Research Article

Technology Opportunity Recognition Algorithm and Decision Assistance for Non-Drug Antidepressant Field in China

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The aim of this study is to propose a framework for non-pharmaceutical antidepressant technology opportunity identification in China, based on patent analysis and assisted decision making. Semantic mining technology was used to divide technology life cycle, classify technology, identify key technology associated opportunities, and identify core technology functions of 532 non-drug antidepressant patent data in China from 1995 to 2021. Combined with co-occurrence and multi-dimensional scale analysis, strategic coordinate maps and technology decision assistance maps were drawn. The development of non-drug antidepressant technology in China was divided into embryonic stage, formative stage, and development stage. Six technical categories, 30 high-frequency technical associated opportunities, and low-frequency and high-frequency core technical opportunities for non-drug antidepressants were summarized. Based on four technical fields and four functional clusters of strategic coordinate graphs, the technical opportunity decision auxiliary atlas was constructed. By comparison, this map is more intuitive than the technology-efficacy matrix, when presenting technology efficiency mapping. This study provides a set of systematic algorithms for opportunity identification and decision assistance based on patent data, in addition to reference for strategic decision making of non-drug antidepressant technology subjects in China.

1. Introduction

Depression is a common recurrent chronic mental disorder, with main clinical manifestations including emotional depression, sleep disorders, physical pain, self-harm, and suicide [1, 2]. The basic treatment for depression is psychotherapy, and in severe cases, antidepressants are needed for co-treatment. Drug treatment for depression has many problems such as dependence, addiction, slow efficacy, and more adverse reactions [3]. On the other hand, there are many non-drug antidepressant treatment methods, which are safe, effective, and practical. The potential of non-drug antidepressant therapy has attracted increasing attention. With the accelerating speed of technological innovation and the increasingly fierce market competition, it has become critical for enterprises to formulate and adjust technological competitive strategies in time according to technological competitive intelligence [4–6].

Identifying technological opportunities is the key to the success or failure of technological innovation. Improving the ability of technological opportunity identification is paramount to the development of research enterprises and technology fields [7]. Enterprise leaders aspire to discover potential technological opportunities through technical opportunity analysis, save production cost and time to increase value [8, 9]. The concept of technological opportunity analysis was proposed by Porter and Detampel in 1957 [10], where technological opportunity analysis was defined as the identification and analysis of the possibility of technological innovation in the future by using various analysis algorithms at the current technological level. The research on technology opportunity identification can be divided into three directions: future technology trend identification, technology innovation combination identification, and key technology identification [11, 12]. Patent literature is an important carrier and expression of scientific and
technological innovation achievements, and the information that the majority of scholars focus on when exploring technological innovation opportunities [13]. Wang et al. [14] used text mining combined with clustering to analyze patent data in the field of microalgae biofuel and investigated the gap between scientific and technical knowledge to identify the potential technological opportunities. Han et al. [15] analyzed patent classification numbers in the field of information and communication and identified opportunities for integration with other technical fields by association rules. Opportunity identification analysis based on patent data is fundamental for making a series of innovation decisions. Liu et al. [16] constructed a technology efficiency matrix based on patent data for technological opportunity identification, and performed decision analysis on technological means and technical problems from three dimensions.

Based on the patent data, the development stages of non-drug antidepressant technologies in China were divided according to the technology life cycle theory. The Louvain algorithm was used to classify the technology categories in this field, and the Apriori algorithm was used to analyze and mine the core technology opportunities. A technology-efficacy matrix was constructed to assist non-drug antidepressant technology R&D institutions to predict technological innovation from the perspective of functional requirements. Finally, the functional strategic coordinate map was obtained by multi-dimensional scale analysis, and the technical opportunity decision auxiliary Atlas was constructed using co-occurrence analysis. Identifying potential technical opportunities of non-drug antidepressant technologies in China is critical for improving the quality of life of patients and establishing the core competitiveness of companies.

2. Methods and Data

2.1. Model Building

2.1.1. Louvain Algorithm. The Louvain algorithm was employed to cluster the proposed patented technology keywords to identify the technology type. The Louvain algorithm is a community clustering algorithm based on multi-level optimization module degree theory, which can classify the technical elements [17, 18]. In brief, the process is as follows: try to plan each node in the network to the community in turn and calculate before and after modularity allocation $\Delta Q$. Assuming that there are any nodes in the network, if the node is assigned to the community of the node with the largest $\Delta Q$, otherwise it remains unchanged. These steps are repeated until the community of the network remains unchanged. $\Delta Q$ is defined as:

$$\Delta Q = \left[\frac{\sum _{in} + 2d_{a,in}}{2m} - \left(\frac{\sum _{tot} + d_a}{2m}\right)^2\right]$$

$$-\left[\frac{\sum _{in}}{2m} - \left(\frac{\sum _{tot}}{2m}\right)^2 - \left(\frac{d_a}{2m}\right)^2\right],$$

where $\sum _{in}$ is the total degree of all edges in community $C$, $\sum _{tot}$ is the total degree of all edges to nodes in community $C$, $d_{a,in}$ is the number of edges of all nodes from $d_a$ to community $C$, and $m$ is the total number of edges in the network.

2.1.2. Apriori Algorithm. The Apriori algorithm was used to mine the potential relevance of innovation elements in patent data, analyze the constitution rules of innovation elements, and identify the potential opportunities of technological relevance. The method iteratively mined frequent item sets through layer-by-layer search and generated strong association rules [19, 20]. Support and Confidence are commonly used to measure whether a rule meets the expectations. Support measures the probability of two events occurring at the same time, and Confidence measures the probability of another event occurring, given one event occurs. The formula is expressed as follows ($A$ and $B$ are any two events):

$$\text{Support}(A \rightarrow B) = \frac{P(AB)}{P(A)},$$

$$\text{Confidence}(A \rightarrow B) = \frac{P(AB)}{P(A)}.$$  \hspace{1in} (2)

2.1.3. Technology-Efficacy Matrix. The technology-efficacy matrix was used to map the technology categories and demand efficiency and to identify core technical functions. From the standpoint of technology, multiple technical means will produce the same efficacy, and the same sort of technical means can also achieve different efficacy [21]. The technology-efficacy matrix heat map was plotted according to the co-occurrence frequency between the technology field in which the patent was located and the efficiency generated.

2.1.4. Multi-Dimensional Scale Analysis and Co-Occurrence Analysis. Multi-dimensional scale analysis was used to map technological and functional strategic coordinates. Co-occurrence analysis was conducted based on the technological family and functional cluster to map the technical opportunity decision auxiliary Atlas in the non-drug antidepressant field in China. Multi-dimensional scale analysis involves the use of the heterogeneous matrix of various technical means to distribute to different areas in coordinates in the form of points, and intuitively display the relationship between various technologies [22, 23]. Generally, the clustering elements in the first quadrant are closely related to each other and are at the center of the network. The second quadrant has relatively loose cluster structure and has further development space. The third quadrant is internally connected at the technological edge. The fourth quadrant is the edge of the entire field and is of low importance [24]. Co-occurrence analysis is a quantitative method of various information carriers, aiming to reveal the correlation characteristics between various technical fields and functional clusters [25].
2.2. Data Source and Preprocessing

2.2.1. Data Source. The CNKI China patent database, which accurately reflects the latest patent inventions in China, was used as the data source. The search time was May 5, 2022, and the search scope was up to December 31, 2021. Excluding the patents whose applicants were from overseas institutions of China, and keeping the latest application version for repeated applications, 1920 valid patents (including invention patents and utility model patents) were finally obtained. Each patent was manually classified by two researchers independently and back to back, and 532 patents of non-drug antidepressant technologies were screened out by reading titles and abstracts. Then, the IPC classification number, title, application year, and abstract were extracted for subsequent analysis.

2.2.2. Data Preprocessing. There is no given keyword in patent literature, so it is necessary to transform patent text data into structured data convenient for processing. Therefore, the Jieba tool was used in this study for word segmentation of patent abstract text, and a self-defined dictionary of anti-depression technology fields was added to optimize the word segmentation. Based on the Harbin Institute of Technology stop words dictionary, meaningless stop words were eliminated and content words such as nouns, verbs, and adjectives were extracted. For each patent document, 3–8 keywords highly related to the content were selected as keyword candidates. The keyword technology database was established by merging the synonyms of technical keywords and deleting low-frequency words.

The common structure of utility phrases was a combination of phrases such as verb-object or subject-predicate structures. Examples include “reduce the price and cost,” “easy to operate,” etc.; or they can appear together with clue words, e.g., “the invention . . . enables/facilitates/facilitates the use of . . .” The study combined cue words with functional precture to extract rule-compliant efficacy phrases in the abstract. The efficacy phrases were homogenized, and the same or similar efficacy was combined to build an efficacy corpus.

Each patent matched multiple IPC classification numbers, according to its field. Multiple IPC classification numbers appear in the same patent, which are associated with the relevance and integration of technologies [26]. The first four IPC classification numbers (sub-categories) were analyzed in this study and the core technologies in this field were observed. Table 1 shows 72 IPC subclasses of non-drug antidepressant patents involved in this study and their meanings. The top 26 IPC subclasses with frequencies greater than three are given in Table 1.

3. Identification of Technical Opportunities in the Non-Pharmaceutical Antidepressant Field in China

3.1. Life Cycle Analysis of Non-Pharmaceutical Antidepressant Technologies in China. At present, the relatively mature theory of technology life cycle includes germination, growth, maturity, and decline [27, 28]. Another categorization is division in three stages: start-up, development, and maturity [29]. Although these two theories have different bases for decomposing the stages of technological evolution, they share the same kernel. Due to incomplete data from 2022, only patents from 1995 to 2021 were included in this study. Based on the life cycle theory, the development trend of non-drug antidepressant technology in China was divided into three stages: embryonic stage (1995–2016), formative stage (2017–2020), and development stage (2021-present) (Figure 1). Before 2016, the technology germination period, the field did not receive enough attention; 2016–2020 is the period of technological development, during which the enterprises began to attach importance to the research value of non-drug antidepressant technologies, and the growth rate increased. From 2021 to the present is the development period, with a trend of substantial increase in patents and an improvement in the scope of technical requirements. Patent data since the development period are more forward looking for mining technology opportunities.

3.2. Technical Classification of Non-Drug Antidepressant Field in China. Word frequency analysis was used to sort the frequency of technical keywords, and finally 130 keywords with frequency of ≥3 were identified as the core innovation elements in the non-pharmaceutical field of antidepressant technology in China. The core innovation elements were clustered based on the Louvain algorithm, and seven major technical topics in this field were identified and further subdivided into six categories and fifteen sub-categories. The final classification of technical fields is shown in Table 2.
3.3. Association Identification of Key Technologies for Non-Drug Antidepressants in China. The Apriori algorithm was used to rank the technology combinations in the examined time period according to frequency. In the association rule analysis, minimum Support and minimum confidence values that are too low may reduce the significance of association rules [30]. Therefore, in combination with the number of technology patents in this field, the minimum support and minimum confidence in this study were set as 1% and 10%, respectively. The top 30 combinations of technology fields with the most frequent occurrences were then selected, as shown in Table 3.

Table 3 shows that the main association rules in the field of non-drug antidepressants in China are concentrated in the six fields of A47G (Household or table utensils), C12G (Alcoholic beverages and their preparation), A23F (Manufacturing and preparation or brewing of substitutes for coffee and tea), A23L (Food and edibles or non-alcoholic beverages and their preparation or handling), A61Q (Cosmetic or similar make-up for a specific purpose), and C11B (Essential oils and spices...
and their configuration or extraction). The most frequent pairs of association rules were A23G (Cocoa products, cocoa products substitutes, candy, chewing gum, and ice cream and its preparation) and A61K (Pharmaceutical products or other biological compositions, and their preparation or treatment methods), A61Q and A61K, C12G and A61K, A47C (Chairs, sofas, and beds) and A61M (A device for introducing or on a human body, an instrument for transferring or removing a human body medium, used to produce or end sleep or coma), C12G and A61P (Specific therapeutic activity of a compound or drug preparation), F21S (Non-portable lighting devices or systems, specially adapted for vehicle lighting outside the vehicle) and F21V (A functional feature or component of a lighting installation or its system), C12G and (A61K, A61P), (A61P, A61H (Physiotherapy device, artificial respiration, massage, bathing device used for special therapeutic or health purposes)) and (A61K, A61M), (A61K, A61H) and (A61M, A61P). The obtained high-frequency association rules were the focus of research in the field.

### 3.4. Identification of Core Technology Functions in the Non-Drug Antidepressant Field in China

Based on the IPC classification number and characteristic phrase of efficacy after 2021, the technology-efficacy matrices of high-frequency (Figure 2) and low-frequency efficacy (Figure 3) in the development period were drawn, respectively. The main technology patents cover A61B (Instruments and methods for diagnostic surgery and human identification), G16H (ICT specifically for the disposal or processing of medical or health data), G06K (Graphic data reading, presentation of data, record carrier, and processing record carrier), G06N (Computer system based on a specific computing model), G06F (Electrical digital data processing), A61K, A61M, G10L (Speech analysis or synthesis, speech recognition, speech or voice processing, speech or audio encoding or decoding), A61P, G06V (Image or video recognition or understanding), C12G (Methods for determination or examination of nucleic acids containing enzymes or microorganisms, preparation methods and conditional reaction control), G01N (Methods for the determination or examination of enzymes and nucleic acids or microorganisms, preparation methods, and conditioned reaction control), A61N (Electrotherapy, magnetic therapy, radiation therapy, and ultrasound therapy), A23L, G06Q (Data processing system or method designed for administrative, commercial, financial, managerial, supervisory, or forecasting purposes), A61G, G06T (General image data processing or generation), C12N (Microorganisms or enzymes and their compositions, microbial propagation and preservation or maintenance, variation or genetic engineering, media), A47C (The parts or accessories of a chair or stool), G16B (Information and communication technologies for processing genetic or protein-related data in computational molecular biology). This stage involves information technology application, biotechnology detection, and artificial intelligence development. The development of key fields in the entire examined period varies greatly, indicating that the non-drug antidepressant technology development in China has not matured yet and has great potential.

The study divided high- and low-frequency efficacy technologies into two categories according to the frequency of the occurrence of function phrases. High-frequency efficacy words are the basic key technical requirements for the current development of this field, and the technical functions that enterprises with relatively weak technical foundation need to consider. Low-frequency efficacy words are potentially popular future technology demands in this field, which is considered by enterprises with a certain technical basis in order to establish competitive advantages. R&D companies can select technological opportunities based on the efficacy dimension, or they can select patents based on different efficacy perspectives [31]. Using the constructed technology-efficacy matrix, R&D enterprises can analyze whether the current innovation opportunities meet the current development strategy and technical requirements, and analyze the unrealized functions.

### 4. Opportunity Decision Assistance Analysis of Non-Pharmaceutical Antidepressant Technologies in China

#### 4.1. Coordinate Chart of Efficacy and Technical Strategy of the Non-Drug Antidepressant Field in China

The similarity level of different technical means is indicated by the coordinate
distance. Highly similar technologies are clustered together, which become the hotspot of disciplinary research. This study conducted multi-dimensional scale clustering of the dissimilarity matrix of patent IPC classification numbers and efficacy terms of non-pharmaceutical antidepressant technologies until 2021. Thus, the technology and efficacy strategy coordinate maps were obtained (Figures 4 and 5). Combined with the meaning of IPC classification number, in Figure 4, Field 2 refers to the application of big data technology in the de-scaled depression screening method, which is located in the first quadrant of the coordinate chart and is currently the research focus and hotspot in the field of non-drug antidepressants. Field 1 includes the use of microorganisms, compounds, and enzymes in the detection or testing of depression. This field is located in the second quadrant, indicating that this kind of technology field has potential importance and development space, and it is the direction that the enterprises focus on when making opportunity decisions. Field 3 includes functional furniture that relieves stress and improves mood. Although new functional technologies may be added, it is on the edge of technical research. Field 4 is distributed in the fourth quadrant of the strategic coordinate system, and the clustering of technical factors is relatively discrete, indicating that this field includes immature edge antidepressant technologies and needs to be avoided in enterprise decision-making.

In Figure 5, functional cluster 2 emphasizes the fun, simplicity, and innovation of psychological intervention. Cluster 2 is located in the first quadrant and is the key strategic demand for enterprises to increase their competitiveness. Cluster 1 focuses on the intelligence and practicality of depression diagnosis technology, and lies in the second quadrant, which is a new opportunity and challenge for enterprises. Cluster 3 can be divided into two categories according to the distance of each functional word: the first category focuses on the objectivity and efficiency of depression screening technology, which is located in the center of the third quadrant and is the basic requirement of screening technology. The other category emphasizes sensitivity and precision, which is close to the junction of the second and third quadrants and is critical in the
establishment of technological advantages in screening technology patents. Cluster 4 focuses on the taste and safety of antidepressant foods and the low cost of their production, and is in the fourth quadrant, which holds the least importance.

4.2. Opportunity Decision Assistance Atlas of Non-Pharmaceutical Antidepressant Technology in China. The concept of information visualization was first proposed by American scholar Robertson et al. [32] in 1989. In their work, it was proposed that the information visualization is the process of showing the hidden rules of various data. Information visualization is not only used in information industry, but also in other industries, commerce, agriculture, education, and other fields of social life, which promote the development of social economy. In this study, the co-occurrence relationship between technical fields and operational functional clusters was visualized. In Figure 6, the thickness of the arrows represents the co-occurrence frequency, and thus the
decision auxiliary Atlas was drawn. This Atlas can be utilized by research institutions to adjust their technology development strategies and grasp technological opportunities. Among them, the frequency of technical field 1 and functional cluster are in the following order: Cluster 4 (37), Cluster 1 (36), Cluster 3 (19), and Cluster 2 (17). For technical field 2: Cluster 3 (163), Cluster 2 (50), Cluster 1 (30), and Cluster 4 (22). For technical field 3: Cluster 3 (163), Cluster 2 (50), Cluster 1 (30), and Cluster 4 (22). For technical field 4: Cluster 3 (163), Cluster 2 (50), Cluster 1 (30), and Cluster 4 (22).

In terms of the frequency and domain characteristics, Figure 6 shows that Field 1 (application of microorganisms, compounds, and enzymes in the detection or testing of depression) is mostly associated with low cost and practicality. Such technology enterprises often emphasize the advancement of technology, but high technology brings high cost. When the cost of technology rises to offset or even exceed the technological advantage, such technology may not be applicable. In this context, low cost and strong practicality are to seize the market advantage of the key. Field 2 is the application of data processing models or systems in depression screening, with its current goal being the pursuit of objectivity, efficiency, and accuracy. Traditional scale screening has disadvantages such as subjectivity, passivity, and limitations. Big data technology can bypass the problems and make early warning depression screening possible. Field 3 is functional furniture, which focuses on low cost, fun, simplicity, and innovation. With the social attention to mental health, age-appropriate furniture, barrier-free furniture, and other functional furniture with the effect of relieving pressure gradually rise. Innovative design and simple modeling is the key to break through the market.

5. Conclusions and Limitations

5.1. Conclusions. Based on the patent data of 532 non-drug antidepressant technologies in China from 1995 to 2021, a set of technical opportunity identification descriptions based on text classification, text association, and feature co-occurrence is proposed in this study, in addition to auxiliary determination analysis based on multi-dimensional scale analysis and collinear analysis.

The technical opportunity identification analysis draws the following conclusions:

The development of non-drug antidepressant technology can be divided into the embryonic, formative, and development stage. At present, the overall number of patents in
this field is small and has not yet reached maturity. Six technology categories and 15 technology sub-categories were determined in this field, including treatment mode, application of information technology, detection of biotechnology, application of traditional Chinese medicine, and development of artificial intelligence and healthy food technology.

The main innovation opportunities in the field of non-drug antidepressants in China involve food and health care, physiotherapy, and wearable devices. The key points of technical association rules are the combination of antidepressant drug compositions with food and beverage development, combination of antidepressant drug compositions with cosmetics development, furniture with depression relief and sleep improvement function, and massage physiotherapy devices to relieve stress.

Technical requirements such as high precision, quick and efficient, objective quantitative, ease depression, disease diagnosis, pertinency, generalizability, monitor the effects of medication, evaluation of comprehensive, disease screening, cheaper cost, sleep improvement, enjoyment, and intellectualization are fundamental in the field of the current development. Sensitivity, simple operation, wide applicability, high security, practicability, multi-modal, psychological intervention, effectiveness, automation, stability and adaptivity, interactivity, portability, immediacy, based, and palatability may become future hot technology demands in this field.

The results of auxiliary decision analysis are as follows:

Based on multi-dimensional scale clustering results and co-occurrence analysis, the technical opportunity decision assistance Atlas of non-drug antidepressants in China was plotted based on the technical and functional clusters. The application of microorganisms, compounds, and enzymes in the detection or testing of depression is primarily associated with low cost and usefulness. The application of data processing models or systems in depression screening pursues the objectivity, accuracy, and efficiency of the measurement results. Functional furniture is mainly concerned with low production cost, fun, simplicity, and innovation.

5.2. Limitations. Only patent data was considered in this study to conduct technical opportunity identification and decision-assisted analysis for the non-pharmaceutical antidepressant field in China. Because different patent types represent different stages of technological development, the results of this study can only reflect the actual situation of the technological application stage, and other relevant dimensional information should be considered in actual decision-making [33].

Data Availability

The figures and tables used to support the findings of this study are included in the article.

Conflicts of Interest

The authors declare no conflicts of interest.

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