Research on Identifying Technological Opportunities in Intelligent Logistics Systems

Hongyu Liu* and Ningman Xu

School of management, Guangzhou College of Technology and Business, Foshan, 528138 China

*Corresponding author's e-mail: liouhongyu@gzgs.edu.cn

Abstract. With the rapid development of emerging technologies such as the Internet of Things (IoT), big data, and artificial intelligence (AI), intelligent logistics systems have become a crucial component of the logistics industry. This paper utilizes patent data related to intelligent logistics system technologies to perform keyword segmentation and employs co-word clustering to identify six major technical hot spots. Finally, it combines IPC classification groups to conduct technical hot spot identification and analysis. This research identifies six major categories of technical opportunities in the field of intelligent logistics systems, revealing significant advancements and patent applications that drive the industry forward and promise further growth and innovation.

Keywords: Intelligent logistics systems; Co-word clustering; IPC classification

1 Introduction

With the development of AI technology, intelligent logistics systems have become a major trend in modern logistics. Based on advanced intelligent transportation systems and related computer technologies, intelligent logistics systems operate in an e-commerce manner, comprehensively applying IoT, big data analysis, and AI to achieve intelligent, automated, and efficient logistics processes. Current research has explored smart logistics based on IoT technology[1-3], AI applications in logistics[4-5] and new logistics models[6-7], but little attention has been paid to identifying future technological breakthroughs using patent data. Patent data not only reveal specific situations in technical fields but also help understand the evolution and development trends of these fields, identifying potential technological opportunities. Analyzing patent information using data mining techniques can provide strong support for the development of intelligent logistics system technologies.

2 Analysis of Intelligent Logistics System Technology Themes

When constructing the search formula, keywords and IPC category numbers relevant to the intelligent logistics field were comprehensively utilized to obtain a broad range

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of patents in this domain. A patent search was conducted in the Incopat patent retrieval system under the G06Q10/00 classification. Using the constructed search formula, 28,241 patent data entries were obtained. After manually screening and cleaning irrelevant data, 13,396 relevant patents on intelligent logistics systems were finally obtained.

By analyzing the themes, abstracts, and classification numbers in the patent directory, we can reveal the technical characteristics of patent applications, providing scientific evidence to support patent applications and approvals in China, thereby increasing application and approval rates. When handling unstructured patent information, it is necessary to preprocess it to convert it into a data frame. Common preprocessing steps include word segmentation, part-of-speech tagging, and removal of invalid words. Therefore, this study uses the Jieba segmentation tool to filter stop words, extract keywords, and perform word frequency analysis, selecting feature vectors to construct a correlation coefficient matrix. Finally, through clustering based on feature vectors and eigenvalues, data mining analysis is achieved. By sorting keyword frequencies and excluding common stop words, a Chinese stop word list suitable for our needs is formed to improve the accuracy of segmentation. Finally, the filtered keywords are re-imported into the program for segmentation operations. Table 1 shows the segmented results with stop words (partial).

Table 1. Patent title with stop words segmentation results (partial)

Patent name	Keyword of patent name
Real-time tracking of package systems, methods, and equipment	[‘real time’, ‘tracking’, ‘package’, ‘system’, ‘device’]
Systems and methods for safely receiving and storing delivery	[‘receive’ , ‘store' , ‘deliver' , ‘system’]
Improved cargo handling safety handling system and method.	[‘improvement’ , ‘cargo’ , ‘system’]
Cargo transportation system for perishable products	[‘perishable’ , ‘product’ , ‘freight’ , ‘system’]

3 Text Clustering-Based Exploration of Intelligent Logistics System Technology Themes

By processing the results of word segmentation, filtering low-frequency keywords based on their occurrence frequency, removing low-frequency, semantically identical or similar words, and converting English words or numbers into related Chinese noun concepts, we obtain a high-frequency keyword list.

To compute the frequency of each keyword, the formula used is:

$$\text{Keyword Frequency}(k_i) = \frac{Number\ of\ occurrences\ of\ k_i}{Total\ number\ of\ keywords}$$

where k_i denotes the i-th keyword.

Table 2 contains the top 50 keywords. The selection of these keywords reflects the current hot fields in patent technology. By conducting an in-depth study of these keywords, we can more accurately identify the hot areas of technology applications. This is significant for understanding technological development trends and formulating relevant strategies.

Table 2. Partial Results of Title Keyword Frequency Statistics

Serial number	Keyword	Quantity	Serial number	Keyword	Quantity
1	method	8701	26	The server	252
2	be used for	2910	27	Electronics	249
3	device	2512	28	Value chain	248
4	information	935	29	generate	236
5	intelligence	842	30	medium	227
6	data	787	31	enterprise	208
7	Operation and maintenance	741	32	state	207
8	storage medium	687	33	long-range	205
9	fault	535	34	recovery	203
10	information processing	534	35	On-Site Inspection	191
11	maintain	479	36	business	188
12	program	402	37	record	186
13	control	400	38	distinguish	184
14	dispatch	384	39	assets	177
15	product	377	40	plan	174
16	platform	368	41	logistics	174
17	track	362	42	technical support	173
18	technology	352	43	image	171
19	to configure	334	44	content	168
20	network	312	45	plan	167
21	vehicle	301	46	task	167
22	stock	301	47	visualization	167
23	terminal	284	48	process	161
24	computer	282	49	goods	161
25	repair	281	50	dynamic	161

To gain a more comprehensive understanding of the hotspots in technological innovation, it is necessary to explore three or more highly correlated technologies. Therefore, this study uses a correlation coefficient matrix to delve into the closeness and relevance between these technologies and classify them accordingly. By thoroughly analyzing these highly correlated technology combinations, we can identify technology clusters that meet clustering requirements.

To analyze the correlation between technologies, the correlation coefficient matrix is employed, defined as:

$$\text{Correlation Coefficient}(r) = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

where x and y are the values of two variables, and n is the number of observations.

The co-word analysis provided in the document effectively transforms high-dimensional, unstructured textual data into highly structured, low-dimensional data, which is machine-readable and suitable for simulation. From table 3, the analysis resulted in the identification of 946 co-word pairs, which were then integrated into a low-dimensional co-word matrix.The co-occurrence matrix represents the relationships between words, reflecting the frequency of simultaneous appearance of high-frequency keywords within the same text. This frequency directly correlates with the strength of the association between two keywords.

The correlation matrix shows that the frequency of two keywords appearing together is positively correlated with their closeness. This allows us to determine how tightly connected certain technological concepts are within the field of intelligent logistics systems.From table 4, it is evident that combinations of low-frequency words decline with a decrease in low-frequency words. However, combinations of high-frequency and low-frequency words still exhibit strong correlations, indicating that high-frequency keywords have more technological innovation points. Thus, in patent applications, high-frequency keywords become popular areas of interest.

Table 3. Keyword Co-Occurrence Matrix (Partial)

	Visual-ization	Track-ing	Tech Sup-port	Storage Me-dium	Intelli-gence	Recy-cling	Plan-ning	…
Visual-ization	190	0	0	4	13	0	0	…
Track-ing	0	232	0	2	5	5	1	…
Tech Sup-port	0	0	676	0	0	0	58	…
Storage Me-dium	4	2	0	1728	33	17	0	…
Intelli-gence	13	5	0	33	1237	29	19	…

Recy-cling	0	5	0	17	29	178	1	…
Plan-ning	0	1	58	0	19	1	427	…
…	…	…	…	…	…	…	…	…

Table 4. Correlation Coefficient Matrix (Partial)

	Visuali-zation	Track-ing	Tech Support	Storage Medium	Intelli-gence	Recy-cling	Plan-ning	…
Visuali-zation	1	0.289	-0.127	0.127	0.62	0.446	-0.08	…
Tracking	0.289	1	-0.099	-0.02	-0.051	0.185	-0.124	…
Tech Support	-0.127	-0.099	1	-0.121	0.263	-0.188	0.872	…
Storage Medium	0.127	-0.02	-0.121	1	0.132	0.385	-0.119	…
Intelli-gence	0.62	-0.051	0.263	0.132	1	0.094	0.191	…
Recy-cling	0.446	0.185	-0.188	0.385	0.094	1	-0.119	…
Planning	-0.08	-0.124	0.872	-0.119	0.191	-0.119	1	…
…	…	…	…	…	…	…	…	…

The analysis reveals several high-frequency keywords such as “technology support,” “intelligence, ” and “storage medium, ” which are crucial in the intelligent logistics system domain. These keywords indicate major technological innovation points and are areas of significant interest for patent applications.High-frequency keywords often appear together with other high-frequency or low-frequency keywords, demonstrating strong correlations. For example, “intelligence” shows strong associations with “visualization” and “technology support, ” highlighting their interconnectedness in intelligent logistics applications. The clustering and correlation analysis identify key technological hotspots, such as enterprise value chain planning, asset inventory management, image recognition and information processing, planning generation and recording medium technology, equipment maintenance and transportation scheduling, and terminal control and data processing. These hotspots represent the primary areas of technological innovation and development in intelligent logistics systems. The identified technological hotspots align with the observed trends in patent applications, reflecting rapid advancements and a focus on enhancing efficiency, accuracy, and automation in logistics systems through emerging technologies.

To perform clustering analysis, the K-means clustering algorithm is utilized. The objective function is:

$$\text{Minimize} \sum_{i=1}^{k} \sum_{x \in C_i} ||x - \mu_i||^2$$

where C_i is the i-th cluster, μ_i, is the centroid of the i-th cluster, and x is a data point.

Based on the results, it can be seen that the current technical hotspots in the intelligent logistics system industry can be categorized into the following six major areas:

Enterprise Value Chain Planning and Configuration Technology

Keywords: technology support, planning, value chain, configuration, technology, enterprise, network.

Focus: The research hotspot in this category is the planning and configuration of the enterprise value chain. The smart logistics distribution management system uses big data analysis, IoT, and AI technologies to achieve precise tracking and control throughout the logistics distribution process. The system can instantly understand the logistics situation, status, and transportation conditions, providing accurate and timely decision support, optimizing distribution paths and modes, reducing distribution costs, and improving logistics efficiency. The intelligent logistics system can integrate supply chain resources, optimize resource allocation, create more business opportunities and competitive advantages, and flexibly adjust resources according to market changes and customer demands, ensuring the stability and reliability of logistics services.

Asset Inventory Management Technology

Keywords: logistics, assets, inventory, intelligent.

Focus: The research hotspot in this category is asset inventory management. The intelligent logistics system can monitor asset status in real-time, such as vehicles, warehouses, and equipment, perform intelligent maintenance and management, provide timely warnings, and arrange for repairs or replacements, ensuring efficient operation and extending the service life of assets. Simultaneously, the system can accurately calculate asset costs and benefits, providing data support for enterprise decision-making. The system can also intelligently predict and plan inventory, achieve optimal allocation, update inventory information in real-time, prevent loss or damage of goods, and reduce operational risks.

Image Recognition and Information Processing Technology

Keywords: tracking, image, content, products, programs, information processing, control.

Focus: The research hotspot in this category is image recognition and information processing. The intelligent logistics system has strong tracking capabilities, can locate goods in real-time, use image recognition technology to monitor the status of goods, ensure safety, and provide rich content information to support decision-making and resource allocation. The system can process and analyze vast amounts of data, perform real-time predictions, provide data support for decision-makers, predict future development trends, and offer forward-looking decision-making advice.

Planning Generation and Recording Medium Technology

Keywords: information, medium, planning.

Focus: The research hotspot in this category is planning generation devices, methods, programs, and recording media. The intelligent logistics system requires a large amount of data support, collects and analyzes logistics data through big data platforms, provides real-time, accurate information, and helps decision-makers make the best decisions. IoT technology improves logistics efficiency and transparency, RFID and sensor technology achieve real-time tracking and status monitoring of goods, AI and big data analysis predict future demand and supply, formulate optimal transportation plans, and achieve optimal resource allocation.

Equipment Maintenance and Transportation Scheduling Technology

Keywords: recycling, operation and maintenance, repair, maintenance, status, inspection, scheduling, identification, data, remote, visualization, platform, business, management system.

Focus: The research hotspot in this category is equipment maintenance, transportation scheduling, and remote visualized operation and maintenance. The system can predict the lifespan of items, arrange for repairs and replacements in advance, and maximize resource utilization. By monitoring and analyzing equipment status in real-time, it predicts maintenance needs, reduces downtime, and provides remote maintenance support. The status inspection system regularly checks the equipment to ensure normal operation and visually displays inspection data, allowing managers to understand the health status of the equipment.

Terminal Control and Data Processing Technology

Keywords: recording, server, electronic, terminal, vehicle, fault, computer, storage medium, generation.

Focus: The research hotspot in this category is terminal control methods, devices, and storage media. The server processes data and instructions and provides services to terminal devices. Terminal devices include onboard terminals of transport vehicles and control terminals of logistics centers, monitoring vehicle positions, speeds, directions, and other information in real-time to achieve precise control. Electronic technology is crucial in intelligent logistics systems, with sensors monitoring driving conditions, cargo temperature, humidity, and other information, generating reports and warnings to help managers handle issues promptly.

4 Analysis of Technical Hotspots Based on IPC Classification Groups

By analyzing the hotspots of IPC classification groups and conducting big data analysis on high-frequency keywords, we identified the top ten IPC classification groups by word frequency. The results are shown in Table 5.

Table 5. IPC Group word frequency statistics

The category name	Technology	Quantity
G06Q10/00	Administration; management	5721
G06Q10/06	Management of resources, workflows, people, or projects; enterprise or organizational planning; enterprise or organizational modeling	842
G06F17/60	A data-processing system or method specially adapted for administrative, commercial, financial, regulatory, supervisory, or forecasting purposes; Systems or methods of processing that are intended for administrative, commercial, financial, regulatory, supervisory, or predictive purposes not covered by other categories	751
H04L29/08	Transmission control procedures	357

G06F17/30	Information Retrieval; database structure; file system structure	299
G06Q10/04	Prediction or optimization especially for administrative or managerial purposes	276
G06F	A computer system based on a specific computational model	196
G06Q10/10	Office automation; Time Management	195
G06F17/00	The utility model is particularly suitable for a specific functional digital computing device or a data processing device or a data processing method	173
G06Q10/08	Logistics, e. g. warehousing, loading, or distribution; inventory or inventory management	167

Based on the data from IPC classification groups, an in-depth exploration and filtering of the patent database have revealed the most prominent patent applications in the field of intelligent logistics systems. The results indicate that the top ten patent application areas encompass numerous technological innovations, demonstrating rapid progress in China's intelligent logistics sector. These technologies have become core drivers of industry development.

Among these, patents classified under G06Q10/00, G06Q10/06, and G06F17/60 primarily focus on processing systems, methods, and management systems. Capabilities in data processing, information monitoring, and predictive functions form the foundation of the logistics field, essential for efficient operations. These technologies possess specific digital computing or data processing capabilities, allowing precise analysis and control in complex logistics environments to ensure efficient system operation.

At the application level, classifications such as H04L29/08 and G06Q10/08 concentrate on control processes within logistics and transportation. The application of these technologies, from warehouse management and loading distribution to inventory management, significantly enhances the coordination and responsiveness of logistics networks.

Additionally, image or video recognition technologies and time calibration servers are also receiving extensive attention. Image recognition technologies, through barcode and product image identification, improve data entry and picking efficiency, achieving warehouse automation. Time calibration servers, utilizing global positioning systems to synchronize time, send precise timing information across the network, monitor and feedback on supply, production, and transportation processes in real-time, prevent data tampering, and protect data security, significantly enhancing enterprise efficiency.

These emerging technologies are continuously being researched, developed, and applied in practice, playing a crucial role in improving the efficiency and accuracy of intelligent logistics systems. As technology continues to evolve, more innovative patents are expected to emerge in this field, indicating a significant increase in patent applications for intelligent logistics systems.

5 Conclusion

This study identifies six key areas of technical opportunities within intelligent logistics systems. By leveraging data mining techniques on patent data, the research reveals significant advancements in enterprise value chain planning, asset inventory management, image recognition, planning generation, equipment maintenance, and terminal control. These findings provide insights into the current technological trends and future development paths, supporting the growth and innovation of intelligent logistics systems in China.

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