ACO-Based Enterprise Patent Value Analysis Method Design and System Implementation*Postprint

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Abstract

【目的】To enhance the efficiency of patent value analysis and provide enterprises with accurate and reliable patent value information.

【方法】Employing ACO and a scientific evaluation system to perform systematic analysis of enterprise patent value and comparative analysis against expert evaluation results.

【结果】System operation demonstrates that the numerical error between system analysis results and expert evaluation results is less than 10%, with an accuracy rate exceeding 86% and efficiency improved nearly tenfold.

【局限】This system is suitable for patent value analysis scenarios involving large patent portfolios; for enterprises with limited patent holdings, the analysis is insufficiently accurate and requires further improvement and refinement.

【结论】The system enables rapid analysis of large-scale patent values, offering additional alternatives for enterprise patent value analysis.

Full Text

Preamble

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Design and Implementation of an Enterprise Patent Value Analysis Method Based on ACO

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Abstract

[**Objective**] To improve the efficiency of patent value analysis and provide enterprises with accurate and reliable patent value information. [**Methods**] We utilized ACO and a scientific evaluation system to systematically analyze enterprise patent values and compared the results with expert evaluations. [**Results**] System operation demonstrated that the numerical error between system analysis results and expert evaluation results was less than 10%, with accuracy greater than 86% and efficiency improved nearly tenfold. [**Limitations**] This system is suitable for patent value analysis when the number of patents is relatively large; for enterprises with fewer patents, the analysis is less accurate and requires improvement. [**Conclusions**] The system can rapidly analyze the value of large patent portfolios, providing enterprises with more options for patent value analysis.

Keywords: ACO; Enterprise; Patent value; Analysis system
Classification Number: G350

Introduction

As economic globalization deepens, China' s economy faces competition shifting from domestic to international markets. This has led more enterprises to emphasize technology R&D and protect their core technologies through patent applications, thereby enhancing technological competitiveness. However, large patent portfolios create confusion for enterprises, making it urgent to determine the value of their patents in a timely manner. Japanese company Omron considers patent value evaluation and analysis as a business strategy that facilitates inter-enterprise cooperation and aids in industrial restructuring and corporate reorganization [1]. The patent value analysis process is complex, requiring analysis before evaluation to identify high-quality patents for valuation. The most authoritative domestic approach is the results from the State Intellectual Property Office's patent value analysis. When facing large patent volumes in medium and large enterprises, these methods require long evaluation cycles. Coupled with market changes affecting evaluation results, patent value becomes difficult to grasp, causing some high-quality, high-benefit patents to remain undiscovered [2]. Without reliable patent value information, enterprises cannot make informed decisions about R&D investment and long-term development.

To address the problem of lengthy manual evaluation cycles for patent value analysis, this paper analyzes patent value based on information inherent in patents themselves. To enable faster analysis, we combine Ant Colony Optimization (ACO) to design and implement an enterprise patent value analysis system that calculates patent value degrees.

2.1 Current Status at Home and Abroad

No unified definition of patent value analysis exists internationally or domestically. In the United States, Harhoff et al. [3] analyzed patent value through

forward and backward citations. Wan Xiaoli et al. [4] and Wen Peng et al. [5] analyzed patent value using fuzzy comprehensive evaluation methods. Hu Qichao [6] applied BP neural network methods for patent value analysis. The State Intellectual Property Office' s *Patent Value Analysis Indicator System Operation Manual* analyzes patent value through three dimensions: legal, economic, and technical [7]. Xiao Guohua et al. [8] added academic value, establishing a patent value analysis system and method through four dimensions. While theoretical research on patent value analysis and evaluation is abundant domestically, systematic implementation is scarce. Sun Yuyan et al. [9] implemented patent value calculation through systematic software, but the system still requires professionals to evaluate each patent individually. When encountering large patent datasets, evaluation remains time-consuming and cannot meet enterprise demands for efficient patent value analysis. Therefore, enterprises urgently need fast and effective patent value calculation software.

2.2 Introduction to ACO

ACO is an algorithm model designed by Italian scholar Dorigo et al. [10] in 1990, inspired by ant foraging path selection. In nature, ants in a colony choose paths based on pheromone concentrations left by previous ants, enabling the colony to quickly find efficient routes to food sources. Ant Colony Optimization solves real-world selection problems through mathematical modeling.

Various pieces of information for evaluating each patent are analogous to pheromones in ant colony optimization, which we term "patent pheromones." By using ACO to search for patents with higher pheromone concentrations within an enterprise' s large patent dataset, we can identify patents with higher value degrees.

2.3 Current Applications of ACO

ACO has been widely applied in transportation, power, communications, and other fields. Dorigo et al. [10] applied the algorithm to the traveling salesman problem. Zhang Yaou [11] used ant colony optimization to optimize and select helicopter flight routes, improving flight distance and efficiency. Foong et al. [12] first applied ant colony optimization to rapid maintenance scheduling in power systems. Gu Chunying et al. [13] used the algorithm to solve path planning and selection optimization problems in computer peer-to-peer networks. US Airways has adopted transportation management software directly derived from ant behavior research, using it to quickly formulate effective airline routes, saving $10 million annually. Unilever was the first to use ant colony optimization software to improve efficiency at a toothpaste factory [14]. Xiong Bin et al. [15] analyzed parameter effects on ACO algorithms to obtain more optimized data classification methods.

While many fields apply ant colony optimization in system software, its application in patent value analysis remains limited. Drawing on foreign industry

experience with ACO software applications and combining the function of mining patent information through ant colony optimization, this paper classifies patent importance through a patent analysis system, providing enterprises with timely and effective patent value analysis results.

2.4 Patent Value Analysis Indicators and Level Classification

Based on Ma Weiye' s [7] patent value analysis indicator system, this paper improves it by constructing an evaluation system from three dimensions: legal value degree, technical value degree, and economic value degree. The original 10-point scoring standard was merged to form 4-5 evaluation levels. During evaluation, each indicator can be manually classified according to these level standards, avoiding subjective judgments in expert scoring and eliminating the need for "consistency checks." Patent value analysis indicators and level classifications are shown in Table 1 :

Table 1. Patent Value Analysis Indicators and Level Classification

Primary Indicator	Secondary Indicator	Level Classification	Indicator Description
Legal Value Degree	P11 Stability	Very stable, relatively stable, stable, relatively unstable, very unstable	Number of patent family members, litigation frequency
	P12 Avoidability	Easily avoidable, avoidable, can be avoided, not easily avoidable, difficult to avoid	Degree to which others can design around the patent to avoid legal penalties
	P13 Dependency	Very dependent, relatively dependent, dependent, slightly dependent, not dependent	Whether a patent can be implemented independently to directly obtain benefits
	P14 Infringement Determinability	Relatively easy to determine, easy to determine, determinable, not easy to determine, impossible to determine	Whether the patent can be easily determined as infringing in legal disputes

Primary Indicator	Secondary Indicator	Level Classification	Indicator Description
	P15 Protection Period	Very long, relatively long, medium, relatively short, very short	Remaining implementation time after approval and renewal
	P16 Multi-country Applications	Many, relatively many, not many, none	Number of multi-country applications
	P17 Licensing Status	Many licenses, has license, exclusive license, no license	Number and type of licenses during protection period
Technical Value Degree	P21 Advancement	Very advanced, very advanced, advanced, ordinary, outdated	The patent' s advancement level in its industry at analysis time
	P22 Development Trend	Very good, relatively good, ordinary, poor, relatively poor	Technology development direction in the patent' s industry from analysis time
	P23 Application Scope	Very wide, very wide, ordinary, limited, very few	Industry field range during patent implementation
	P24 Supporting Technology Dependency	Very high, relatively high, ordinary, relatively low, very low	Strength of needing other technologies for good implementation
	P25 Substitutability	Difficult to substitute, can substitute, easily substitute, relatively easy to substitute	Number of patent family or similar patents
	P26 Maturity	Very mature, mature, ordinary, initial stage, immature	Technology stage at analysis time

Primary Indicator	Secondary Indicator	Level Classification	Indicator Description
Economic Value Degree	P31 Market Application	Very easy to apply, easy to apply, ordinary, difficult to apply, relatively difficult to apply	Difficulty of applying patent technology in the market
	P32 Market Size Prospects	Hundred-billion level, ten-billion level, ten-million level, million level, ten-thousand level	Economic value obtainable at analysis time
	P33 Market Share	Very high, relatively high, ordinary, relatively low, very low	Market share obtainable after productization
	P34 Competition	Very strong competition, strong competition, ordinary, relatively weak competition, very weak competition	Number and intensity of competitors in a certain region
	P35 Policy Adaptability	Very supportive, relatively supportive, ordinary, uncertain, restrictive	Degree of national/regional policy encouragement for the technology

3. Application of ACO in Patent Value Analysis

When using ACO for patent value analysis, we need to use patent value pheromones. This paper uses patent value analysis indicator levels as pheromones. According to this system, patent value degree is divided into legal value degree, technical value degree, and economic value degree. For each patent' s secondary indicator level content, the probability value of repetition within that indicator level is represented by Pji (j=1, 2, 3; i=1, 2, ···7). The collection of each patent' s repetition probability Pji in all patents for a certain indicator is represented by Uji. The indicator level collection for each patent is set as Lji, where Max(Lji) represents the highest level rating for that indicator. Max(Uji) represents the highest probability value among all patents for a

certain rating. Using the probability value of a certain indicator level in patent information as the standard for value degree evaluation, the evaluation formula improves upon Gu Chunying et al.' s [13] peer-to-peer network path calculation formula as follows:

$$\mathrm{Max}(U_{ji})/\mathrm{Max}(L_{ji}) \quad \text{Otherwise} \tag{1}$$

Legal Value Degree: Legal value degree evaluates a patent' s value from a legal perspective. According to the level classification standards for legal value secondary indicators in this paper, each secondary indicator' s weight is represented by i (i=1, 2, 3, ···, 7), and each patent' s legal indicator level probability is P1i ( ). Each patent's secondary indicator score P1i for legal value is determined by the ant colony algorithm. The calculation formula improves upon Ma Weiye' s [7] legal value degree calculation as follows:

$$\sum \alpha_i \cdot P_{1i} \tag{2}$$

Technical Value Degree: Technical value degree evaluates a patent' s value from a technical perspective. According to the level classification standards for technical value secondary indicators, each secondary indicator' s weight is represented by i (i=1, 2, 3, ···, 6), and each patent' s technical value secondary indicator level probability is P2i ( ). Each secondary indicator score P2i for technical value is determined by the ant colony algorithm. The calculation formula improves upon Ma Weiye' s [7] technical value degree calculation as follows:

$$\sum \beta_i \cdot P_{2i} \tag{3}$$

Economic Value Degree: Economic value degree evaluates a patent' s value from an enterprise benefit perspective. According to the level classification standards for economic value secondary indicators, each secondary indicator's weight is represented by i (i=1, 2, ···, 5). Each patent' s economic value secondary indicator level probability is P3i ( ). Economic value secondary indicator score P3i is determined by the ant colony algorithm. The calculation formula improves upon Ma Weiye' s [7] economic value degree calculation as follows:

$$\sum \gamma_i \cdot P_{3i}$$

4. Overall System Design

Based on enterprise requirements for efficient patent value analysis and practical application needs, we conducted modular design. After integrating module relationships, the overall framework of the patent value analysis system is shown in Figure 1 [Figure 1: see original paper].

The patent value analysis system adopts an object-oriented design philosophy. To facilitate user operation and reduce complexity, the system minimizes operational procedures while ensuring stability and security. ACO is a swarm intelligence algorithm requiring complete data for implementation, so users must ensure the accuracy of enterprise patent value database information. Given the unpredictable market economy environment, the system includes a feedback adjustment function to obtain more potential patent value analysis results.

4.1 Technical Methods

According to software development requirements, we selected Visual FoxPro (VFP) as the development tool. VFP' s built-in database storage method is simple and doesn' t require connecting to other databases, improving data security. Therefore, this paper uses VFP to construct the enterprise patent value analysis system.

4.2 System Flowchart

Based on system design requirements, we systematically analyzed the main modules—including login module, patent data maintenance module, patent value degree calculation module, and feedback adjustment module—from a software implementation perspective to derive the system flowchart, shown in Figure 2 [Figure 2: see original paper].

The ACO algorithm relies on large amounts of complete data information. Users must first check whether the patent database is complete and promptly maintain any missing or erroneous patent information. Then, the ant colony optimization algorithm calculates probabilities for each field in the patent database and stores relevant data in temporary tables. The patent value calculation module computes patent values based on data in the temporary tables. By comparing and analyzing evaluation results, users can decide whether to accept them as final values; if adjustment is needed, they can use the feedback adjustment function.

4.3 Module Design

The enterprise patent value analysis system provides systematic evaluation of large enterprise patent portfolios. According to enterprise requirements, the system mainly consists of four modules: user management module, patent data maintenance module, value degree calculation module, and feedback adjustment module, as shown in Figure 3 [Figure 3: see original paper].

(1) User Management Module: This module manages system users, dividing them into administrators and regular users. Only users whose entered username, password, and permissions match corresponding fields (username, usertype, password) in the database can successfully log in.

(2) Patent Data Maintenance Module: This module includes 21 fields of patent information based on 18 indicator information items plus patent ap-

plication number, patent name, and serial number. It features patent search, addition, and modification functions.

(3) Value Degree Calculation Module: As the system' s core, this module includes data statistics, patent value calculation, and data protection functions. - **Data Statistics Function**: Calculates probabilities for each indicator rating content of every patent based on data from the patent maintenance module and stores them in corresponding VFP database tables. - **Patent Value Calculation Function**: Uses stored statistical data to iteratively calculate legal value degree, economic value degree, technical value degree, and total value degree for each patent according to default weights, automatically outputting results sorted by patent value degree. - **Data Preservation Function**: After patent value degree calculation, the system immediately prompts users whether to save data or perform feedback adjustment. If users don' t provide instructions for an extended period, the system automatically saves all data in the current module.

(4) Feedback Adjustment Module: After the patent value calculation module runs, this module modifies indicator weights according to enterprise needs to further mine additional patent value information. Its main functions include indicator weight modification and indicator weight validity testing. - **Indicator Weight Modification Function**: Feedback adjustment implementation depends on weight formulation. Since different enterprises have different emphases for patent value analysis, a single weight setting cannot be used. This function can modify both primary and secondary indicator weights for patent value analysis, after which the database recalculates patent value degrees based on new weights. - **Indicator Weight Validity Testing Function**: This function ensures indicator weights are correct and valid, with the sum of weights equaling 1. Default indicator weights follow the State Intellectual Property Office evaluation system weights to ensure valid patent value results.

Through these module settings, the system simplifies traditional patent value analysis complexity while ensuring security, making user operations simple and clear for rapid proficiency.

5.1 System Application Effects

Based on the proposed system design framework and functional modules, we implemented the enterprise patent value analysis system software. Patent management is conducted through the patent data maintenance interface. Clicking the patent value degree calculation interface and the calculate button displays all patent values sorted by importance, as shown in Figure 4 [Figure 4: see original paper]. If enterprises require feedback adjustment, they can modify weights through the feedback adjustment module, as shown in Figure 5 [Figure 5: see original paper].

5.2 Application Effect Evaluation

After system implementation, to verify its effectiveness, this paper selected 100 patents from the "Patent Value Analysis Indicator System for Patent Classification Management and Evaluation"project commissioned by the Fujian Provincial Intellectual Property Information Service Center to the State Intellectual Property Office as data samples. The project involved a panel of dozens of experts from various fields who spent one month completing detailed evaluation reports for the sample, with data that truly reflected patent value analysis results.

We randomly selected two undergraduate students as testers. After training, the testers input each indicator level into the system according to our method. Comparing the expert evaluation results with the system' s patent value results, as shown in Figure 6 [Figure 6: see original paper], and after screening out values with large errors or incorrect results from the patent value analysis system calculations, the final accuracy reached 86.3%. Statistical analysis of numerical errors between the system' s evaluation results and experts' results showed that valid values had error rates within 10%, as shown in Figure 7 [Figure 7: see original paper]. Additionally, we selected two samples from Fujian Starnet Ruijie Communication Co., Ltd. (with 103 and 106 patents respectively) and used the same testers to compare system results, achieving accuracies of 87% and 86.9% respectively. All three sample datasets exceeded 86% accuracy. Experimental results demonstrate that the ACO-based enterprise patent value analysis system can quickly obtain effective patent value analysis results. While each sample required 10 experts and one month to produce analysis results, our system using two testers required only two weeks for the same sample analysis, representing nearly a tenfold efficiency improvement. The system is simple to operate, doesn' t rely on numerous expert professional industry reports, and can be quickly mastered by a few personnel through short-term software training, reducing patent value analysis costs and significantly decreasing tedious workload while improving efficiency.

The system also includes feedback functionality, allowing enterprises to modify evaluation indicator weights according to their different development stage requirements to obtain patent value analysis results more suitable for their development, providing faster and more personalized patent value information for enterprise strategy formulation.

The system' s limitation is its inability to accurately reflect patent value degrees for small sample sizes. The algorithm is not yet optimal for enterprise patent value analysis and has certain limitations requiring further improvement.

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Author Contributions

Chen Longlong, Zhang Wende: Proposed the research proposition and ideas;
Chen Longlong: Designed the scheme, conducted experiments, and drafted the paper;
An Jie: Collected, cleaned, and analyzed data;
Zhang Wende: Revised the final version of the paper.

Conflict of Interest Statement

All authors declare no conflict of interest.

Supporting Data

Supporting data can be found in the journal's online version at http://www.infotech.ac.cn.
[1] Chen Longlong, Zhang Wende, An Jie. Patent evaluation data for the ACO-based enterprise patent value analysis method. All patent value analysis data and calculation results.

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