Analysis on the Trend of Technology Convergence Based on Patent Measurement—Take the Filed of Blockchain and Artificial Intelligence as an Example

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ABSTRACT: This paper chooses the field of artificial intelligence and blockchain as the research object. Based on patent data, the amount of patent applications and the degree of technology convergence are used to judge the degree of technology convergence. Citespace is used to analyze the country where patents belong and the distribution of patentees, so as to understand the research status in the field of fusion. Based on the Derwent manual code, the co-occurrence analysis was carried out after dividing the two time stages, and the co-occurrence frequency, intermediary centrality and Burst value were used to analyze the merged technology, so as to explore the development trend and frontier direction after the technology fusion. The results show that the technology convergence between the two fields is gradually getting closer and closer. Distributed database, machine learning and other related technologies are the current hot technologies. Identification technology and distributed database are the key technologies at present. The emerging technologies are mainly classified technologies in the field of digital computers, while infrared heating in the field of aerospace science and microsystem emerging technologies widely used in many fields are expected to become the development trend of future technology convergence in the field of artificial intelligence and blockchain.

Keywords: Technology convergence, De Winter patent data, citespace, Artificial intelligence and blockchain

1. INTRODUCTION

As the boundary between technologies is gradually blurred, the progress of a single technology is often supplemented and promoted by technologies in multiple fields[1]. Existing studies have proved that many promising fields are developed for technological convergence[2]. So how to find the field and direction of technology convergence with good development prospects, measure the degree of technology convergence, analyze the status quo after technology convergence, and predict the development trend of emerging technologies after technology convergence is of great significance for enterprises to keep up with the tide of the development of The Times, formulate the correct innovation and development strategy, and form the competitiveness of standing in the market.

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2. LITERATURE REVIEW

2.1 Technological convergence

The concept of technological convergence was first proposed by Rosenberg to describe the evolution of the specialized machine tool industry in the United States in the late 1800s -- that is, different industries increasingly rely on the same set of technical skills[3]. Kodama describes technology convergence as a breakthrough innovation created by merging more than two existing technologies into a similar concept[4]. Technology convergence is usually defined as a new technology domain created by a combination of several different technology domains[5]. Although the convergence between countless technological fields is increasing year by year, quantitative analysis of this convergence is still limited[6]. In general, given the recent technological development and the rapid progress in the convergence of various technologies, it is increasingly difficult for enterprises to meet multiple market demands through internal innovation[7]. In this case, relevant studies have emphasized the opportunity of technology convergence and its importance in corporate R&D [8-9].

2.2 Technology convergence measurement method

As technology convergence comes from the correlation between two or more unrelated technology fields, the distance between the two technologies is constantly shrinking, and thus the convergence occurs. Huang Lucheng proposed A method to measure the degree of technology convergence based on association rules, as shown in Formula (1), that is, when patents are used as data sources, the number of patents in fields A and B can be used as reference for the study of technology convergence. The ratio of the number of intersecting patents in the total number of patents in the two fields is defined as the degree of technology convergence. This paper mainly calculates the degree of technological convergence between artificial intelligence and blockchain, so this method is chosen.

$$F_{AB} = \frac{A \sqcap B}{N_{AB}} = \frac{Intersecting\ patent\ number}{Total\ patent\ volume} \quad (1)$$

3. RESEARCH METHOD

The research idea of this paper is as follows: Firstly, statistical data of patents in the fields of artificial intelligence and blockchain are collected, combined with the annual number of patent applications, and the degree of technology convergence is measured by the number of patents in cross-domain. Then, the patents that begin to appear technology fusion are selected, citespace is selected for visual analysis, and the distribution of countries and regions as well as the information of the patentee are applied, so as to explore the current situation in the field of AI and blockchain technology fusion in the past 20 years. Finally, the co-occurrence matrix is constructed to identify the key technologies, hot technologies and emerging technologies after the convergence of the two technology fields through co-occurrence frequency, intermediate centrality, abruptness and Sigma value, and analyze the future development trend.

4. EMPIRICAL ANALYSIS

4.1 Data

This search uses the main technical keywords of artificial intelligence listed in the "artificial intelligence technology patent In-depth Analysis Report" issued by the China Patent Protection Association and the retrieval methods in the past literature, to construct the artificial intelligence field patent search formula #1, subject search results generated 169,143 records.

Secondly, through a lot of literature reading, it is known that the key words of blockchain-related patents are mainly decentralization, distribution, sharing, virtual currency, etc. Therefore, the search formula #2 in the field of blockchain is constructed. The time span is 2008-01-01 -- 2022-07-08, and 36,831 records are generated from the subject search results.

The intersection of search formula #1 and #2 gives 973 records. Since the blockchain concept was proposed in 2008, the time span of cross-search is set from 2008 to July 8, 2022.

4.2 Degree of technological convergence

1) Patent application volume

The intersection of blockchain and artificial intelligence is becoming increasingly frequent. In recent years, the number of patent applications for their common use shows an obvious rising trend, and the trend of technology convergence between them is becoming more obvious and diversified.

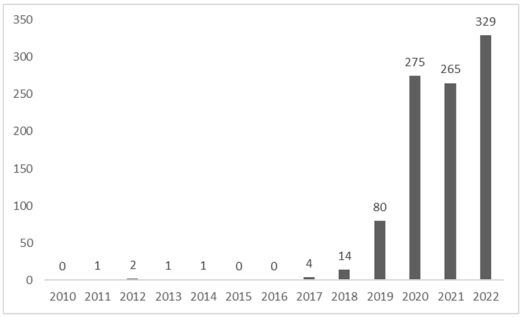

Figure 1. shows the search results by year

Figure 1. shows the number of patents filed for each year since 2010 that resulted in technological intersections. It can be seen that before 2017, the technological convergence of blockchain and artificial intelligence is still in the confused exploration stage. In combination with Figure 1, the overall trend of change in the number of patent applications can be seen. In 2018, the number of patents in a single year exceeded 10 for the first time, and the number of applications showed a significant increase, and then a significant upward trend. In the 2018-2019 time phase, the convergence of the two technologies is in a transition period of small growth. Since 2020, the company has been in a period of rapid growth, with an annual increase of more than 200. In particular, the number of patent applications in 2022 has reached 329 as of July. It is worth noting that the growth rate from 2019 to 2020 reached 249.75%, and the number of patent applications increased by nearly 2.5 times compared with the previous year. Therefore,

2020 is an important time node, which may be closely related to the changes of social environment and technological development in that year.

2) Technology convergence measure

In order to dynamically analyze the changes of technology convergence, this paper combined the two periods of early exploration and small growth transition and defined them as the embryonic stage of technology convergence, while the high-speed growth stage from 2020 to now was divided into the second stage. According to formula (2) of technical convergence degree, the results are shown in Table 1.

Table 1. Degree of technical convergence

stage	Degree of integration between blockchain and artificial intelligence technology
2008-2019	0.0005
2020-2022	0.0042
difference	0.0037
Growth rate /%	740

From the comparison of the technology convergence degree of the two stages, it can be seen that the technology convergence degree of the second stage is greater than that of the first stage, with a growth rate of 740%, which means that the number of cross patents keeps increasing, indicating that the technology convergence is constantly strengthened.

In general, the development of blockchain and artificial intelligence up to now, no matter from the increasing number of patent applications, or from the gradual increase of technology convergence, is enough to show that the relationship between these two fields has changed from sparse to close, from non-interference to mutual convergence, and this phenomenon of complementary technology convergence between fields has become the trend of today's science and technology development.

4.3 Visual analysis

1) Patent application distribution

As can be seen from Table 2, among the current patent applications in the field of blockchain and artificial intelligence technology convergence, the number of Chinese applications has reached more than 50% of the total, and the number of applications is the second place is the United States, followed by South Korea, the World Intellectual Property Organization and India. It can be seen that the current research hotspots in the field of blockchain and artificial intelligence technology convergence are mainly concentrated in the Asia-Pacific region, North America and Europe. The ranking of international or regional organizations is relatively high, indicating that patentees have a strong global awareness of patents.

Table 2. Patent application distribution

	Country/region/organization	Number of patent applications/piece
1	China	523
2	America	346
3	Korea	151
4	WIPO	124
5	India	104

2) Analysis of the principal patentee

As can be seen from Table 3, all the top 10 companies belong to China or the United States. Among them, IBM of the United States applied for the most patents, followed by Ping An International Smart City Technology Co., Ltd. of China. Among the top 10 enterprises, finance and insurance are the main ones, while Tencent's wechat Pay also involves currency transactions, which is consistent with the popular application fields of blockchain. To some extent, this indicates that the current technological convergence of blockchain and artificial intelligence field is mainly related to the underlying technology of digital currency transactions.

Table 3. Principal patentee

	patentee	country	Patent application volume
1	INT BUSINESS MACHINES CORP	America	30
2	PINGAN INT SMART CITY TECHNOLOGY CO LTD	China	16
3	PINGAN TECHNOLOGY SHENZHEN CO LTD	China	13
4	PURE STORAGE INC	America	12
5	TENCENT TECHNOLOGY SHENZHEN CO LTD	China	11
6	BANK CHINA LTD	China	8
7	PINGAN LIFE INSURANCE CO CHINA	China	8
8	BANK OF AMERICA CORP	America	8
9	SHENZHEN ONECONNECT INTELLIGENT TECHNOLO	China	7
10	PINGAN MEDICAL HEALTH MANAGEMENT CO LTD	China	7

4.4 Manual code co-occurrence analysis

This section divides the years 2008-2018 into Phase I and 2019 and beyond into Phase II. In these two stages, the co-occurrence frequency and clustering effect of manual code are analyzed respectively. Finally, the results of the two stages are comprehensively analyzed to form the Derwent co-occurrence view.

1) Hot spot technical analysis

Figure 2.DC co-occurrence chart from 2008 to 2018

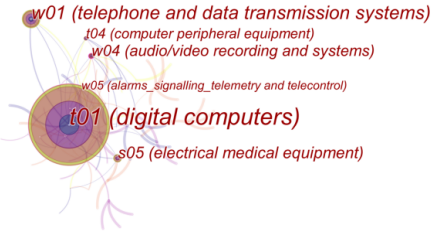

Figure 3.DC co-occurrence from 2019 to 2022

Firstly, the DC code of the patent is analyzed. After data conversion, the corresponding field is DE. The generated Derwent manual code is shown in Figure 2 and Figure 3. From the technology category analysis, the technology research in the embryonic stage of technology convergence mainly focuses on T01, W01, W04, S05, namely digital computer, communication and data transmission system, audio/video recording system, electronic medical equipment, among which the digital computer field is the most popular technology research. Technology research in the high speed growth stage of technology convergence Within the scope of the research in the first stage, added T04, W05, namely computer peripherals, alarm, signal, telemetry and remote control technology hotspots. Through the comprehensive analysis of the two stages, hot topics in the fusion field are shown in Table 4, while the technologies with high co-occurrence frequency are considered hot topics in this field in this paper, as shown in Table 5. In the top 10 Derwent manual codes, Hot technologies include T01-J05B4A(distributed database), T01-J16C2(machine learning), T01-N02B1B(user privilege/cryptography system), T01-D01(data encryption and decryption), T01-S03(claimed software product), T01-J12C(security), and T01-J16C1 (Neural network), T01-N01D(Data conversion), T01-J16(Artificial intelligence), T01-N01A1(Financial intelligence System), covering database, machine learning, user information security, cryptography, data transmission, neural network, finance and other fields. And all of these fields started to be studied between 2016 and 2018.

Table 4. Hot area

number	Key words	year	frequency
1	T01	2011	815
2	W01	2018	196
3	S05	2018	91
4	W04	2016	71
5	T04	2018	49
6	W05	2018	27
7	B04	2011	26
8	T05	2018	25
9	W02	2018	23
10	T06	2011	19

Table 5. Hot spot technology

number	technology	year	frequency
1	T01-J05B4A	2017	539
2	T01-J16C2	2018	309
3	T01-N02B1B	2016	263
4	T01-D01	2017	227
5	T01-S03	2016	222
6	T01-J12C	2017	194
7	T01-J16C1	2018	152
8	T01-N01D	2017	122
9	T01-J16	2018	121
10	T01-N01A1	2016	120

Co-occurrence analysis and clustering were conducted according to SC field, and the visualization results of the two stages were shown in Figure 4 and Figure 5. Through the visualization of Derwent manual code in stages, it can be found that the embryonic technologies are concentrated in the category T, and the nodes with the highest frequency are almost T01 (digital computer). Ten related topics are obtained by clustering, including #0 machine learning algorithm, #1 blockchain-related cognition, #2 master terminal, #3 passive sensor, #4 recommendation system, and #2 machine learning algorithm. #5 cargo container, #6 blockchain network, etc. The technology category in the growth stage still focuses on the category T, including #0 biological category, #1 convolutional neural network, #2 audio signal, #3 information server, #4 live broadcast, #5 hardware processor, #6 target user, #7 automatic system, #8 multimodal single file system node, and #9 switch module. It can be seen that in the process of technology convergence, the exploration limited to blockchain in the embryonic stage gradually developed to the technology field gradually approaching artificial intelligence

technology, which dynamically shows the gradual deepening and expansion of the degree of technology convergence.

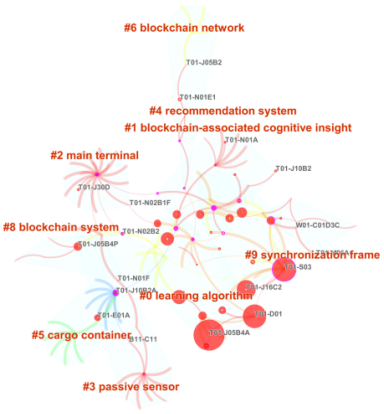

Figure 4.2008-2018 Manual code SC

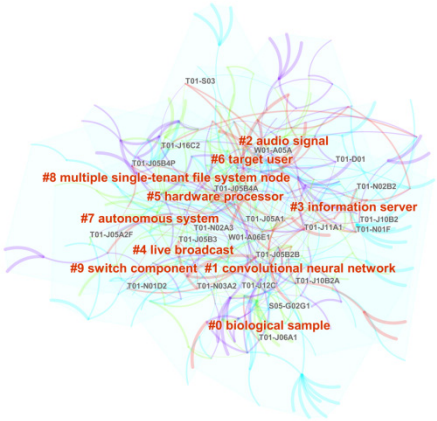

Figure 5.2019-2022 Manual code SC clustering

2) Analysis of key technologies

Intermediation centrality describes the bridge between nodes to establish the relationship between two unrelated nodes. A high intermediation centrality highlights the importance of nodes in the structure. Table 6 lists relevant technologies corresponding to important nodes of technology convergence. Among them, T01-J10B2A (recognition technology), which has high intermediate centrality, The second are T01-J05B4A (distributed database), T01-N01B3 (online education), T01-N02B2(chat room), X25-B01H(infrared heater) T01-J05B4F(image and video database), indicating that these application nodes occupy a key position in the whole co-occurring network system.

Table 6. Key technology

number	technology	year	Intermediation centrality
1	T01-J10B2A	2011	0.36
2	T01-J05B4A	2017	0.23
3	T01-N01B3	2016	0.14
4	T01-N02B2	2016	0.13
5	X25-B01H	2014	0.12
6	T01-J05B4F	2019	0.11
7	T01-S03	2016	0.11
8	T01-D01	2017	0.10
9	T01-E01A	2011	0.10
10	T01-N01D1B	2018	0.10

3) Analysis of emerging technologies

The emergence of an emerging field may indicate the development direction of technology. In citespace, the analysis of hot spots in the network is usually measured by the Burst value, which represents the status of patent emergence and can be used to study the rise of technology. Figure 6 shows the trend of technology change in time. It can be found that the research focus is on

T01 (digital computer) field. The T01-E01A (classification) technology started earliest and lasted from 2011 to 2019. Both T01-N01D3(from a remote site or server) and T01-N01B2B technologies are in the T01-N (Internet and Information Transmission) category, and three technologies are in the key technology positions in the T01-N category, indicating that Internet and information transmission technologies will play an important role in future applications. T01-J07D1(vehicle microprocessor system) is a newly emerged technology, illustrating the application of blockchain and artificial intelligence intersection technology in the field of vehicle, indicating a new prospect of future development.

Figure 6. Technological emergence

5. CONCLUSIONS

To sum up, (1) This study judged the convergence of blockchain and artificial intelligence by the number of patent applications and degree of technology convergence after their convergence. The results showed that the cross-use of technologies in the two fields became more and more frequent, and the convergence of technologies was constantly strengthened. (2) The visualization tool citespace was used for patent country and region analysis and patentee analysis, and then the convergence of blockchain and artificial intelligence technology was summarized. The results showed that among all countries with patent applications in the cross field, China's application volume accounted for more than half of the total, followed by the United States. In the distribution of patentees, IBM of the United States ranks first in the number of patent applications. In addition, among the top ten patentees in the number of applications, 7 are from Chinese companies. (3) The software is used to conduct Derwent manual code co-occurrence analysis, and the technology clustering results are visually displayed. The results show that distributed database, machine learning, cryptography, user information security, neural network, financial intelligence system, etc., are the hot technologies after the technology fusion of blockchain field and artificial intelligence field; The key technologies are mainly reflected in the identification technology, distributed database, online education, chat room, infrared heater and other technologies; The emerging technologies on the trend of technology convergence include classification under digital computer, Internet and information transmission, vehicle microprocessing system technology, etc.

It is worth mentioning that in addition to the intersection of blockchain and artificial intelligence technologies, this study also found the emergence of application fields or emerging technologies under the intersection. For example: S05 (electronic medical equipment) field; X25-B01H(infrared heater), which belongs to the field of aerospace science and technology; T01-J07D1(vehicle microprocessor system), which belongs to microsystem technology, has a wide range of application prospects in the fields of information, biology, aerospace, military and so on. It is of great significance for the country to maintain the technological lead, which may become the future development trend in the field of convergence.

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