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Evaluating patent technology transfer potential : A predictive model based on citation network analysis

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Purpose: **The citing of patents is an indicator of the transfer of technical knowledge and the influence of one technology on subsequent developments. The objective of this paper is to construct a predictive model based on patent and paper citation network to evaluate the potential for technology transfer of patents**

Methodology: **This paper employs a binary classification algorithm from machine learning, specifically the decision tree algorithm, as its methodology. This has facilitated the creation of a predictive index system comprising 16 structured indicators across three dimensions: the degree of technological innovation, the quality of patent document, and the extent of intellectual property rights (IPR) protection. In order to construct the training sample set, patent transfer data for graphene sensors were employed as proxy variables for technology transfer potential.**

Findings: **The findings of the study indicate that the dynamic characteristics of the citation network are a significant factor in the assessment of the potential for technology transfer. The most significant indicator affecting the transformation value of patents is inward degree centrality. Moreover, the results demonstrate that additional evaluation indicators, namely outward proximity centrality, family size, and self-citation frequency, are also of significance. The patent technology transfer potential prediction model presented in this paper, which is based on citation network indicators and a decision tree algorithm, exhibits a high degree of predictive accuracy.**

Value: **The value of this research lies in its novel perspective and method for patent valuation and technology transfer strategies. Furthermore, it offers a more comprehensive reflection of the inheritance and flow of patented technology by integrating the citation relationships between**

patents and scholarly papers. This makes it a valuable contribution to the understanding and promotion of the technology transfer process.

Keywords: *Technology transfer, Patent-paper citation network, Machine learning.*

1. Introduction

Technology transfer refers to the process of exporting and importing knowledge or technology within or between countries, regions, industries and sciences through certain carriers (people, objects, or information) [1]. At present, the licensing and transfer of patents has become the most recognized technology transfer method in the market, which are recognized as an important carrier of knowledge and technological innovation.

Some scholars discuss the issue of patent transferability from the perspective of patent value evaluation, and believe that patents with high technology, legal or market value have a higher possibility of industrialization [2, 3]. Some studies mostly set quantifiable indicators based on the nature of patent documents [4, 5, 6], but these indicators do not change with the development of technology and cannot accurately measure the dynamic characteristics of patent value. Currently, some scholars use patent citation analysis to identify technologies with transfer potential [7, 8, 9, 10]. Patent citation parameters help to identify emerging technologies and key patents, but indicators based on degree centrality only judge the importance of nodes based on neighbor information. Moreover, in most cases, a large number of nodes are easily given the same value, and it is often difficult to distinguish the importance of nodes. This paper presents a prediction model for technology transfer potential, which is based on patent citation analysis. The model employs social network analysis and machine learning algorithms to explore the quantitative correlation between patent parameters and technology transfer.

2. Theoretical background

The successful transfer of patented technology is influenced by multiple factors, including the level of technological innovation contained within the patents, the quality of patent text, and the scope of their legal protection. Furthermore, it develops dynamically with the development of technology and the dissemination of knowledge. Existing studies have found that the citation relationship between patents reflects the development of technology and the flow of knowledge, reflecting its influence on subsequent technologies [11]. Based on this, this study argues that patent citations can be used to measure patent technology transfer potential.

Meanwhile, patents and papers are crucial for the dissemination of technological innovation and scientific knowledge, respectively. The spread of scientific knowledge represented by papers into patents reflects that scientific research drives technology research and development and application; the diffusion of technical knowledge represented by

patents into papers reflects that technology research and development has spawned corresponding scientific research. Therefore, the citation relationship between papers and patents is also an important indicator to measure the level of knowledge diffusion.

Therefore, this paper supplements the citation data of patents to papers into the patent citation network, aiming to fully reflect the inheritance and flow of patented technology.

3. Methodology

3.1 *Indicators*

This paper presents a system for evaluating the transferability of patents. The system employs 16 indicators covering dynamic and static types, which encompass technology, document quality, and intellectual property rights protection (Table 1). Specifically, the characteristics of technological innovation refer to the ability of nodes in the patent citation network to obtain resources and control information relative to their neighbouring nodes and the global structure, which varies dynamically over time. The characteristics of document quality are the quantitative indicators relating to the design of the patent documentation. The degree of IPR protection relate to the changes in the patent family due to product strategies.

3.2 *Model*

In this paper, the binary classification algorithm of machine learning is used to construct the evaluation model, and the above 16 indicators are considered by the decision tree algorithm. Patent transfer data is employed as a proxy variable for the transformation value of patents, the data of patent transfer is used as positive samples, and the data of patents that have not been transferred until the patent expires is used as negative samples. The training and test sample sets are collaboratively formed using the aforementioned data types. Each judgment node in the decision tree corresponds to a certain attribute of the data set, and the attribute closer to the root node is more important for the classification result. Therefore, based on the intuitive logical derivation process of the decision tree algorithm, the importance of the factors affecting patent technology transfer can be studied.

3.3 *Data*

This paper selects patents in the field of graphene sensors for empirical analysis. The patent data comes from the Derwent Innovation Platform, and the patent citation data and paper citation data come from the lens database.

As of the retrieval date (June 27, 2023), there were 10,785 global patents for graphene sensor technology, of which 499 were transferred patent applications, and 2,621 patents cited papers.

Table 1

List of Evaluation Indexes for Patent Technology Transfer Potential

Indicator type	code	Indicator name	Indicator description
the degree of technological innovation	X1	number of countries cited by non-domestic patents	This metric indicates the number of countries in which the patent has been cited by non-domestic patents. A patent that has been cited in multiple countries signifies that it is a technologically innovative patent with significant impact within the field.
	X2	number of self-cited	This metric indicates how many times a patent has been referenced in subsequent patent filings made by its applicant, which is closely related to the iterative innovation ability of the patent applicant. A greater frequency of self-citations demonstrates higher value being placed on the patented technology by the applicant.
	X3	out-degree	This metric reflects the number of times a patent cites other patents, reflecting the degree of integration of the patent into prior research.
	X4	in-degree	This metric denotes the frequency with which a patent is referenced by other patents, reflecting the influence of the patent on subsequent research.
	X5	out-closeness centrality	This metric refers to the inverse of the total minimum distances needed for a patent to be cited, whether directly or indirectly, by all other patents in the field, and reflects the active proximity of the patent, i.e., its ability to assimilate the technical knowledge of previous patents.
	X6	in-closeness centrality	This metric is defined as the sum of all other patents in the citation network's shortest distances that are needed to be directly or indirectly cited by a specific patent, expressed as its reciprocal , which reflects the degree to which the patent can exert influence on subsequent patents without interference from intermediaries.
	X7	betweenness centrality	This metric indicates the number of times a patent node in a patent citation network acts as the shortest bridge between two other nodes, reflecting the intermediary influence of the patent in mediating the flow of knowledge throughout the network.
	X8	Network Constraint Index	This metric indicates to calculate the structural hole nodes in the citation network using the constraint coefficient algorithm, which indicates the limitations or constraints of the nodes in the patent citation network in terms of their structural advantages.

Contd...

the quality of document	X9	scientific intensity	The quantity of non-patent sources referenced by a patent is used to evaluate the relationship between a patented technological innovation and scientific research. The greater the quantity of non-patent citations, the stronger the correlation between the patent and scientific research, and the more advanced the technology.
	X10	Technical coverage	The quantity of IPC classification numbers indicates the extent of the technological area covered by the patent. The greater the count of IPC codes, the wider the range of technical fields involved.
	X11	Technology integration	The number of IPC divisions included in the patent except for the main classification code is used to examine the integration degree of the patent and other fields of technology.
	X12	Number of Claims	The scope of protection is greater when there are more claims, providing more comprehensive technology protection and stable rights.
	X13	Number of words in independent claims	In terms of patent protection, a higher scope can be achieved in independent claims with fewer technical features, while the fewer words in the independent claims may mean fewer technical features.
	X14	Claim Stability	The number of patent oppositions, invalidations, and litigation resistances used to characterize patent legal stability.
IPR protection	X15	Patent Family Size	The quantity of patents contained in a patent family, used to characterize the patentee's focus on technology and markets.
	X16	Geographic scope of patent families	This term describes the geographical boundaries of patent protection. The more expansive the coverage, the higher the value, reflecting the holder's confidence in the technology's market potential.

3.4 *Patent and Paper Citation Network Mapping*

Using the citation data from patents, patent citation papers, and papers cited by patents, a patent and paper citation relationship map has been constructed for the field of graphene sensors. In the citation network, the nodes represent patents or papers, the connection lines represent the citation associations between the nodes, and the arrow direction of the connection lines represents the direction of the citation relationship. The thickness of the connection is a reflection of the reference strength, that is, the number of references is proportional to the thickness of the connection (Figure 1).

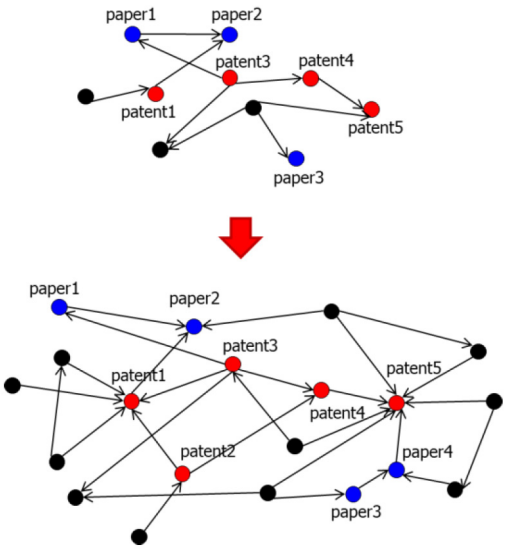

Figure 1

Schematic Diagram of Patent And Paper Citation Dynamic Network

This paper employs Pajek, the social network analysis tool, to analyze the data and determine the influence index of network nodes. This paper believes that the citation network indicators of patents in the year of transfer have reached the standard of transfer transformation, so the citation network dynamic indicators of transactional patents are collected from the citation relationship graph of the transfer year.

4. Results and Discussion

The decision tree model depicted in Figure 2 illustrates that the colour of each block indicates its judgment direction, wherein yellow signifies True and blue signifies False. Furthermore, the darker the colour of the block, the more effective its classification effect. The decision tree model starts at the root node, where it evaluates a specific attribute of the instance. The model then assigns the instance to its child nodes according to the outcome of the evaluation. The evaluation process is performed recursively until the model reaches a leaf node. At this point, the model assigns the instance to the class of the leaf node. The results show that the decision tree model has a total of 72 leaf nodes. The first layer of the tree structure is split according to the inward degree centrality (X4) of the research object, so this paper believes that this index is the most influential factor on the value of patent conversion. The lower nodes are outward proximity centrality (X5), family size (X15), and self-citation frequency (X2). These indicators are located at the top of the decision tree, the number of classified samples is large, and most of the classifications are highly differentiated, indicating that these indicators have an important impact on classification prediction. Among them, the inward degree centrality (X4) and the outward proximity

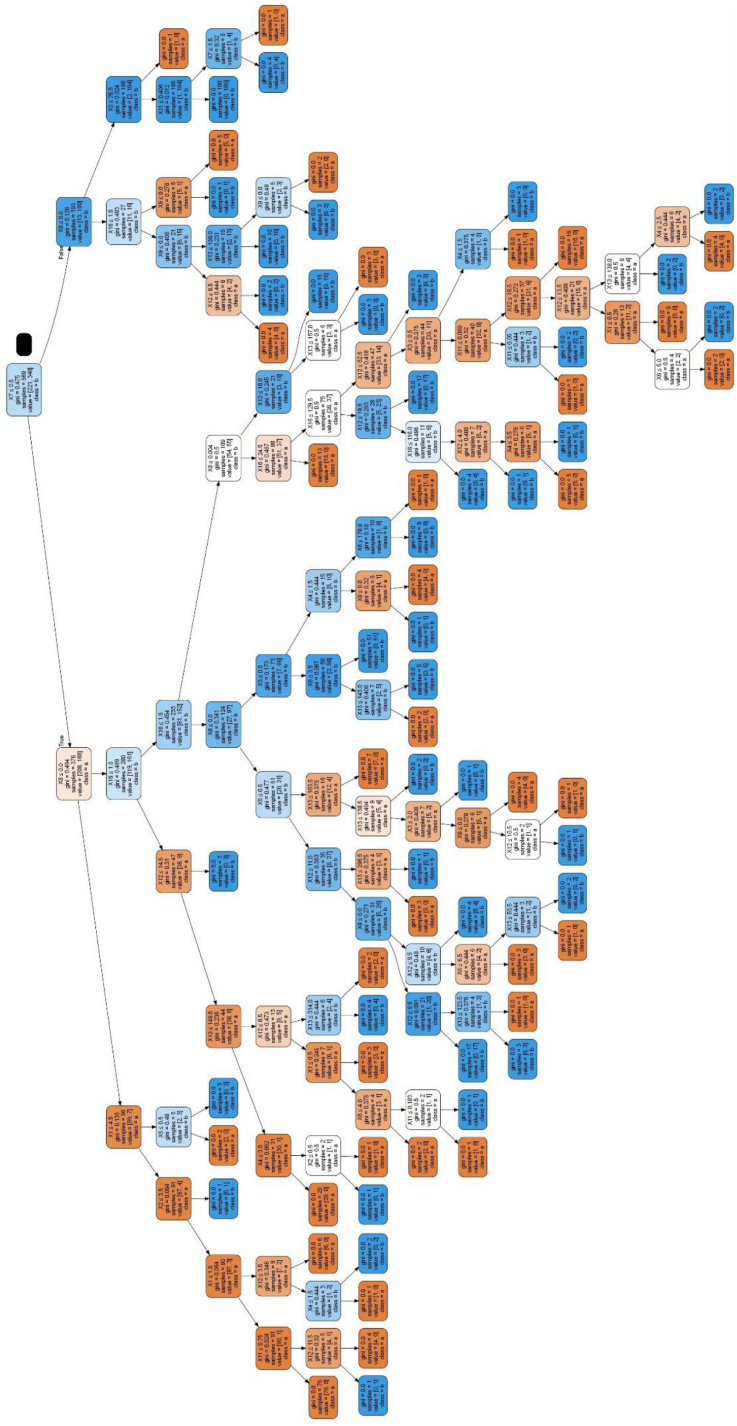

Figure 2

Decision tree framework for prediction of patented technology transfer potential

Table 2

Accurate value and AUC value of patent technology transfer prediction model

	accuracy	roc_auc	cohen_kappa
Model parameters	0.87	0.85	0.69

centrality (X5) are all indicators calculated by the patent citation network. It can be seen that the patent citation network index has become an important judgment factor for the classification of patent value.

In addition, inward proximity centrality (X6), structural hole constraint coefficient (X8), and scientific strength (X9) appear in the middle of the decision tree model, which shows that in the sample set of this test, the above indicators are very important for judging the value of patent transfer transformation. The influence of is weaker than that of the upper nodes.

The results of the decision tree model test are shown in the table below. The accuracy rate of the prediction model is 0.87, indicating that the number of positive and negative cases correctly predicted accounts for 86% of the total, indicating that the model is relatively reliable. The average value of the model hit rate (Precision), coverage (Recall) and other indicators also reached about 0.8, indicating that the model prediction effect is good.

To conclude, it is evident that the patent citation network index is an important judgment factor for the evaluation of technology transfer potential. This paper uses the decision tree analysis method to consider 16 dimensions, assigns different probabilities to different dimensions, and then calculates the value of patent transfer conversion according to the probability values in different situations, so that the final patent evaluation value is closer to the real value. This method can provide conditions for the successful transformation of patents and make it possible for the rapid application of new technologies that have not been commercialized.

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