has wide applicability to various industries. Finally, the application process of this method is explained by the electromagnetic switch industry.

Keywords: Technological innovation, Small and medium-sized enterprises, Radical innovation, International Patent Classification (IPC).
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1 INTRODUCTION

SMEs are crucial to industrial and economic growth. At the same time, SMEs have the characteristics of simple organizational structure and flexible management mechanism, which provide good conditions for improving the existing technological development mode. However, SMEs face a lot of uncertain challenges in the complicated market competition [11]. Improving the level of independent innovation is an effective way to deal with market competition. Therefore, it is necessary to propose a set of design methods to enhance the innovation level of SMEs.

Most of the existing methods to improve the innovation level of SMEs focus on the field of market and project management. Project management considers performance evaluation, project processing and implementation of SMEs [4]. Xu's research found that the level of independent R&D of SMEs that granted equity incentives to executives was significantly higher than that of similar companies [33]. Qin conducted an in-depth analysis of the transmission mechanism of three practical forms of high-performance work systems to RI products through a survey of senior managers of multinational companies in China [26]. In general, the research on the inducement factors and incentive mechanisms in the management field to enhance the innovation level of enterprises has been relatively complete. At the same time, considering the uncertainty of economic fluctuations and it is difficult to grasp the changing laws of the external competitive environment of enterprises in market competition. Therefore, the role of technological innovation in promoting enterprise development has attracted more and more attention from researchers.

For the empirical research on the relationship between technological innovation and SMEs growth has been carried out [2]. In order to ensure the development of corporate performance, Povolná think that enterprises should always pay attention to technological innovation, follow the latest technology [24]. Silvestri believes that the competitive advantage of successful SMEs is based on their product quality but not the price [27]. Comprehensive analysis of the views of the above scholars, technological innovation is fundamental to improve the continued competitiveness of SMEs. According to the different intensities of technological changes, technological innovation can be divided into RI and incremental innovation [19]. Different from incremental innovation, RI brings new technological opportunities to SMEs by generating disruptive technologies or products [6]. Therefore, this paper proposes a design method based on the characteristics of RI with the goal of improving the technological innovation of SMEs.

The rest of the paper is organized as follows. In section 2, the related research on the technological innovation and cross-domain technical knowledge method is introduced. In section 3, a process to improve the technological innovation of SMEs is proposed. To illustrate how to use the proposed method, in section 4, a case is studied and analyzed. We draw conclusions in section 5.

2 LITERATURE REVIEW

2.1 Cross-domain Technical Knowledge for Radical Innovation

Technological innovation is the process of enhancing the sustainable competitiveness of an enterprise by improving its technological development strategy. [34]. RI is an important form of technological innovation. Difference from incremental innovation, RI is based on the exploration and application of new knowledge for disruptive changes in technology. RI is considered as the key driving force for SMEs' growth [29].

The design process of RI is complicated, with high uncertainty, and the coupling of incentives. The research on RI in the field of engineering technology mainly focuses on the improvement of design methods. In order to solve the matter of problem-net coupling in the process of RI, Liang applies the multi-conflict theory to solve the optimal simplified path of the conflict network and simplifies the complex problem-net by solving key problems [18]. Liu proposed a knowledge energy dissipation model to describe the process of product innovation and combined ontology principles to express knowledge of different disciplines. Finally, it demonstrated that cross-domain knowledge can stimulate the generation of RI concepts [17]. Ping combined the dissipative structure theory and the catastrophe theory and put forward a method to solve the negative entropy problem to realize the generation of RI [25]. By summarizing the existing research methods, a large number of scholars have improved the RI design process from the perspective of knowledge. This is because, from the generation mechanism of RI, cross-domain resources and knowledge are the internal driving force that stimulates its generation. For SMEs, due to limited internal resources, it is difficult to achieve RI with their own resources [10]. Empirical research found that many successful SMEs introduced external knowledge to improve competitiveness [1]. Therefore, the introduction of technical knowledge in other fields is essential to realize RI for SMEs [7]. The introduction of cross-domain technical knowledge without discrimination will cause a large influx of invalid and low-level technologies. Designers need to spend a lot of energy to distinguish, which will significantly extend the development cycle, and it is also difficult to stimulate designers' high-level innovation inspiration. In fact, only highly innovative technical features are valuable. Therefore, in the process of introducing cross-domain technical knowledge, it is necessary to screen the innovation of technical features. However, the low evaluation efficiency of existing methods requires continuous improvement in theory.

The measurement of technology distance between knowledge is the prerequisite for identifying cross-domain knowledge. There are three measures of the technology distance: Min-complement distance, Cosine of the angle, and Euclidean distance measure [31]. Simon quantified the technological relationship between two enterprises based on their technology distance for the knowledge transferring [28]. Kay used the network map for the distance between technical fields [14]. A comprehensive analysis of the existing research on technology distance shows that the above methods are mainly used to measure the technological relationship between innovation subjects, analyze the development trend of competitors or partners, and clarify the development status of own company in market competition. These methods are still at a relatively macro level and are difficult to be used to determine the distance between technologies. Therefore, this paper proposes a method for measuring the distance between technologies based on the idea of existing measurement.

2.2 Technical Feature Evaluation

Highly innovative technical features can effectively stimulate the generation of RI concepts, so the innovative evaluation of technical features is particularly important.

Liu [16] proposed a method for evaluating innovation based on binary regression and empirical analysis and further used logistic regression methods to limit the calculation results to two values of 0 and 1, where 1 indicates that the technical feature belongs to RI, and 0 is the opposite. The proposed evaluation formula provides a concrete and operable method for the distinction of RI, and provides important theoretical support for innovation evaluation, and has strong practical value for helping companies to screen out highly innovative technical features. Guo [5] provides a quantitative model for evaluating disruptive innovation design schemes in advance from the perspective of functions, performance, and resources. Using this model can effectively increase product innovation opportunities for enterprises and reduce investment risks.

However, Due to the huge number of patents with related technical features in the industry, the screening efficiency of the existing RI evaluation formulas is too low. It is difficult for designers to apply in actual operation, which will greatly extend the product development cycle. Therefore, this article will improve the existing innovative evaluation methods and narrow the evaluation scope of technical features from multiple angles.

The selection of highly innovative technical features can effectively stimulate the innovation inspiration of SMEs’ designers, and ultimately achieve the improvement of the overall technological innovation level of the enterprise. A computer-aided software tool is also developed to improve the processing efficiency of patent knowledge.

3 METHODOLOGY

Cross-domain technical knowledge can effectively stimulate the RI concepts. Therefore, this article expands the distance measurement method used to measure the strategic relationship between enterprises and proposes a calculation method for calculating the technical distance between technologies to locate cross-domain technical knowledge. At the same time, highly innovative technical features can effectively stimulate designers’ creative inspiration. Therefore, based on the mining of cross-domain technical knowledge data, this article improves the existing innovative evaluation methods of technical features to improve evaluation efficiency. Combining the above analysis process, this paper proposes a screening method of highly innovative technical features based on cross-domain technical knowledge and perfects the theoretical research framework. This method can effectively improve the technological innovation level of SMEs, and at the same time can reduce the R&D cycle for RI. A process of improving the technological innovation based on the patent knowledge is proposed as shown in Figure 1.

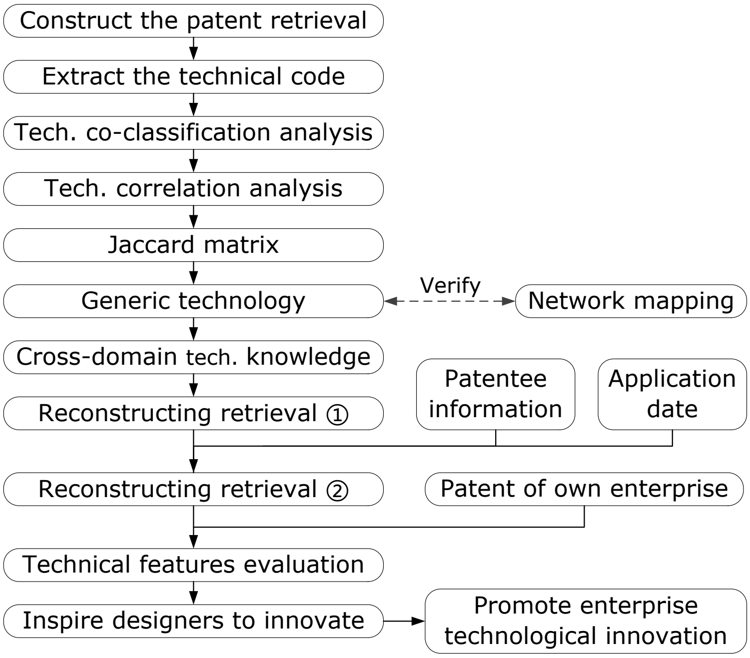


Figure 1: Improving SMEs technological innovation based on the patent knowledge.

3.1 Technology Distance

New knowledge can effectively improve the level of innovation of SMEs. A large number of technical features in patents is valuable knowledge resources [8]. More latecomer companies grow rapidly by introducing cross-domain technical knowledge from advanced companies [3].

Patent knowledge is an open resource [20] with valuable information in the industry, innovation, policy planning, and technological change [35]. International Patent Classification (IPC) system classifies patents according to their technical fields [12]. The structured knowledge in patents is an important resource to calculate technical distance. The style of the IPC system is shown in Figure 2.

A Part: Human necessities
A41 Class: Wearing apparel
A41F Subclass: Garment fastenings; Suspenders
A41F3/00 Group: Braces
A41F3/02 Subgroup: Strips, tongues, or the like, for attaching to the trousers

Figure 2: International patent classification system.

The IPC system is divided into five levels: Part, Class, Subclass, Group, Subgroup. The five levels are divided according to the continuous detailed description of the realized functions. Considering that the technology represented by IPC codes can describe the functions implemented in detail, IPC codes should not be too complicated to prevent the technology represented by it from not being generalized. Therefore, this article selects the group-level code in the IPC system for follow-up analysis.

The technical layout chart can quantitatively describe the technical application situation in the industry. This article uses Patsnap business software to do the technical layout analysis, and the statistical results are limited to the group-level of the IPC system. Figure 3 shows the technical layout of the cutting machine industry and counts the top ten technologies according to the number of applications.

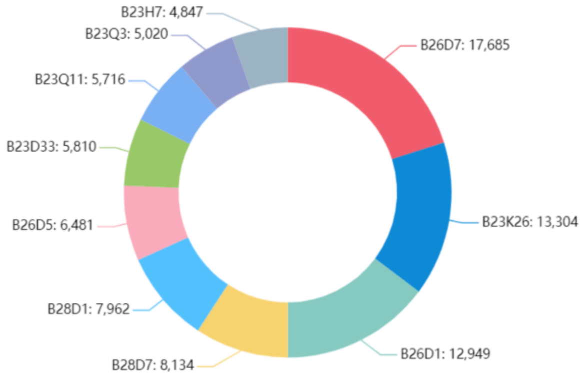


Figure 3: Technical layout within the industry.

Generic technology is the foundation to support the development of the industry, and it is also the technology with the largest number of applications supporting product R&D [13]. We propose a method to determine the generic technology and technology distance of an industry using the co-occurrence matrix and Jaccard correlation evaluation [32].

Patents carry a large number of technical knowledge in the co-occurrence of technologies [23]. For example, patent WO2017162209A1 records four IPC codes at the same time: H01H50/20, H01H50/56, H01H50/58, F02N11/08, to show the co-occurrence of these four technologies. Therefore, the IPC codes of the patent can be used for technology co-classification analysis and Jaccard correlation evaluation.

IPC codes of a patent can be found using the software tool Patsnap, such as Formula (1). In order to carry out the co-occurrence analysis, Formula (1) needs to be further processed.

Formula (1): H01H50/20 | H01H50/56 | H01H50/58 | F02N11/08

Replace "/*|" with";", and realize the identifier replacement except for the last code. The style is shown in formula (2).

Formula (2): H01H50; H01H50; H01H50; F02N11/08

Delete the character after the identifier "/*", and the style is shown in Formula (3).

Formula (3): H01H50; H01H50; H01H50; F02N11

Set the cell format to text, and customize the format to "@";"", such as formula (4).

Formula (4): H01H50; H01H50; H01H50; F02N11;

Through the above operations, the data is processed and input into the software Citespace for technology co-occurrence analysis. We assemble the above data processing into software, and the operation interface is shown in Figure 8. An example of the technology co-classification matrix is shown in Table 1.

	T1	T2	T3	T4	…
T1	34	12	9	8	…
T2	12	46	17	12	…
T3	9	17	54	11	…
T4	8	12	11	39	…
…	…	…	…	…	…

Table 1: Technology co-classification matrix.

The number in the diagonal of the co-classification matrix indicates the total number of times that the corresponding technology appears, and the number in other positions indicates the number of times that the corresponding two technologies appear in a patent at the same time. Jaccard coefficient is used to decide the correlation between two technologies by Formula (5).

$$J(i,j)=\frac{coo(i,j)}{occ(i)+occ(j)-coo(i,j)} \tag{5}$$

where J(*i*, *j*) represents the co-occurrence strength of technology *i* and technology *j*. coo (*i*, *j*) indicates times of the co-occurrence of technologies *i* and *j*, and occ(*i*) is the frequency of patents involving technology *i*, so as occ(*j*), as shown in Figure 4.

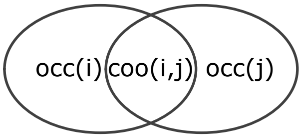


Figure 4: Technology co-occurrence strength.

Table 2 shows the Jaccard coefficient matrix obtained by Formula (5). Table 1 and Table 2 are symmetric triangular matrices.

	T1	T2	T3	T4	…	Sum
T1	1	0.176	0.114	0.123		0.413
T2	0.176	1	0.205	0.164		0.545
T3	0.114	0.205	1	0.134		0.453
T4	0.123	0.164	0.134	1		0.421
…						…

Table 2: Jaccard coefficient matrix of technologies.

Data in Table 2 show the strength of correlations between technologies. The sum of correlation coefficients of each technology can represent the comprehensive application of a technology in the industry, the magnitude of the value reflects the versatility of the technology. A technology with a larger value is expressed as having a wider connection with other technologies and has a stronger role in supporting the development of the industry. Therefore, the sum of the correlation coefficients of a technology is defined as the contribution. The technology with greater contribution is called generic technology. Based on the generic technology, we can redefine the technical distance: the correlation coefficient between each technology and the generic technology. The smaller the value, the weaker the correlation with the generic technology and the farther the technical distance.

As shown in Table 2, T2 has the largest contribution, it is the generic technology. It is difficult to produce RI only by using generic technology. The Jaccard coefficients between T1, T3, T4, and the generic technology T2 are 0.176, 0.205, 0.164, respectively. The correlation coefficient between T4 and T2 is the smallest, so T4 is the farthest away from the technology of industry knowledge. As remote domain knowledge is an effective resource to stimulate RI, technology T4 should be the main direction of industry research and development.

3.2 Technical Feature Evaluation

The purpose of the technical feature evaluation is to quantitatively evaluate the innovation, and the highly innovative technical features can effectively stimulate the designer's innovation inspiration.

Based on binary regression, Liu proposed a method to evaluate whether technical features belong to RI [16], and the calculation formula is shown in formula (6). If the technical features of the experimental group belong to RI, the RI value is 1, otherwise, the RI value is 0.

$$RI = \left(1 - e^{-z}\right)^{-1}; \quad Z = 106.1 + 18.6 \times WE + 10.1 \times CE + 3.5 \times EE + 0 \times TE \tag{6}$$

where *WE* is the expected attribute of the working unit; *CE* is the expected attribute of control; *EE* is the expected attribute of the engine; *TE* is the expected attribute of transmission.

These four variables are assigned by the technique pedigree tree method [30]. According to the different degrees of technological change of two innovation structures, physical principles, working principles, embodiments, and details are assigned to 10, 6, 3, and 1, respectively [30]. If the technology is changed to a positive beneficial effect, the value will be a positive number, otherwise, it will be a negative number.

The data source for evaluating highly innovative technical features is all patent texts in the industry. It is necessary to rely on the manual reading of patent texts to calculate the innovation of technical features according to formula (6). Manual reading of a large number of samples will reduce efficiency and increase R&D costs. Moreover, the data samples are full of a large number of low-tech, invalid, and difficult-to-implement patents. Therefore, it is necessary to conduct preliminary a screening of the data samples before the evaluation of RI to reduce the number of samples. Therefore, based on the analysis in Section 3.1, this paper proposes three indicators to reduce the number of evaluation samples.

The first one is cross-domain technical knowledge. Compared with knowledge in the industry, cross-domain technical knowledge is highly novel, difficult to apply, and less applied by innovation subjects, so the patents containing cross-domain technical knowledge are more innovative. Therefore, cross-domain technical knowledge can be used as an indicator for screening and evaluating the number of samples, and the calculation method is shown in the 3.1 section.

The second one is the patentee. The number of patents is an important measure of the R&D strength of innovative entities. This article ranks patentees according to the number of patent applications and selects leading companies. Leading companies have played an important role in setting industry standards and leading the industry's R&D direction. They also occupy an absolute market share. In addition, leading companies have exclusive R&D and design institutions, so the patents they apply for will have higher novelty. Therefore, the indicator of patentees can be used to further reduce the number of evaluation samples.

The last one is the patent application time. Patent data can reflect the dynamic changes of customer requirements in the market. Therefore, the technical features which applied in recent years can more accurately meet current customer requirements. Therefore, according to the indicator of patent application time, this paper selects the data of the past five years for innovation evaluation [21].

Before evaluating the innovation of technical features, the use of the above three indicators can effectively reduce the number of evaluation samples and improve the efficiency of innovation evaluation. Through the improved above design methods, the highly innovative technical features screened out based on cross-domain technical knowledge can effectively stimulate the designers' innovation inspiration and ultimately achieve the overall improvement of the enterprise's innovation level.

4 CASE STUDY

The low voltage electrical switch is a kind of equipment that can manually or automatically turn on and off the electrical circuit. The electromagnetic switch is widely used in various fields of industry. This paper uses electromagnetic switch enterprises as an example to apply the proposed method.

4.1 Technology Distance Analysis

According to keywords and patent application date, a patent retrieval formula can be constructed. Seen in Formula (7).

Formula (7): TTL: ((solid switch) or (Electromagnetic switch)) AND APD: [* TO 20200101].

A total of 5, 834 patents were retrieved. Kedu Electric Co. Ltd. is the target enterprise (TTE) of this paper. It is located in Zhejiang Province, China, an SME of a low voltage electrical switch product with 20 electromagnetic switch patents.

We conducted an analysis of the technical layout of the electromagnetic switch industry. It contains a total of 187 technologies. According to the number of applications, we have drawn the technical layout of the top 15 technologies, as shown in Figure 5.

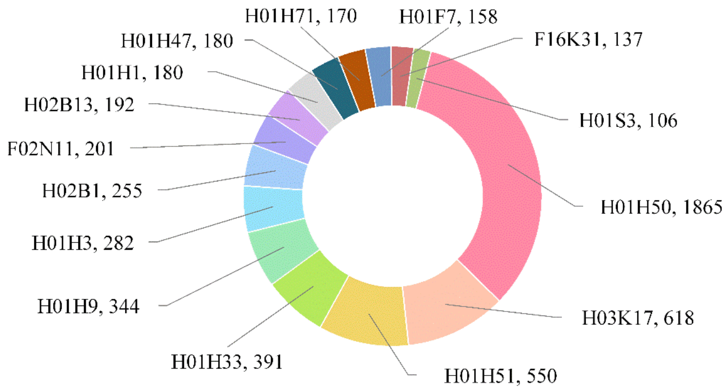


Figure 5: Technology layout of the electromagnetic switch industry.

According to the technical application situation of the electromagnetic switch industry, we conducted a technology co-classification analysis. According to formula (1) - (4), the retrieved IPC codes are programmed, and the technology co-classification matrix of the top 15 technologies in the electromagnetic switch industry is drawn. The matrix of technologies co-classification is shown in Table 3. The meanings of T1, T2, …, T15 in Table 3 correspond to the technologies in Figure 5.

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15
T1	1865	2	228	11	71	42	3	124	0	38	52	23	51	0	0
T2	2	618	0	0	7	3	2	0	0	11	1	0	0	1	0
T3	228	0	550	6	39	21	1	59	0	13	26	10	26	0	0
T4	11	0	6	391	17	15	24	0	38	4	9	1	17	0	0
T5	71	7	39	17	344	40	8	5	3	19	29	12	7	0	0
T6	42	3	21	15	40	282	5	9	1	4	12	10	14	0	0
T7	3	2	1	24	8	5	255	0	68	0	0	0	0	0	0
T8	124	0	59	0	5	9	0	201	0	2	4	0	7	0	0
T9	0	0	0	38	3	1	68	0	192	0	1	0	0	0	0
T10	38	11	13	4	19	4	0	2	0	180	3	7	12	2	0
T11	52	1	26	9	29	12	0	4	1	3	180	4	3	0	0
T12	23	0	10	1	12	10	0	0	0	7	4	170	11	0	0
T13	51	0	26	17	7	14	0	7	0	12	3	11	158	6	0
T14	0	1	0	0	0	0	0	0	0	2	0	0	6	137	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	106

Table 3: Matrix of technologies co-classification.

Then, draw the knowledge network map of the electromagnetic switch industry for generic technology analysis. We selected the technology with an application frequency greater than 25 for analysis. The network map is shown in Figure 6. The centrality of each node is calculated. The largest centrality is the H01H50 technology, with a center degree of 141.

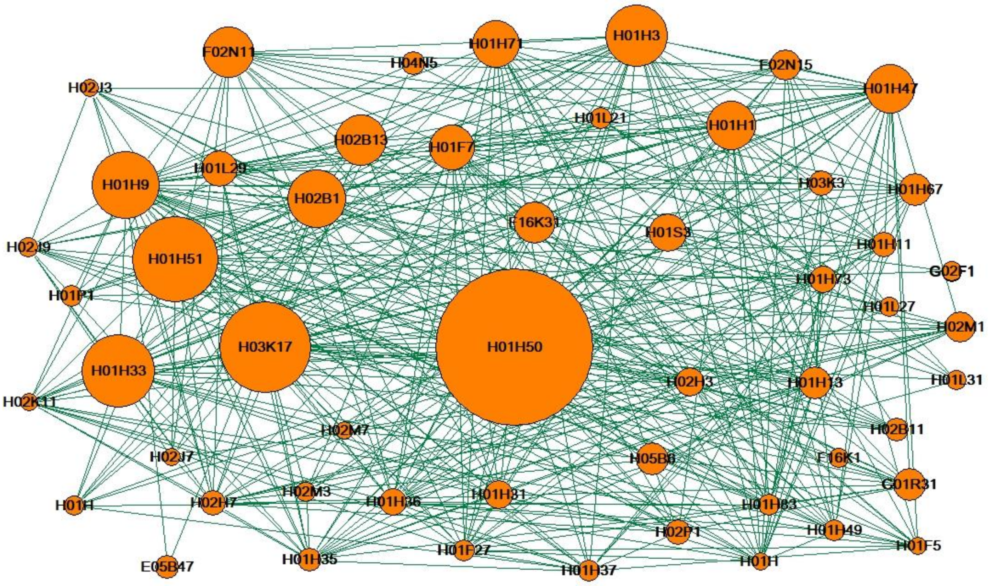


Figure 6: Knowledge network map of the electromagnetic switch industry.

According to Formula (5), the Jaccard correlation coefficient is decided by using data in the Table 3. The Jaccard coefficient matrix of technologies co-occurrence is shown in Table 4.

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15
T1	1	0.0008	0.1043	0.0049	0.0332	0.02	0.0014	0.0639	0	0.0189	0.0261	0.0114	0.0259	0	0
T2	0.0008	1	0	0	0.0073	0.0033	0.0023	0	0	0.014	0.0013	0	0	0.0013	0
T3	0.1043	0	1	0.0064	0.0456	0.0259	0.0012	0.0853	0	0.0181	0.0369	0.0141	0.0381	0	0
T4	0.0049	0	0.0064	1	0.0237	0.0228	0.0386	0	0.0697	0.0071	0.016	0.0018	0.032	0	0
T5	0.0332	0.0073	0.0456	0.0237	1	0.0683	0.0135	0.0093	0.0056	0.0376	0.0586	0.0239	0.0141	0	0
T6	0.02	0.0033	0.0259	0.0228	0.0683	1	0.0094	0.019	0.0021	0.0087	0.0267	0.0226	0.0329	0	0
T7	0.0014	0.0023	0.0012	0.0386	0.0135	0.0094	1	0	0.1794	0	0	0	0	0	0
T8	0.0639	0	0.0853	0	0.0093	0.019	0	1	0	0.0053	0.0106	0	0.0199	0	0
T9	0	0	0	0.0697	0.0056	0.0021	0.1794	0	1	0	0.0027	0	0	0	0
T10	0.0189	0.014	0.0181	0.0071	0.0376	0.0087	0	0.0053	0	1	0.0084	0.0204	0.0368	0.0063	0
T11	0.0261	0.0013	0.0369	0.016	0.0586	0.0267	0	0.0106	0.0027	0.0084	1	0.0116	0.009	0	0
T12	0.0114	0	0.0141	0.0018	0.0239	0.0226	0	0	0	0.0204	0.0116	1	0.0347	0	0
T13	0.0259	0	0.0381	0.032	0.0141	0.0329	0	0.0199	0	0.0368	0.009	0.0347	1	0.0208	0
T14	0	0.0013	0	0	0	0	0	0	0	0.0063	0	0	0.0208	1	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 4: Jaccard coefficient matrix of technologies co-occurrence.

According to the Jaccard coefficient matrix to calculate the contribution of each technology, the top three technologies are T1, T3, T5. It shows that these technologies have a strong comprehensive correlation with other technologies, and have a universal supporting role for the development of the industry. The maximum node degrees calculated according to the network map method are T1 and T3. Therefore, the generic technology calculated by the Jaccard coefficient method and the network map method is consistent. At the same time, the calculation results have a supplementary effect on the network map method.

The three technologies with the least correlation with generic technologies are T2, T4, T7, which indicates that those technologies are far away from the knowledge in the field of the electromagnetic switch. The correlation between T15 and other technologies is 0, which indicates that it is too hard to apply this knowledge. Therefore, the remote knowledge of these successful examples should be focused on by TTE, such as H03K17, H01H9, and H02B1.

4.2 Technical Feature Evaluation

The use of cross-domain technical knowledge can effectively stimulate RI. Highly innovative technical features can obviously stimulate the designers' innovative inspiration. Therefore, based on cross-domain technical knowledge information, the patent data in the industry can be screened to make preliminary preparations for the technical feature evaluation. According to the analysis results in Section 4.1, Formula (7) can be reconstructed to obtain patent retrieval Formula (8).

Formula (8): (TTL: ((solid switch) OR (Electromagnetic switch)) AND APD: [* TO 20200101]) AND (IPC:[H03K17 OR H01H33 OR H02B1])

A total of 361 patents was retrieved. The scope of patent search is accurate by 93.81%, and the screening efficiency of highly innovative technical features has been greatly improved. The ranking of applications of patentees in the field of the electromagnetic switch is shown in Figure 7. The company names corresponding to the codes in the figure are shown in Table 5.

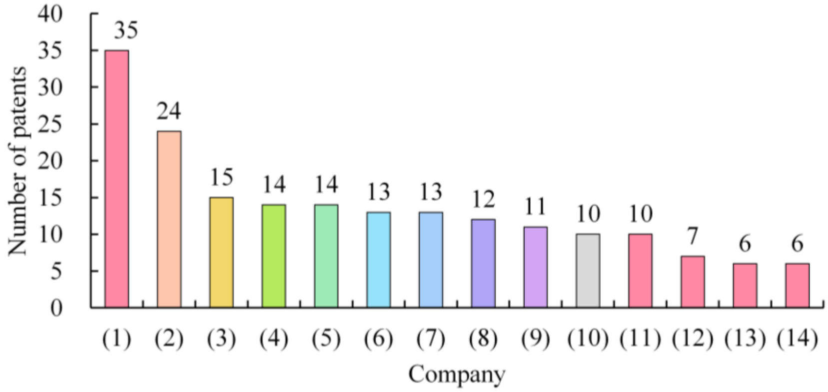


Figure 7: Patentee ranking.

According to the number of applications, Table 5 shows the top 14 applicants. There are 8 companies that have applied for patents since 2015, including 21 patents.

Code	*Enterprise name*	*Time range*	*Code*	*Enterprise name*	*Time range*
(1)	Mitsubishi Electric Corporation	1976-2018	(8)	Fuji Electric Co., Ltd.	2011-2014
(2)	Siemens	1971-2016	(9)	British Ministry of Defence	1988-1990
(3)	LS Electric Co., Ltd.	1996-2015	(10)	Shenyang Haocen Electric Co., Ltd.	2007-2014
(4)	Liu Tianbao	1992-2012	(11)	G&W ELECTRIC COMPANY	2012-2015
(5)	Toshiba Corporation	2001-2012	(12)	State Grid Corporation	2013-2018
(6)	Beijing Shuangjie Electric Co., Ltd.	2010-2018	(13)	Zhuhai Kangjin Electric Co., Ltd.	2011-2018
(7)	ABB Switzerland AG	1999-2017	(14)	Moeller gmbh	1999

Table 5: Time range of patent application.

According to the technique pedigree tree method [30], four variables are scored, and patents with higher innovation than TTE are selected. Two patents in the field of the electromagnetic switch are listed in Table 6 to explain the process of innovation evaluation.

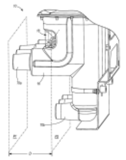
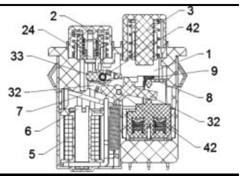
Name	*Patent number*	*Patent name*	*Structure drawing*
Control group	US9659728B2	Solid-dielectric switch including a molded viewing window	
Experimental group	CN111048359A	An electromagnetic switch	

Table 6: Two patents on electromagnetic switch.

The control group is the patent applied by G&W ELECTRIC COMPANY in United States Patent Office in 2017. The experimental group is the invention patent applied by the TTE in China in 2019. Both patents have been authorized and are within the protection period. According to the scoring principle of the technique pedigree tree, the experimental group was given scores based on the control group. The scoring process and results are shown in Table 7.

	Control group	*Experimental group*	*Score*
EE	Manual or automatic control.	It is still pressed manually. No change.	−3
TE	Simple mechanical structure.	Add new locking and driving parts.	+6
WE	Two switches in series are more stable.	New jump structure to improve touch feedback.	−10
CE	Observe the switch status through the visual window to enhance the safety.	New locking structure to improve reliability.	+6

Table 7: Comparison of technical feature.

After comparing the technical features of the two patents, scoring results are calculated by using Formula (6) as shown in Formula (9). *RI* = 0 indicates that the innovation of patents in the experimental group is lower than that in the control group. TTE needs to focus on the technical features of this patent. For example, in the patent of the control group, the knife switch is connected in series with a vacuum interrupter to ensure that no arc occurs when the equipment is running. The visual window can observe the switch status of the knife, and the setting of these components can improve the stability of the equipment and the safety of the operator. These improved technical features solve the functional problems with unexpected beneficial effects for the application category of *RI*.

$$Z = 106.1 - 18.6\times 10 + 10.1\times 6 - 3.5\times 3 + 0 = -29.8;$$
$$RI = \frac{1}{1-e^{29.8}} = 0 \tag{9}$$

Based on the relative innovation of the patents of the TTE and patents in the patent pool, patents with higher innovation than TTE are selected. Analyzing the working principle of technical features can effectively stimulate innovative inspiration.

In order to enhance the enterprise's ability of RI and improve the efficiency of patent knowledge acquisition, a tool of applying the method is compiled using MATLAB to integrate methods of the technology co-classification matrix, Formula (1) - (6). The user interface is shown in Figure 8 [9].

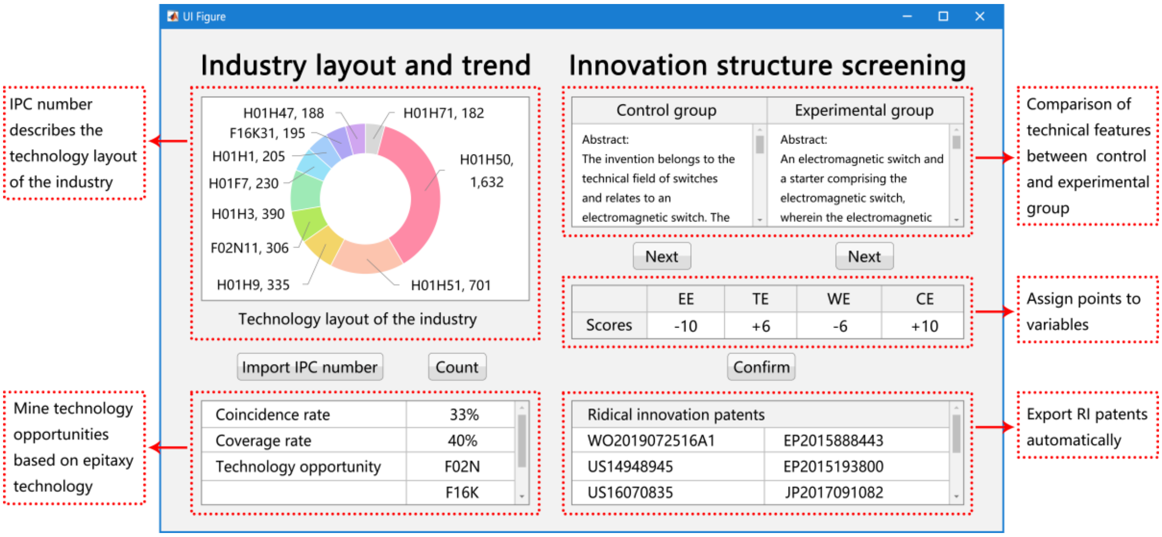


Figure 8: User interface.

5 CONCLUSIONS

Based on patent knowledge and structured IPC code data, this paper developed a method to improve the innovation ability of SMEs. This paper proposes a method for screening the characteristics of highly innovative technologies, and analyzing the highly innovative technical features can effectively stimulate designers' innovation inspiration. This method has three dimensions: cross-domain technical knowledge, patentee information, and application date to improve the efficiency of judging the innovation of technical features. In addition, this paper improves the calculation method of generic technology and perfects Liu's method that only considers the number of technical applications [15]. Furthermore, based on the idea of determining the competitive relationship between innovation subjects, this article redefines the technical distance calculation method based on generic technology based on the technology co-classification analysis and the Jaccard correlation analysis. Finally, A tool is developed to improve the efficiency of technology distance calculation and high RI patent screening.

Montecchi [22] introduced a search method for technical features to evaluate the latest state of products or technologies and support technology transfer activities. The method he introduced based on Function / Behaviour-Oriented Search has a high degree of recognition in the field of design methodology. It is similar to our manuscript in that the two methods are both problem-oriented and the design process of searching and solving solutions based on patent data. The difference between the two methods is that Professor Montecchi puts more emphasis on searching for technical features that achieve similar functions. Our article is biased towards RI-oriented cross-domain technology search methods. A comprehensive analysis of the two methods can conclude that the advantage of our paper compared with the existing research is that on the basis of the technical features of searching for similar functions, the method of this paper can also effectively improve the innovation of the solution. In addition, the three parameters designed in this paper can effectively improve the search efficiency of technical features.

The method also has some limitations. The proposed method is based on patent application data, the robustness of using existing data to decide future R&D direction is not very outstanding. So the technology prediction method will be considered in future research.

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