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Research on Industry University Research Cooperation in Artificial Intelligence Technology

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Abstract: With the rapid development and widespread application of artificial intelligence technology, industry university research cooperation, as an effective innovative model, can promote the transformation and application of scientific research achievements, accelerate the development and industrialization process of artificial intelligence technology. By conducting in-depth research on the innovative output characteristics of industry university research cooperation in artificial intelligence technology, we can better understand the internal mechanism and path of industry university research cooperation, and provide theoretical support and technical guidance for building a closer and more efficient industry university research cooperation system.

1. Introduction

This article analyzes artificial intelligence technology invention patent applications in 31 provinces and cities in China from 2012 to 2011, explores the characteristics of artificial intelligence technology innovation output, and first analyzes the changes in centrality and network centrality indicators of the industry university research cooperation innovation network in different years. In addition, the centrality of important nodes was compared, and the structural hole index was analyzed to accurately describe the current situation of artificial intelligence technology innovation output in China, providing scientific decision-making support for the development of artificial intelligence technology in China.

2. Background of the study area

In the current context of technological industry transformation, the strategic position of artificial intelligence is increasingly prominent. In October 2022, the report of the 20th National Congress of the Communist Party of China and the 2024 Central Economic Work Conference both emphasized the necessity of promoting the development of the digital economy and accelerating the process of artificial intelligence.

Industry university research cooperation, as an effective mode of technological innovation, has been proven to promote resource sharing and technological exchange between enterprises, research institutes, and higher education institutions, thereby accelerating the transformation and application of scientific and technological achievements. According to the research conducted by He Zehui and

others in 2020, it is known that enterprises can obtain the resources they originally lacked by collaborating with universities, research institutes, and other non academic institutions, effectively shortening the research and development cycle, and reducing research and development costs. He Zehui[3]. In addition, numerous scholars have confirmed in multiple fields such as collaborative innovation in higher education institutions and the cultivation of applied talents that industry university research cooperation has a significant promoting effect on improving the innovation performance of enterprises[4-5].

The core of collaborative innovation between industry, academia, and research is to complement the advantages of resources among different entities, aiming to achieve better innovation results. In the field of artificial intelligence, promoting technological collaborative innovation based on industry university research cooperation is crucial for enhancing industrial technological innovation capabilities. By collecting relevant data and applying modeling analysis, the current situation and challenges of collaborative innovation can be revealed. However, there are still certain shortcomings in its research in the field of artificial intelligence, such as successful technological transformation, talent shortage, and insufficient funds and resources.

3. Data and methods

3.1 Data

This article selects the number of artificial intelligence technology industry university research cooperation invention patents from 31 provinces and cities in China (excluding Hong Kong, Macao, and Taiwan) from 2012 to 2021 as the sample. The data is sourced from the incoPat patent database. In China, invention patents are highly valued for their high innovation and technological content. In view of this, this article selects invention patent application data from 31 provinces and cities in China from 2012 to 2021 as the analysis object. The term "patent" mentioned in this article specifically refers to invention patent applications in the field of artificial intelligence technology. After excluding individual and overseas patents and selecting cooperative patents with a number of applicants greater than or equal to 2, 5483 industry university research cooperative invention patents were obtained. The patent application addresses were taken from the addresses of various enterprises, universities, and research institutes, reflecting the innovation subject space and revealing the current situation of the industry university research innovation network.

3.2 Methods

3.2.1 Centrality analysis

Centrality reflects the power value of nodes in the entire network[1], while degree centrality, intermediate centrality, and network centrality reflect the status of each node in the network.

① Degree centrality

An indicator that measures the number of nodes directly connected to a node in a network, that is, the degree of direct connection between that node and other nodes. Formula:

$$C_{\mathrm{xd}}(i)=\frac{C_{zd}(i)}{n-1} \tag{1}$$

$C_{xd}(i)$ is the relative degree centrality of the node, $C_{zd}(i)$ is the other nodes connected to the node, n is the number of existing edges in the network.

② Middle centrality

A measure of a node's ability to act as an intermediary in communication with other nodes in a network. Reflect to what extent a node controls the communication or resource flow between other nodes. Formula:

$$C_{DAi} = \frac{2C_{DBi}}{n^2 - 3n + 2} \tag{2}$$

C_{DAi}, C_{DBi} represents the relative and absolute centrality of the nodes, and n represents the number of existing edges in the network.

3.2.2 Structural Hole Analysis

In a network structure, not all nodes are directly connected, and sometimes the association between two nodes is achieved through a third node as a bridge[2]. In the existing field of network research, indicators such as effective scale, degree of limitation, degree of hierarchy, and efficiency are commonly used.

① Effective scale

Determine whether there is duplication or redundancy in the connections between nodes, in order to measure the control of one node over other nodes. Formula:

$$C_{DAi} = \frac{2C_{DBi}}{n^2 - 3n + 2} \tag{3}$$

j is the node connected to i, q is the node other than j and i, p_{iq} represents the weight that node i invests its innovative elementsinto q, p_{iq} and m_{jq} represent the degree of redundancy between i and j. m_{jq} is the marginal intensity from j to q.

② Restriction degree

Reflect how nodes utilize the advantages of their structural holes, that is, to what extent they can strengthen their association with other nodes. Formula:

$$C_{ij} = (p_{ij} + p_{iq} p_{qj})^2 \tag{4}$$

p_{iq} is the proportion of scale in which node q invests innovative elements into node p_{qj}; Similarly. p_{ij} represents direct input, and the value of C_{ij} is 0-1.

③ Grade degree

Describe to what extent limitations revolve around one actor, or rather focus on one actor. Formula:

$$H = \frac{\sum_j (\frac{C_{ij}}{C/N}) \ln(\frac{C_{ij}}{C/N})}{N \ln(N)} \tag{5}$$

N is the individual network size of the node, C/N is the expected limit degree of the node, and $N \ln(N)$ is the maximum possible sum, with a value of 0-1.

④ Efficiency

By comparing the ratio of effective scale to actual scale, the efficiency of the connections

between nodes in the network structure can be revealed.

4. Analysis of nodes in the innovation network of industry university research cooperation in artificial intelligence technology

To explore the key roles played by institutions in the collaborative innovation process of artificial intelligence technology, enterprises, universities, and research institutions are taken as nodes, focusing on the top three industry university research institutions in terms of centrality. Combined with the structural hole index, the position and influence of industry university research institutions in the collaborative network are analyzed.

4.1 Analysis of nodes in the innovation network of industry university research cooperation in artificial intelligence technology

Table 1: Key nodes of the National Artificial Intelligence Technology Industry University Research Cooperation Innovation Network from 2012 to 2021

Year	Enterprise			Institutions and universities		
	Name	Degree centrality	Middle centrality	Name	Degree centrality	Middle centrality
2012	State Grid Corporation of China	0.039	0.001	Hohai University	0.037	0.001
	Tencent Technology (Shenzhen) Co., Ltd	0.037	0.023	Guangdong Power Grid Corporation Electric Power Science Research Institute	0.019	0.000
	Shenzhen Yihua Computer Co., Ltd	0.037	0.001	University of Electronic Science and technology	0.019	0.000
2015	State Grid Corporation of China	0.087	0.044	South China University of Technology	0.038	0.002
	State Grid Zhejiang Electric Power Company	0.024	0.001	State Grid Smart Grid Research Institute	0.028	0.010
	Henan Xuji Instrument Co., Ltd	0.019	0.001	China Electric Power Research Institute	0.028	0.001
2018	State Grid Corporation of China Limited	0.171	0.062	State Grid Inner Mongolia East Electric Power Co., Ltd. Economic and Technological Research Institute	0.011	0.001
	Suzhou Zhongke Tianqi Remote Sensing Technology Co., Ltd	0.011	0.013	State Grid Jiangsu Electric Power Co., Ltd. Electric Power Science Research Institute	0.011	0.020
	State Grid Corporation of China	0.011	0.021	State Grid Jiangsu Electric Power Co., Ltd. Economic and Technical Research Institute	0.011	0.001
2021	State Grid Corporation of China Limited	0.026	0.001	Zhejiang University	0.015	0.001
	China Electric Power Research Institute Co., Ltd	0.034	0.001	Tsinghua University	0.013	0.001
	Zhuhai Lianyun Technology Co., Ltd	0.027	0.000	Shanghai Jiao Tong University	0.019	0.001

Using industry university research institutions with collaborative innovation relationships as nodes, the centrality and important nodes in the network were analyzed based on the cooperation between industry university research institutions in artificial intelligence technology in 2012, 2015,

2018, and 2021, as shown in Table 1.

As shown in Table 1, among the top three key nodes in the degree centrality of industry university research institutions, half of them are related to electricity, indicating that electricity related institutions are gradually enhancing their control role in the network. Because these institutions have high patent conversion efficiency, they play a promoting role in the development of artificial intelligence. Among them, in 2012, the degree centrality of the University of Electronic Science and Technology of China ranked third, becoming an important node in the network through collaborative innovation. The cooperative object of this node is fixed and has path dependency characteristics.

4.2 Analysis of holes in the network structure of collaborative innovation

This article analyzes the structure of China's artificial intelligence technology industry university research cooperation innovation network by using Burt's structural hole index and Freeman's intermediate centrality. The structural hole index of China's industry university research institutions from 2012 to 2021 (selecting degree centrality>3 and ranking the top 20 in descending order) is used, as shown in Table 2.

Table 2: Structural Hole Index of China's Artificial Intelligence Technology Industry University Research Cooperation Innovation Network

Institution name	Burt structural hole index				Middle centrality
	Effective scale	Efficiency	Restriction degree	Grade degree	
State Grid Corporation of China Limited	110	0.972	0.749	0.059	0.087
Tsinghua University	75	0.720	0.613	0.086	0.074
China Electric Power Research Institute Co., Ltd	68	0.810	0.415	0.198	0.646
State Grid Corporation of China	64	0.935	0.716	0.051	0.062
Zhejiang University	48	0.765	0.721	0.032	0.065
South China University of Technology	47	0.639	0.521	0.022	0.033
Shanghai Jiao Tong University	40	0.537	0.323	0.034	0.040
Beijing University of Posts and Telecommunications	38	0.487	0.426	0.041	0.256
Southeast University	36	0.529	0.228	0.021	0.214
Shandong University	33	0.653	0.430	0.019	0.208
Huazhong University of Science and Technology	33	0.671	0.730	0.024	0.314
Beihang University	32	0.762	0.431	0.045	0.313
Global Energy Internet Research Institute Co., Ltd	31	0.834	0.332	0.050	0.207
North China Electric Power University	31	0.758	0.232	0.067	0.210
State Grid Zhejiang Electric Power Co., Ltd. Electric Power Science Research Institute	30	0.652	0.733	0.078	0.114
WuHan University	29	0.384	0.634	0.037	0.412
Saier Network Co., Ltd	27	0.563	0.437	0.036	0.232
University of Electronic Science and technology	25	0.624	0.740	0.044	0.322
Institute of Automation, Chinese Academy of Sciences	24	0.761	0.642	0.057	0.209
Harbin Institute of Technology	23	0.562	0.643	0.028	0.207

① Effective scale

Taking State Grid Corporation of China as an example, the effective scale of State Grid Corporation of China is 110, which is expressed as the scale of the individual network of the node

where the node is located minus the average degree of other members in the network. The larger the value, the more nodes it has a cooperative relationship with State Grid Corporation of China, but lacks cooperative relationships with members outside the node.

② Efficiency

According to Table 2, the innovation efficiency ratio of most institutions is relatively high. This means that these institutions have a faster flow of innovative elements in the network and a higher level of innovation.

③ Restriction degree

Table 2 shows that the selected institutions have established cooperative relationships with multiple innovative entities to a certain extent. This means that these institutions can effectively utilize the structural hole theory to enhance their influence and gain more benefits through cooperation with different innovative entities.

④ Grade degree

The degree of hierarchy reflects the distribution of a node's constraint conditions throughout the entire network. When all the constraints of an actor are concentrated on the same node, its degree is 1, indicating that the actor's ability is limited in the structural hole; On the contrary, if the constraints of the actor are the same as those of all other nodes, then its level is 0, which means that the actor's ability in the structural hole is not limited. The limitations of the institutions in Table 2 are generally not high, indicating that although there are differences in limitations between these institutions and different collaborators, these differences are not significant.

⑤ Middle centrality

The high value of centrality in the middle indicates that the subject occupies an intermediary position in the network, which makes them play a crucial role in connecting different nodes. The advantage of this position lies in its ability to control and transmit information and resources, thereby having a significant impact on other nodes. Specifically, these institutions with high to medium centrality, such as State Grid Corporation of China, China Electric Power Research Institute, Tsinghua University, etc., have become key nodes for information and resource sharing due to their special position in the network. The existence of such structural holes not only enhances the information control ability of these institutions, but also promotes their role in exploratory innovation activities, as they can provide unique non redundant information, which is particularly important for innovation activities.

5. Conclusions

This article selects the number of artificial intelligence technology industry university research cooperation invention patents in various provinces and cities of China from 2012 to 2021 as the sample, and uses centrality and structural hole analysis methods to analyze the development level of China's artificial intelligence technology industry university research cooperation innovation output. The research results indicate that in a collaborative network with industry university research institutions as nodes, the number of participating institutions increases and the scale of cooperation expands. However, there are significant differences in the structural hole index among different institutions, indicating significant differences in resource utilization capabilities.

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