Title:
**Improvement of Technological Innovation of SMEs Using Patent Knowledge**

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Introduction:
SMEs are crucial to the industry and economy growth. However, SMEs face a lot of uncertain challenges in the technological innovation and market competition. Enterprises should always pay attention to technological innovation, follow the latest technology [5]. The competitive advantage of successful SMEs is based on product quality. Technological innovation is fundamental competitiveness. This paper proposes a method to enhance the competitiveness of SMEs through technological innovation.

This paper uses the technology distance and patent data to mine the technology knowledge for radical innovation (RI), seek new technology opportunities and improve competitiveness of SMEs. Due to the large number of patents, it is difficult to select high novelty patents. This paper simplifies the process of selecting high innovative technical features based on the RI patent evaluation.

Proposed Method:
A process of improving the technological innovation based on the patent knowledge is proposed as shown in Fig. 1.

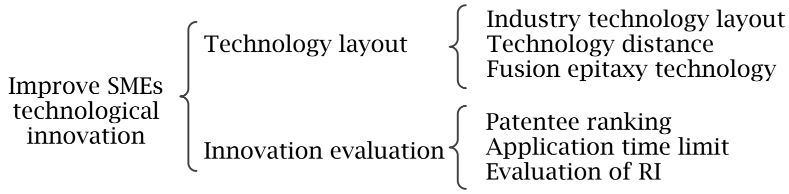


Fig. 1: Improving SMEs technological innovation based on the patent knowledge.

*Technology distance with IPC code*
Generic technology is the foundation to support the development of the industry [1]. We propose a method to determine the generic technology and technology distance of an industry using the co-occurrence matrix and Jaccard correlation evaluation. The technology distance is the sum of correlation coefficients of a technology, which can indicate the technology distance between this technology and the industry. The smaller the value, the larger the technology distance, and the technology corresponding to small value can be indicated as remote domain knowledge.

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Patents carry a large number of technical knowledge in the co-occurrence of technologies [4]. 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. And the technology distance can be calculated by Jaccard correlation analysis.

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 the last code. The style is shown in formula (2).

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

Delete the character after "/*" 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 for technology co-occurrence analysis. We assemble the above data processing into software, which can realize the computer-aided processing of data. An example of the technology co-classification matrix is shown in Tab. 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 | |
| … | … | … | … | … | … |

Tab. 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*). Tab. 2 shows the Jaccard coefficient matrix obtained by Formula (5). Tab. 1 and Tab. 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 |
| … | | | | | | … |

Tab. 2: Jaccard coefficient matrix of technologies.

Data in Tab. 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 large value shows the strong versatility of the technology.

As T2 has the largest technology distance, it is the generic technology in the industry. It is difficult to produce RI only by using generic technology. As the sum of correlation coefficients of technology T1 is the smallest, T1 is the farthest away from the technology of industry knowledge. As the remote domain knowledge is an effective resource to stimulate RI, technology T1 should be the main direction of industry research and development.

*Radical innovation evaluation*
The RI evaluation compares the technical value of two patents. It is time-consuming to evaluate a large number of patents. We use the patentee and time limit to simplify the scope of patents in innovation evaluation. The number of patents owned by enterprises represents their R&D strength. Patentees are ranked according to the total number of patents for selection. Leading enterprises have a high discursive power in the industry, and an absolute share of the market.

Since patents applied in recent years can reflect the market demand, patents of leading enterprises are sorted by patent application time. The patent applications in recent five years are selected [3]. A patent pool is composed of the leading enterprises and patents in recent 5 years. By limiting two parameters, the patentee and time, the scope of patents can be effectively reduced to search for the high innovation solution. Patents of target enterprises are compared using Formula (6) [2]. If RI = 1, the technical solution belongs to RI. If RI = 0, the innovation of the technical solution is insufficient.

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

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

These four variables are assigned by the technique pedigree tree method [6]. 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 [6]. If the technology is changed to a positive beneficial effect, the value will be a positive number, otherwise it will be a negative number.

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 low voltage electrical switch enterprises as an example to apply the proposed method.

*Technology distance analysis*
Kedu Electric Co. Ltd. is the target enterprise (TTE) of this paper. It is an SME of low voltage electrical switch product with 20 electromagnetic switch patents. The total technology layout of the electromagnetic switch industry is shown in Fig. 2 for top 15 technologies.

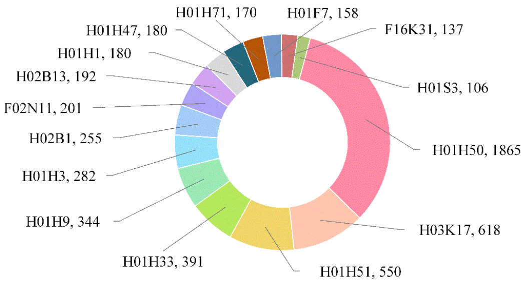


Fig. 2: Technology layout of the industry.

According to Formula (5), the Jaccard coefficient matrix of technologies co-occurrence is shown in Tab. 3. It can be seen that T1, T3, and T5 have the largest sum of correlation coefficients. Therefore, these technologies are generic technologies in the field of electromagnetic switch. Two technologies with the sum of correlation coefficient less than 0.1 are T2 and T14, which indicates that the two technologies are far away from the knowledge in the field of electromagnetic switch. The correlation between T15 and other technologies is 0, which indicates that it is difficult to apply this knowledge in the field of electromagnetic switch.

| | 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 |
| Sum | 0.3107 | 0.0303 | 0.376 | 0.2229 | 0.3408 | 0.2616 | 0.2459 | 0.2131 | 0.2596 | 0.1817 | 0.2078 | 0.1405 | 0.2641 | 0.0284 | 0 |

Tab. 3: Jaccard coefficient matrix of technologies co-occurrence.

TTE applications of four main technologies, namely H01H50, H01H9, H01H3, and H01H47. The sum of correlation coefficients of these technologies is large. The less remote domain knowledge is used. Therefore, the remote knowledge of these successful examples should be focused on by TTE, such as H03K17 and F16K31, which have a relatively small sum of technical correlations.

*Radical innovation evaluation*

The ranking of patent applications of patentees in the field of the electromagnetic switch is shown in Tab. 4. The patentee with the largest number of patent applications is Mitsubishi Electric Corporation. It has applied for 294 patents in the field of the electromagnetic switch, which shows a leading role of this company.

Because of the dynamic customer demand, patents applied in recent years can better reflect changes of the customer demand in the market. Considering the time limit, only patents applied in the past five years were collected for a total of 106 patents.

| Code | Enterprise name | Time range | Code | Enterprise name | Time range |
|---|---|---|---|---|---|
| (1) | Mitsubishi Electric Corporation | 1976-2019 | (6) | Panasonic Co., Ltd. | 1969-2006 |
| (2) | Nidec Corporation | 1978-2015 | (7) | LS Industrial Systems Co., Ltd | 1996-2017 |
| (3) | Siemens Ag Fwb | 2006-2015 | (8) | Midea Group | 2010-2018 |
| (4) | Robert Bosch | 1927-2018 | (9) | Zhejiang huanfang Automobile Electric Appliance Co., Ltd., | 2006-2016 |
| (5) | Fuji Electric Co., Ltd | 1978-2017 | (10) | Fuji Denshi Kogyo Kk | 1991-2015 |

Tab. 4: Time range of patent application.

According to the technique pedigree tree method [6], four variables are scored, and patents with the higher innovation than TTE are selected. Two patents in the field of the electromagnetic switch are selected to explain the innovation evaluation. The scoring process and results are shown in Tab. 5.

| | Experimental group | Control group | Score |
|---|---|---|---|
| *EE* | The spring's elasticity changes to the ampere force of electromagnetism. | It is still pressed manually. No change | −10 |
| *TE* | No improvement. | New locking and driving parts are added. | +6 |

| | | | |
|---|---|---|---|
| *WE* | One energy input becomes two working outputs: motor and DC motor | New jump structure to improve touch feedback. | −6 |
| *CE* | Three controllers are added. The complexity is improved | New locking structure to improve reliability. | +10 |

Tab. 5: Comparison of technical feature.

After comparing technical features of the two patents, scoring results are calculated by using Formula (6) as shown in Formula (7). 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 Robert patent.

$$Z = 106.1 - 18.6\times 6 + 10.1\times 10 - 3.5\times 10 + 0 = -80.52;$$
$$RI = \frac{1}{1-e^{80.52}} = 0 \qquad (7)$$

Based on the relative innovation of the patents of the TTE and patents in the patent pool, patents with the higher innovation than TTE are selected. These are technical features with the high novelty. Analyzing the working principle of technical features can effectively stimulate the innovative inspiration. The RI ability and sustainable competitiveness of enterprises are improved.

## Conclusions:

Based on patent knowledge, this paper developed a method to improve the innovation ability of SMEs. The method includes the identification of the remote knowledge and screening RI technology features. We use IPC code to do technology co-classification analysis and express technology distance. Two parameters are used to narrow the scope of the screening. A tool is developed to improve efficiency of technology distance decision and high RI patent screening.

The concept of technology distance proposed in this paper refers to the distance between a technology and the industry, in order to find the cross-domain knowledge of the industry. This method improves the deficiency that the existing technology distance can only be used to determine the inter-departmental partners.

The method also has some limitations. Such as the applicability of this method in other fields need to be evaluated in future research. The proposed method is based on patent application data, the robustness of using existing data to decide future R&D direction is poor. So the technology prediction method should be applied in future research.

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