Postprint: Enterprise Competitor and Technology Opportunity Identification Based on Technical Similarity and Benchmarking Analysis

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Abstract

[Purpose / Significance] Technology competition serves as a powerful instrument for enterprises to sustain competitive advantages in the new market environment. This study constructs a process framework suitable for small and medium-sized enterprises (SMEs) to identify technology opportunities, aiming to excavate promising technology development opportunities for enterprises and achieve breakthrough technological innovations by fully utilizing limited R&D resources. [Method / Process] Benchmarking analysis is employed as the primary methodology. Competitor benchmarks for target enterprises are selected based on two dimensions: technology similarity and technological capability. Potential technology categories are delineated by integrating the technology landscape of benchmark enterprises with the overall industry status. Finally, the time dimension is introduced to construct a three-dimensional technology-function-time matrix for identifying technology opportunities, with the vacuum cleaner industry serving as a validation case study. [Results / Conclusion] The incorporation of the time dimension into the technology-function matrix can intuitively reflect the sustainability of technology R&D. The constructed framework helps ensure the implementability of the identified technology opportunities for target enterprises.

Full Text

Enterprise Competitors and Technology Opportunity Identification Based on Technology Proximity and Benchmarking Analysis

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Abstract:
[Purpose/significance] Technology competition is a powerful weapon for enterprises to maintain their advantages in the new market environment. The fundamental purpose of this paper is to construct a framework suitable for small and medium-sized enterprises to identify technological opportunities, so as to tap potential technological development opportunities for enterprises and make full use of limited R&D resources to obtain technological breakthrough and innovation. [Method/process] Benchmarking analysis was used as the main method to select the competitor benchmarking of the target enterprise from the two dimensions of technical proximity and technical capability. Combined with the situation of benchmarking enterprises and the overall technical situation of the industry, potential technology categories were divided, and a three-dimensional patent technology/function matrix was constructed to identify technical opportunities, and the vacuum cleaner industry was taken as an example to verify. [Result/conclusion] The time dimension is introduced into the patent technology/function matrix to directly reflect the sustainability of technology research and development. The framework constructed helps to ensure that the identified technology opportunities can be implemented for the target enterprises.

Keywords: Benchmarking; Patent Analysis; Technical Opportunity Identification; Technology-Effect Matrix

1 Introduction

With the continuous development of science and technology, competition among enterprises in the industry has shifted from traditional primary production factors such as capital, scale, and labor to technology competition. To establish a foothold in competition, enterprises must continuously innovate technologically, reduce production costs, and introduce new products to the market. However, once there is a deviation in the identification and selection of key technology directions, it will not only miss opportunities and cause waste of human and material resources, but may also affect the further development of the enterprise's future technology. The inherent risks of investing in and launching new technologies require enterprises to properly position technology opportunity analysis strategically, viewing technology opportunity identification as a key factor for successful technological innovation activities [1]. Benchmarking analysis is a process of evaluating and improving oneself by taking highly competitive or well-known leaders in the industry as benchmarks, which plays a guiding role in the development direction and technology roadmap for small and medium-sized enterprises [2]. Based on this, the authors identify and determine the competitor benchmarks of enterprises through a combination of technology similarity and technology capability, and identify appropriate technology opportunities for small and medium-sized enterprises through patent analysis of the benchmarks, in order to provide new ideas for their technology R&D.

2.2 Technology Opportunity Identification

The concept of "technology opportunity" was first formally proposed by A. L. Porter et al. [13] in 1995, referring to technology development trends that exist in the process of technology development and are closely related to current technology. Y. Lee et al. [14] believe that technology opportunity is the possibility of technological progress or the potential for technological advancement within a specific field or between different industries. Technology opportunity identification is the process of predicting and identifying emerging technology forms or technology development points through technical means [13]. As more and more technologies and products appear in the market with increasingly shorter life cycles, the ability to identify technology opportunities is regarded as the core competitiveness of national and enterprise R&D, which will create new profits for the sustainable development of enterprises [15-16].

Early research on technology opportunity identification mainly used qualitative analysis methods, including Delphi method, analytic hierarchy process, and scenario analysis. These methods are highly dependent on expert experience. Although they can obtain creative and forward-looking predictions, they are highly subjective and the methods and conclusions are often difficult to replicate [17]. In recent years, research on technology opportunity identification has become richer in methods, fields, and processes. B. Yoon [18] and Wang Jinfeng [19] used keywords in patents to construct morphological matrices of technology and products. Zhu Donghua et al. [20] and Feng Ling et al. [21] drew technology roadmaps and key technology development time zone diagrams based on extracted technology keywords to mine technology opportunities in multiple fields. Compared with traditional keyword-based analysis methods, the emerging SAO (Subject–Action-Object) semantic analysis method retains the semantic relationship between keywords and can more deeply analyze the internal connections between independent phrases. S. Choi et al. [22] applied SAO structure to mine and analyze patent text information, developing technology trees to analyze technology opportunities. Li Qianrui et al. [23] and Guo Junfang et al. [24] introduced SAO analysis into technology roadmaps to identify possible technological innovation solutions. Since citation relationships also exist in technical literature, citation analysis methods are also used for patent technology analysis. B. Kim et al. [25] identified technology fields with high integration potential by constructing patent citation networks and screening core patent pairs. Han Yan et al. [26] identified key patent-document pairs by constructing paper and patent citation networks, extracting and reorganizing high-frequency knowledge units to identify technology opportunities in the medical service robot field. Technology gap analysis and outlier patent detection methods based on patent literature are also commonly used for domain technology discovery. Gong Huiqun et al. [27] collected and structured text data, drew patent maps of robot industry technology through kernel principal component analysis, and searched for technology gaps. Feng Lijie et al. [28] innovatively constructed multi-dimensional patent maps of mobile phone power supply systems to mine technology gap areas in this field. Huang Lucheng et al. [29] used outlier detection methods to identify outlier patents with potential technology opportunities, and determined technology opportunities in the target field by combining an improved market value evaluation model. C. Lee et al. [30] applied local outlier factor methods to detect outlier patents and displayed potential technology opportunities in the form of patent maps. In addition, there are comprehensive studies using scenario analysis and patent maps [31], integrating patent maps, K-Means clustering, text mining, and Condorcet voting methods [32] to construct unique technology opportunity identification process frameworks.

The above studies mostly use patent databases as data sources and patent literature as research objects, selecting different research methods based on different goals and technology optimization focuses to discover technology development trends and mine potential technology opportunities in specific fields. However, there are few targeted studies for small and medium-sized enterprises to seek appropriate technology opportunities. Therefore, the authors intend to comprehensively use multiple methods to construct a process framework suitable for small and medium-sized enterprises to identify technology opportunities, helping enterprises determine valuable R&D directions.

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3 Technology Opportunity Benchmarking Analysis Identification Model

Benchmarking analysis is an important means for enterprises to discover competitor advantages, identify their own gaps, and improve business activities. Its implementation steps are systematic and structured. After reviewing relevant literature, it is found that the specific processes vary in different studies. Based on the benchmarking analysis process, the authors identify competitor benchmarks for small and medium-sized enterprises, integrate patent technology analysis methods for specific analysis, and gradually discover valuable technology opportunities for small and medium-sized enterprises, constructing an enterprise technology opportunity identification model as shown in Figure 1 [Figure 1: see original paper].

The constructed identification model mainly consists of three parts: competitor benchmark identification, data collection and organization, and patent technology benchmarking analysis process. Competitor identification is the core content of competitive intelligence. Analyzing competitor development routes helps enterprises adjust their strategies in a timely manner and avoid touching industry barriers in the process of technology R&D [9]. From the perspective of technology evolution, industry competitors should be industry technology leaders with high technical capabilities. However, when enterprises select competitor benchmarks for benchmarking analysis, they also need to consider the similarity between their technical achievements and the enterprise's own technology expectations. Therefore, in the competitor benchmark identification stage, the authors innovatively evaluate the relative competitiveness of enterprises from two dimensions: technology similarity and enterprise technology capability, selecting enterprises with similar technology preferences and high technical capabilities as competitor benchmarks. Patent analysis is an effective means to identify competitors, understand competitor technology development strategies, and grasp overall industry technology development trends. In the data collection and organization stage, the authors use the State Intellectual Property Office (http://www.sipo.gov.cn/) as the patent data source, construct appropriate search formulas to retrieve industry-wide and competitor benchmark patent data, and organize and deduplicate the data. In the patent technology benchmarking analysis, based on the collected patent data, the authors analyze industry development trends and competitor technology trends, combine the enterprise's own technology preferences to mine technology trends and future R&D priorities, determine key IPC categories for R&D, conduct qualitative analysis of patents under the identified key IPC categories, and construct a two-dimensional technology-effect matrix to reveal the relationship between technical themes and functional effects in patent literature, mining technology-intensive areas, sparse areas, and blank areas to narrow the scope of technology opportunity identification. Although traditional two-dimensional technology-effect matrices can mine technology areas with different densities, the results are too flat to reflect the dynamic trends of technology development and are insufficient when examining the sustainability of patent R&D. Therefore, the authors introduce the time dimension into the two-dimensional technology-effect matrix to construct a three-dimensional technology-effect-time matrix to further explore the continuity of sparse area technologies and the developability of blank area technologies, thereby completing the goal of enterprise technology opportunity identification.

4.1 Competitor Benchmark Identification

4.1.1 Technical Capability Patent data contains rich technical information. Patents are literature carriers that record technology R&D achievements. Patent literature accounts for about 10% of journal literature but can provide about 40% of new product information, displaying more than 90% of new technologies to the public [33]. The number of patent applications shows the input and output of enterprises in the field. By analyzing the number of patents owned by enterprises, we can see their scientific research strength [7]. Enterprises with high cumulative patent application numbers often also have advantages in cumulative patent citations, number of inventors, and years of enterprise activity. The authors use the number of patent applications in the industry under study over the past 10 years as an indicator of enterprise technical capability, ensuring that enterprises remain technologically active in recent years while evaluating their capabilities.

4.1.2 Technology Similarity Similarity analysis often uses the cosine similarity method, but direct application of cosine similarity to technology similarity has certain defects. First, only when the patent coverage scope and patent tendency of enterprises are similar will the technology have high similarity, while there are technical gaps between the two parties in benchmarking analysis, and the patent coverage scope of small and medium-sized enterprises is always smaller than that of leading enterprises. In addition, cosine similarity is absolute data, and the similarity between two research objects is fixed. In actual situations, small enterprise M takes leading enterprise A as a benchmark, but leading enterprise A generally does not consider small enterprise M as its competitor. Therefore, when calculating cosine similarity, the authors do not use all patent classification numbers (IPC) involved in the industry as calculation dimensions, but only use the technology IPC owned by the target enterprise as the dimension for cosine similarity calculation, thereby obtaining candidate enterprises relatively similar to the target enterprise's patent technology, and when similar enterprises have broader technology coverage than the target enterprise, it does not affect the similarity result.

4.1.3 Relative Competitive Capability The traditional method of identifying competitors based on patent quantity and citation ranking lacks specificity. For example, for a certain enterprise M, the top-ranked enterprise in the industry is A, and the second-ranked is B. Enterprise A has more patent technologies than enterprise B and stronger R&D capabilities. However, if enterprise B's patent distribution is more similar to enterprise M's than enterprise A's, then under the premise that enterprise B's technical capabilities are also at the industry leading level, taking B as the competitor benchmark for benchmarking analysis may be more appropriate. Therefore, enterprises need to determine competitor benchmarks by considering the combination of enterprise technical capabilities and technology similarity.

The relative competitive capability of candidate enterprises facing the target enterprise is comprehensively evaluated from two dimensions: technical capability and technology similarity, constructing a similarity-capability quadrant diagram with high technical capability level and high similarity enterprises as main competitors, as shown in Figure 2 [Figure 2: see original paper]. When there are many marked points falling in the high technical capability-high similarity area, considering that analyzing competitor technology trends requires a certain amount of patent data as the research basis, and enterprises with high patent application volume are in a leading position in the industry with greater technology discourse power, the authors prioritize the technical capability dimension for competitor benchmark identification.

4.2 Data Collection and Organization

The State Intellectual Property Office (http://www.sipo.gov.cn/) provides complete and detailed patent text data for domestic enterprises, including International Patent Classification (IPC), patent applicants, patent content, and other information. Since there is a two-year lag from patent application to publication, the authors use the State Intellectual Property Office website as the patent data source, construct appropriate search formulas, set the time interval to 2010-2019, and collect patent data for the overall industry, target enterprises, and competitor benchmark enterprises.

4.2.1 Industry Overall Data After selecting the target small and medium-sized enterprise, the authors retrieve and collect the patent application status of the overall industry where the enterprise is located between 2010-2019, analyze the dynamic change trend of overall industry patent applications in the past 10 years, use International Patent Classification (IPC) as the basis, mine key technology R&D types in industry-related patents, collect the number of patent applications and patent applicants in key technology R&D categories over the past 10 years, thereby determining the life cycle stage of key technologies and delineating technology categories with high activity and good R&D prospects in the industry.

4.2.2 Enterprise Data The authors respectively use the target enterprise and competitor benchmark enterprise as applicants to construct search formulas, collect patent application data of the two enterprises between 2010-2019, analyze the patent R&D history of the target enterprise and competitor benchmark enterprise, predict future technology priority strategies, and verify the similarity of the two enterprises' technology development strategies and the reference value of the benchmark enterprise for the target enterprise's technology opportunities.

Finally, based on the comprehensive analysis of the overall industry, target enterprise, and competitor enterprise R&D trends, the authors select IPC categories that have high overall R&D space and are likely to become the target enterprise's future key R&D objects, collect all patent text data of the competitor benchmark enterprise under these categories for subsequent patent text interpretation. Since patent texts are highly structured, text preprocessing mainly involves cleaning and deduplication.

4.3 Patent Technology Benchmarking Analysis

4.3.1 Technology Trends and Priorities (1) Industry Technology Development Trends. Enterprises' R&D investment in different technology categories changes with years and has primary and secondary priorities. Paying attention to the changes in overall industry R&D trends and understanding key technology categories is very necessary for target enterprises to adjust their

R&D directions and identify technology opportunities. Dividing technology categories according to International Patent Classification (IPC), using years as the time dimension of patent trends, and using patent quantity as the basis to judge the investment degree of different technology categories, drawing classified technology trend charts can clearly distinguish technology categories that the overall industry focuses on R&D and that are vibrant.

(2) Competitor Benchmark Technology Situation. Patents, like products, have life cycles. In different life cycle stages, the number of patent applicants and patent applications show different characteristics. As shown in Figure 3 [Figure 3: see original paper], each node represents a year in chronological order. According to the number of patent applicants and patent applications in each year, five stages can be divided: technology germination period, growth period, maturity period, decline period, and redevelopment period. Competitor benchmark technology situation analysis includes two parts: competitor benchmark technology development trend analysis and key technology life cycle judgment. By drawing the overall technology trend and classified technology trend charts of competitor benchmark enterprises to find their R&D priorities, and judging the life cycle of active technologies that are priorities in the research trend helps to identify technologies with great development potential and opportunities.

(3) Enterprise Own Technology Preferences. Since the goal of benchmarking analysis is to evaluate and improve oneself, it is also necessary to examine the target enterprise's technology development trends, analyze the patent distribution of the target enterprise in different time periods and discuss its own technology preferences, and comprehensively compare the target enterprise's technology status and trends with the overall industry and the potential technologies of the identified competitor benchmark enterprises to ensure that the technology R&D opportunities are implementable for the target enterprise and conform to the enterprise's strategic planning.

4.3.2 Technology Opportunity Areas The authors plan to explore technology opportunity areas through a technology-effect matrix. Considering that the title and abstract are the two cores of patent literature, containing the main content and innovation points, the title and abstract are used as the main text objects in patent interpretation. First, text preprocessing is conducted on patent literature, namely text segmentation and removal of stop words, and information extraction is performed on the processed corpus. Traditional technology-effect matrices use technical means as the horizontal axis and achievable effects as the vertical axis, with the intersection of the horizontal and vertical axes representing the number of patent documents corresponding to this technology-effect. Technical means are noun phrases presenting core technology in patent literature titles and abstracts, which are fully discussed in these main fields. Therefore, the authors extract technical words based on statistical methods, using Python 3.7 software to extract high-frequency words in the field from the corpus, and further manually annotate keywords representing technical themes or innovative content based on the part of speech and meaning of high-frequency words combined with expert knowledge. Effect phrases are often composed of phrases conforming to verb-object structures (v+n/a+n) or subject-predicate structures (n+a), such as "improve dust collection efficiency" and "low noise"; or exist in functional sentences in abstract texts, appearing together with clue words such as "the present invention… can/satisfy/facilitate/be beneficial to." The authors formulate effect phrase identification rules based on clue word characteristics and structural characteristics, locate functional sentences conforming to the rules according to clue words, extract phrases satisfying the effect sentence structure as effect word candidates, and finally manually unify them, merging the same or similar effects to keep the number of categories within a controllable range.

Using technical means adopted in patent literature as the horizontal axis and expected effects as the vertical axis, patents in the technology field are classified according to their technology and effect, and represented in corresponding cells in the form of bubble charts, with bubble size reflecting the number of patents. Visualization methods are used to distinguish technology forbidden zones, profitable areas, and undeveloped areas in the distribution of dense, sparse, and blank areas in the constructed technology-effect matrix, compressing the scope of high-potential opportunity identification areas.

4.3.3 Technology Opportunity Identification Based on the above steps, after further narrowing the scope of opportunity identification areas, the time dimension is introduced. Using Matlab 9.5.0 software, a three-dimensional technology-effect-time matrix is constructed with technical features as the x-axis, effect features as the y-axis, and application year as the z-axis. Similarly, bubble charts are used to reflect the number of patents, to compensate for the deficiency that two-dimensional matrices cannot reflect the dynamic trends of technology changes over time. This allows analysis of the continuity of technologies in profitable areas and comprehensive discussion of technology forbidden zones and technologies that have not been developed but have development potential, ultimately completing the identification of enterprise potential technology opportunities.

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5 Empirical Analysis

From the 2020 market perspective, the traditional small home appliance market shrank, while the emerging health home appliance market represented by vacuum cleaners and other cleaning appliances developed rapidly, still showing good performance during the epidemic period. In 2020, the domestic sales scale of vacuum cleaners was 23.18 billion yuan, a year-on-year increase of 15.3%. According to data from the China National Household Electric Appliance Research Institute and the All-China Household Electric Appliance Industry Information

Center, Dyson, Ecovacs, Midea, Xiaomi, Roborock and other enterprises are in the leading position in the vacuum cleaner market, occupying 64.2% of the online market [34]. Established in June 2009, "Suzhou Baojiali Electric Appliance Co., Ltd." was jointly funded and established by the famous German electrical appliance company BOB-HOME and Suzhou Delipu Trading Company. Although it currently occupies a small market share and still belongs to small and medium-sized enterprises, its investment and outstanding performance in the sterilization and mite removal functions of vacuum cleaners fully demonstrate the "Suzhou Baojiali Electric Appliance Co., Ltd."'s ambition in technological innovation.

The authors apply the above method to the vacuum cleaner manufacturing and sales industry, taking "Suzhou Baojiali Intelligent Technology Co., Ltd." (hereinafter referred to as "Baojiali Company") as the target enterprise for empirical analysis, identifying its main competitors, and identifying potential technology opportunities for the enterprise through industry overall trends and competitor benchmark analysis.

In the State Intellectual Property Office website, the authors retrieved patents with vacuum cleaner as the keyword and enterprise as the applicant between 2010-2019, detecting a total of 9,319 data entries. They selected 30 enterprises with patent application volume higher than Baojiali Company for technology similarity and technology capability analysis. Using the 14 patent IPC categories involved in Baojiali Company's patent literature in the past 10 years as the dimension for cosine similarity calculation, they constructed an enterprise-IPC matrix, with part of the matrix shown in Table 1 . The first row in the table shows the 14 IPC classification numbers involved in Baojiali Company's patents, and the values in the table represent the number of patent applications of the 30 enterprises with application volume higher than Baojiali Company in these 14 IPC classifications.

Using Python 3.7 software to calculate the cosine similarity of the matrix data, they obtained the relative technology similarity of 30 enterprises with Baojiali Company, as specifically shown in Table 2 .

They used the number of patent applications in different categories to represent the technical capability of this type of technology. From the two dimensions of technology similarity and technical capability, they drew a quadrant diagram to evaluate the relative competitiveness of enterprises, identifying enterprises with high similarity and high capability as competitor benchmarks for the target enterprise, as shown in Figure 4 [Figure 4: see original paper].

Prioritizing the technical capability dimension, they selected Jiangsu Midea Cleaning Appliance Co., Ltd. as Baojiali Company's competitor benchmark. Jiangsu Midea Cleaning Appliance Co., Ltd. has similar R&D tendencies to the target enterprise in the 14 patent categories and occupies a leading position in the vacuum cleaner manufacturing and sales industry. Using it as a benchmark for patent distribution and R&D priority analysis helps identify possible technology R&D opportunities for the target enterprise, thereby evaluating and improving Baojiali Company's technology development strategy.

5.2 Patent Technology Benchmarking Analysis

5.2.1 Technology Trends and Priorities The overall industry patent application trend is shown in Figure 5 [Figure 5: see original paper]. Vacuum cleaner-related patents gradually started from 2010-2014, and continued to develop rapidly during the six years from 2014-2019, with the number of patent applicants also continuing to rise. It can be considered that technology competition in the vacuum cleaner industry is still in full swing, and small and medium-sized enterprises urgently need innovation and breakthroughs to ensure their vitality in long-term competition.

The top ten patent technology categories in the vacuum cleaner industry in terms of application quantity in the past 10 years and their application trends are shown in Figure 6 [Figure 6: see original paper]. A47L9/00 is the key R&D category in the vacuum cleaner industry, with overall application volume far higher than other categories. Its subcategory A47L9/28 also has obvious distinction from other categories.

Judging the technology life cycle stage of A47L9/00 and A47L9/28 reveals that technologies related to A47L9/28 have gradually entered the maturity stage, showing a decline trend in both patent application quantity and applicant quantity, while technologies under A47L9/00 are still in the growth stage overall, with high R&D space, as shown in Figure 7 [Figure 7: see original paper].

The patent application trend of the benchmark enterprise Jiangsu Midea Cleaning Appliance Co., Ltd. is similar to the overall industry, as shown in Figure 8 [Figure 8: see original paper]. Before 2014, the enterprise was still in a technologically weak position, with patents showing explosive growth between 2014-2016. The year 2016 was the most active year for the enterprise's patent applications, and A47L9/00 is also the key R&D category for this enterprise.

Baojiali Company began patent applications as early as 2016, with research hotspots in three categories: A47L7/00, A47L9/00, and A01M3/00. However, since 2018, the number of newly applied patents from Baojiali Company has dropped sharply, as shown in Figure 9 [Figure 9: see original paper]. This shows that it faces certain difficulties in technological innovation, making it highly necessary to analyze reliable technology opportunities for it. Based on the above technology distribution and trend analysis, A47L9/00 (parts or auxiliary appliances of vacuum cleaners) and its subclasses have long been the technology concentration area of the vacuum cleaner industry. Therefore, the patent texts of this category are used for subsequent literature interpretation to delineate appropriate opportunity identification areas.

5.2.2 Technology Opportunity Areas The authors plan to explore technology opportunity areas through a technology-effect matrix. To ensure analysis effectiveness, technology-effect analysis often limits text data volume to within 500 entries. They retrieved patent texts under the A47L9/00 classification of the competitor benchmark Jiangsu Midea Cleaning Appliance Co., Ltd., obtaining 462 technology data entries. Using Python's Jieba component for word segmentation of patent literature titles and abstracts, they cleaned punctuation marks in the text, removed non-content words such as modal particles through a custom dictionary, and finally extracted high-frequency words in the field based on word frequency statistics for technical word annotation. They located functional sentences in abstract texts based on clue words, extracted effect candidate words, and performed unification processing, describing the technical means and expected effects of each patent, with partial results shown in Table 3 .

Through literature interpretation, they obtained the technical and effect features of the constructed patent dataset, creating a technology-effect matrix for the A47L9/00 category of the competitor benchmark enterprise for 2010-2019, as shown in Figure 10 [Figure 10: see original paper].

Technical features are summarized as detail design, body structure, shell cover design, accessory design, dust cup assembly, mute device, indicator device, airflow device, overall structure, fixing parts, and motor assembly. Effect features are summarized as reliability, production/assembly efficiency, space optimization, user experience, noise reduction, cleaning efficiency, appearance beautification, and loss reduction. When a certain technology has a considerable number of R&D results in many effects, it means that this type of technology R&D has become relatively complete and has tendency in effects. When there are fewer blank points, its R&D innovation prospects are also poorer. Therefore, when distinguishing dense, sparse, and blank areas of technology-effect from bubble distribution, using the body structure-space optimization pair radius as the benchmark radius, technologies with more bubbles exceeding the benchmark radius than or equal to 3 or blank points fewer than 2 are identified as dense technologies. It is found that detail design, body structure, shell cover design, accessory design, overall structure, and motor assembly-related technologies have obtained considerable results, with relatively dense patent applications. Analyzing the technology-effect correspondence of blank points in these six categories reveals that their implementation possibility is low, so the technology opportunity identification area is narrowed down to the remaining five categories.

5.2.3 Technology Opportunity Identification Using Matlab 9.5.0 software, the authors constructed a three-dimensional technology-effect-time matrix containing the time dimension for the benchmark enterprise, observing the application trend of each technology-effect over time, as specifically shown in Figure 11 [Figure 11: see original paper].

Focusing on the time change trends of the five categories of technology sparse areas: dust cup assembly, mute device, indicator device, airflow device, and fixing parts, it is found that dust cup assembly, mute device, and indicator device still have development space in terms of application quantity, and new patents have appeared in consecutive years, indicating good technology continuity, as shown in Figure 12 [Figure 12: see original paper].

The above three categories of technology-effect correspondences are marked as mute device-noise reduction, indicator device-user experience, and dust cup assembly-user experience, which can be identified as having technology R&D opportunities. Finally, since technology blank areas usually have two opportunity possibilities—one means that this technology-effect correspondence hardly exists or is extremely difficult and costly to develop; the other means that this field is achievable but has not been developed due to reasons such as insufficient technology foundation—such blank points are worth continuous attention from enterprises and have certain technology R&D opportunities. Therefore, the authors further discuss the technology-effect blank points of the five categories of technologies, exclude blank areas that are difficult to implement, and believe that blank points such as improving assembly efficiency, space utilization, or achieving appearance beautification by improving airflow device structure, and designing new fixing parts to reduce physical loss during vacuum cleaner retrieval are also possible technology R&D directions worth continuous attention from enterprises.

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6 Conclusion

Small and medium-sized enterprises have relatively limited R&D resources, and grasping appropriate technology opportunities to provide new products to the market is very necessary for maintaining competitive advantages. The benchmarking analysis method selected by the authors is based on technical facts and takes industry leaders as models to inspire the technology R&D direction of target enterprises. Combining relative technology similarity and technical capability to select competitor benchmarks, and mining technology opportunities based on the target enterprise's own preferences and benchmark enterprise technology situation analysis, to a certain extent ensures the implementability and strategic alignment of the identified technology opportunities for the target enterprise. When identifying specific opportunities, the time dimension is introduced into the technology-effect matrix to observe its dynamic evolution trend, more intuitively reflecting the sustainability of technology R&D. Finally, empirical analysis verifies that this identification process is achievable and can help small and medium-sized enterprises in the industry seek technology innovation opportunities.

Applying the model to the vacuum cleaner industry for empirical analysis, the results show that the competitor identification combining technology similarity and technical capability dimensions can ensure that the benchmark enterprise's technology R&D level is at the industry leading position while its R&D strategic emphasis is also adapted to the target enterprise, providing new ideas and means for enterprise benchmark selection in benchmarking analysis practice. Introducing the time dimension into the technology-effect matrix can observe technology development dynamic trends that traditional technology-effect matrices cannot display, especially being able to judge whether sparse area technologies have development continuity, making technology opportunity identification results more comprehensive and scientific. The model relies on data from patent databases and has certain reference significance for technology opportunity identification of small and medium-sized enterprises in various technology fields.

Under sufficient resource conditions, there is still room for improvement in this paper in the future. For example, the judgment of technical feasibility of blank points can rely on more experienced technical personnel. The identified technology opportunities can be calculated for relative value from dimensions such as cost, expected benefits, and innovativeness to determine the best or priority technology opportunities, which also requires the support of professional technical personnel's experience.

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Note: Figure translations are in progress. See original paper for figures.