Title:
Identification of Technology Opportunity Based on a Three-Dimensional Technology Effect Model

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Introduction:
Patents contain rich information of the technology development, it is therefore a key to use patent data for effectively identifying technology opportunities. Technology Effect Matrix (TEM) provides an effective method of patent data mining, which can show details of the patent analysis in a form of charts. It can greatly support to identify technology blank areas and discover potential R&D directions [7]. Many scholars have studied TEM for text mining [9], clustering analysis [4], and technology prediction [2]. However, the existing research on the opportunity identification seldom considers the conformation of selected technologies to the law of technological evolution.

This paper combines the TEM and technology readiness level to propose a method of three-dimensional technology effect model (3D TEM). Our proposed method provides a systematic approach to the technology opportunity identification. It improves the existing method to identify technology blank areas for not only a macro perspective, but also the micro level analysis.

Proposed Method:
A flowchart of the proposed 3D TEM is shown in Fig. 1 to search the potential technical information of patents systematically.

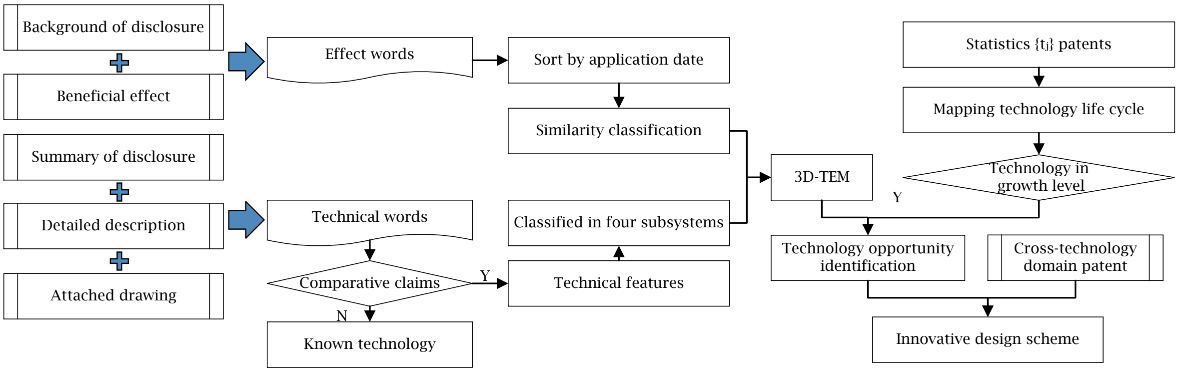


Fig. 1: Process of 3D technology function model.

Three-dimensional technology effect model

The traditional TEM uses technical words and effect words as the coordinate axis, and the size of bubbles at the intersection represents the number of patents. Two large adjacent bubbles at the intersection overlap each other, and the overlapping area produces information coupling. In order to reveal the potential information of overlapping, 3D TEM can identify three factors in independent coordinates of technology, effect, and patent amount. The patent amount is drawn in a form of scatter plots. The scatter plots are then fitted to a smooth 3D surface to clearly show overlapping information.

Coordinate nodes on the effect axis are effect words. First, the relevant patents are searched in a target field, and sorted according to patent application dates. Each patent is numbered to construct a patent space A = $\{a_i\}$ (i=1, 2, 3, ..., m). Patent a_i is looked at one by one to sum up its functions. Effect words e_k are extracted from "Background of disclosure" and "Beneficial effect", these effect words are merged with the similar expression to finally construct an effect words space E= $\{e_k\}$ (k=1, 2, 3, …, n).

Coordinate nodes on the technical axis are technical words. In order to merge similar technical words effectively. A concept of the technical system integrity is introduced. A complete electromechanical product or technical system consists of four parts of energy system, transmission system, execution system and control system [6], as shown in Fig. 2. Because the patent design scheme meets the integrity of the technical system, four subsystems can be used as the technical words.

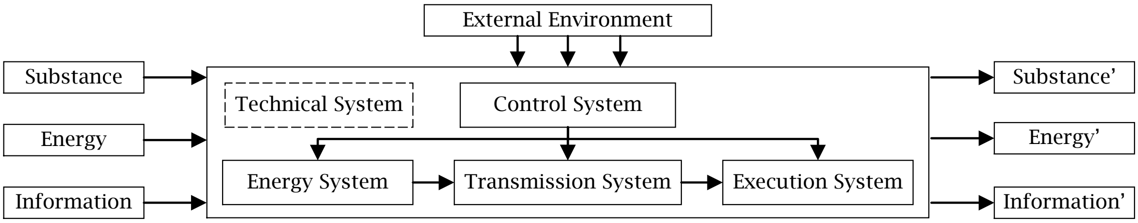


Fig. 2: Composition of a electromechanical technical system.

Technical features are extracted from summary of the disclosure, detailed descriptions and attached drawings. Its novelty is judged by patent claims. According to the matching relationship between technical features and four subsystems, the selected technical features can be finally classified. Where, t_1 represents energy, t_2 is transmission, t_3 is control, and t_4 is execution.

Both numbers of patents and eligible patents are recorded at the intersection of Tab. 1 to include more patent information in the model. Patents are marked with multiple innovative technical solutions to achieve multiple functions with underline. These patents are of great help for designers to produce innovative design schemes.

	t_1	t_2	t_3	t_4
e_1	$\underline{a_1}$, a_2, $\underline{a_6}$ (3)	$\underline{a_4}$, a_7 (2)	$\underline{a_1}$ (1)	a_5, $\underline{a_9}$ (2)
e_2	a_8, $\underline{a_{10}}$ (2)	a_3 (1)	$\underline{a_6}$, $\underline{a_{12}}$ (2)	$\underline{a_{13}}$ (1)
⋮	⋮	⋮	⋮	⋮
e_k	$\underline{a_{12}}$ (1)	$\underline{a_{10}}$ (1)	$\underline{a_4}$ (1)	$\underline{a_9}$, $\underline{a_{13}}$ (2)

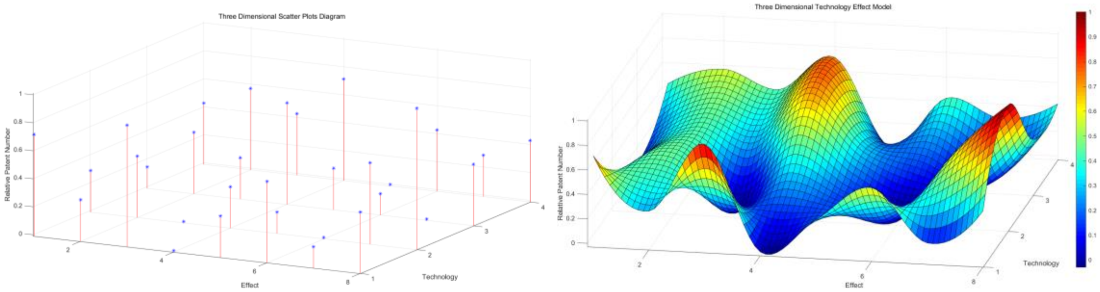
Tab. 1: Patent technology effect matching matrix.

The number of patents at each intersection in the matrix is represented by h_{kj}. A 3D TEM is established with the number of patents as the vertical axis. In order to unify dimensions of the three coordinate axes, it is necessary to remove dimensions of the patent amount coordinate axis, as shown in Formula (1).

$$h'_{kj} = \frac{h_{kj}}{\max(h_{kj})} \quad (j=1, 2, 3, 4;\ k=1, 2, 3, \ldots n) \tag{1}$$

Scatter plots are drawn with the number of patents, as shown in Fig. 3(a). The scatter plots are then connected to draw a 3D TEM of polyline. Finally, a cubic spline interpolation method of Formula (2) is used to smooth the polyline surface. The processing result is shown in Fig. 3(b).

$$S(x)=\sum_{j=0}^{n}[y_j\alpha_j(x)+m_j\beta_j(x)] \tag{2}$$



(a) (b)

Fig. 3: (a) 3D scatter plots diagram; (b) 3D TEM.

Identification of technology readiness level

The 3D technology effect model can easily judge the patent layout. The purpose of identification of technology readiness level is to screen out more development potential technologies. The combination of the two methods can identify technology opportunities more scientifically. After the establishment of 3D TEM, it is necessary to decide the technology readiness level of four types of technologies mentioned in Fig. 2. Altshuller uses the S-curve to describe four stages of the technology readiness level: introduction, growth, maturity, and decline [1]. Common methods to decide the technology readiness level include the patent index [10], relative growth rate [1], and technology life cycle diagram [5]. In this paper, the technology life cycle diagram method is selected to evaluate the readiness level as the difficulty of patent index statistics.

Tan used TRIZ tools to study the characteristics of each stage of the technology readiness level [8], as shown in Tab. 2.

Level	Feature	Strategy
Introduction	There are few patent applications, technology R&D activities have just started.	Make full use of resources in the system.
Growth	The product market expanding constantly with the development of technology. The number of enterprises involved has also increased, and the number of patent applications has expanded.	Promote the product performance to the best and seize the market opportunity.
Maturity	The amount of participating enterprises decreases. The growth rate of patent applications declines.	Simplify product systems and improve appearance.
Decline	Enterprises withdraw from the market as the profits shrink. The growth rate is negative.	Looking for alternative technologies for new areas.

Tab. 2: Four stages of technology readiness level.

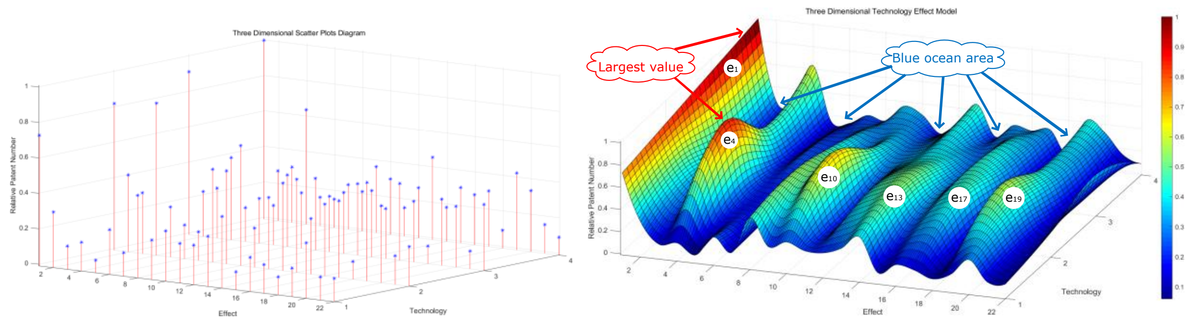
Distinguishing the development level of a technology is essential for enterprises to make correct decisions in R&D directions. Through the analysis of four stages characteristics, we can see that it is easier to occupy the market and obtain high profits of the technology located in a growth level.

Using data of the number of patent applications and the number of applicants vary with time, according to relationships of four types of technologies, the technology readiness level can be decided to select the technology located in the growth level for development.

Case study

We use the lithium cobaltate powder drying technology as an example to illustrate the use of 3D TEM. Firstly, patents are searched for powder drying, and 214 patents are obtained after screening. Through merging similar expressions and sorting according to the patent application date. 22 effect words are finally extracted. A patent technology effect matching matrix is finally constructed.

The 3D scatter plots diagram is formed using Formula (1). All vertices are then connected to establish 3D TEM according to Formula (2) as shown in Fig. 4.

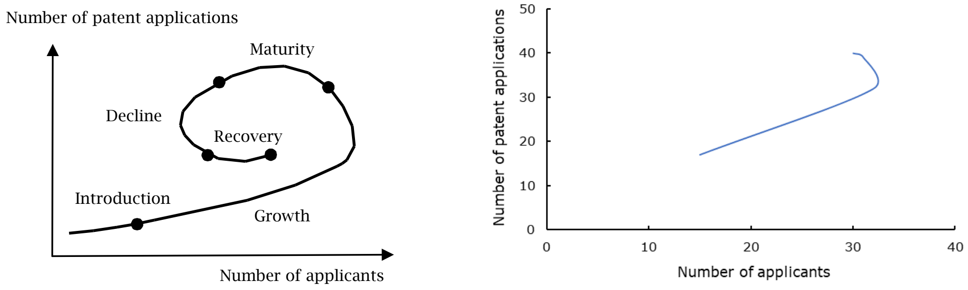


(a) (b)

Fig. 4: (a) 3D scatter plots diagram; (b) 3D TEM of powder drying.

As can be seen from Fig 4 (b), the overall shape is wavy, and the value of two earliest appearing effect patents involving e_1 and e_2 is the largest, as shown in the dark red area. For the opportunity identification, these blank areas with dark blue area of the canyon shape are called blue ocean, which should be paid more attention. On the technology axis, the number of patents from t_1 to t_4 generally shows a trend from more to less. With the continuous maturation of mechatronics technology, increasing the degree of equipment automation from the perspective of control technology, and reducing human participation will be the drying equipment development trend in future.

According to the time varying situation between the number of patent applications and applicants, the technology life cycle diagrams of four types of technologies are drawn respectively. Comparing with the standard diagram to decide the readiness level as shown in Fig. 5 (a). Taking t_2 technology as an example, it located in the late stage of growth, as shown in Fig. 5 (b). The other three technologies are energy technology located in introduction, control and execution technology located in the early stage of growth.



(a) (b)

Fig. 5: (a) Technology life cycle standard diagram; (b) t_2 technology life cycle diagram.

Transmission, control and execution technologies are selected as the main R&D technologies. The opportunity identification of the powder drying theme is determined through the analysis of blue ocean and the technology located in growth level, such as to improve the drying effect and effective utilization of energy, simplify the operation of equipment, improve the operation safety, thoroughly dry the powder inside, and eliminate static electricity. In the process of innovative structure design, patents that span three technology categories are mainly used for references, including a_8: CN201710242862.9, a_{52}: CN201711193866.9, a_{100}: CN201810349904.3, and a_{119}: CN201810613408.4. The use of circulating drying to achieve the efficient utilization of energy; improve the automation of the drying equipment to reduce manual operations, and increase the drying path of the drying pipe to improve drying efficiency and quality. A new lithium cobaltate powder drying structure can be finally developed.

Conclusion:

This paper integrates two methods of TEM and technology readiness level to construct a 3D TEM. The visualization effect of data mining is enhanced, and the selection of the blue ocean area in the 3D TEM can clearly show the direction of technology development. The identification of technology opportunity is improved through the readiness level. Through the patent analysis of a powder drying, the blue ocean area is selected for the opportunity identification analysis to decide the R&D direction. Based on the analysis of cross-technology patents, an improved powder dryer is designed and applied for patent.

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