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Comparative Analysis between International Research Hotspots and National-Level Policy Keywords on Artificial Intelligence in China from 2009 to 2018

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Abstract: In the last decade, artificial intelligence (AI) has undergone many important developments in China and has risen to the level of national strategy, which is closely related to the areas of research and policy promotion. The interactive relationship between the hotspots of China's international AI research and its national-level policy keywords is the basis for further clarification and reference in academics and political circles. There has been very little research on the interaction between academic research and policy making. Understanding the relationship between the content of academic research and the content emphasized by actual operational policy will help scholars to better apply research to practice, and help decision-makers to manage effectively. Based on 3577 English publications about AI published by Chinese scholars in 2009–2018, and 262 Chinese national-level policy documents published during this period, this study carried out scientometric analysis and quantitative analysis of policy documents through the knowledge maps of AI international research hotspots in China and the co-occurrence maps of Chinese policy keywords, and conducted a comparative analysis that divided China's AI development into three stages: the initial exploration stage, the steady rising stage, and the rapid development stage. The studies showed that in the initial exploration stage (2009–2012), research hotspots and policy keywords had a certain alienation relationship; in the steady rising stage (2013–2015), research hotspots focused more on cutting-edge technologies and policy keywords focused more on macro-guidance, and the relationship began to become close; and in the rapid development stage (2016–2018), the research hotspots and policy keywords became closely integrated, and they were mutually infiltrated and complementary, thus realizing organic integration and close connection. Through comparative analysis between international research hotspots and national-level policy keywords on AI in China from 2009 to 2018, the development of AI in China was revealed to some extent, along with the interaction between academics and politics in the past ten years, which is of great significance for the sustainable development and effective governance of China's artificial intelligence.

Keywords: artificial intelligence; international research; knowledge map visualization; policy documents quantification; research hotspot; policy keyword

1. Introduction

What is artificial intelligence (AI)? There is no direct definition of AI or a consensus thereon, and AI is often understood as a set of techniques designed to use machines to approximate certain aspects of human or animal cognition. Early theorists believed that the symbolic system (the organization of abstract symbols using logical rules) was the most productive way to pursue a computer that could "think"; however, as originally unimagined by Turing and others, the strategy of constructing an inference engine did not achieve the initial cognitive tasks, and it seemed that the theoretically possible concepts had not produced many feasible applications in practice [1]. Li and Wang gave five common definitions of artificial intelligences (AI) in their book *Artificial Intelligence*: (1) AI is a computer program which makes people feel inconceivable; (2) AI is a computer program similar to human thinking; (3) AI is a computer program similar to human behavior; (4) AI is a computer program that can learn; (5) AI is a computer program that can make reasonable actions according to the perception of the environment and obtain the most profitable benefits [2]. They believe that the fifth definition relates to the comprehensive definition used by Wikipedia, which offers a relatively recognized, textbook-like definition of the academic world, and it is comprehensively balanced and emphasized. The first few definitions are from the perspective of public, pragmatism, or machine learning. The perspective of trends it is not comprehensive enough and slightly biased; of course, AI is a field with a wide range of meaning and rich enrichment, and it is necessary for the scientific community and society to continue to extend, expand, and apply its connotations and denotations [2]. Some scholars believe that AI is the intelligent simulation of human behavior through the use of advanced technology, and that the process involves extremely complex human–machine relationships; from the perspective of information perception, data management, deep learning, bionic behavior, and language interaction, AI includes five core elements: cross media perceptual computing, autonomous deep learning, big data intelligent management, virtualized bionics, and simulated language interaction [3].

The research of artificial intelligence has attracted the attention of many scholars, and many fields involves the application of artificial intelligence, machine learning, and pattern recognition, etc. There are published studies and applications involving data transmission, pattern recognition, behavioral research, robotics, and computer engineering [4–8], as well as research and applications in physical sciences, health-related issues, natural sciences, and industrial academic areas [9–11]. Furthermore, there have also been some studies related to applications of different sensors, such as binary, digital cameras, depth data, and wearable sensors, that use AI and data classification fields [12–18].

The latest *China AI Development Report 2018* proposed that the two main lines of development of AI core technologies are brain science and brain-like intelligence technology, and machine learning represented by deep neural networks; currently, brain science and brain-like intelligence technology research progress is limited. Machine learning is developing rapidly, and has become the mainstream paradigm of AI technology today; people often even equate the concepts of "AI" and "machine learning"; in general, the AI we know today is based on modern algorithms and supported by historical data to form artificial programs or systems that can perceive, recognize, make decisions, and execute actions like human beings [19].

Discussions and studies on AI were published in *Sciences*, *Artificial Intelligence*, and other important academic journals in 1980s and 1990s. At that time, most of them discussed the relationship between AI and computer information processing, and the significance of AI for future innovation and new ideas [20,21]. Boden believed that AI could simulate and realize the creativity of human intelligence in the future [21]. Since the beginning of the new century, research into and application of AI has become more and more abundant, rapid, and in-depth, and it has played an increasingly obvious role in promoting scientific and technological innovation and economic and social development; especially in the past decade, artificial intelligence has garnered a considerable amount of attention from academia and governments of many countries and regions. Scholars' research keeps pace with contemporary trends and benefits from the government's policy guidance and promotion; meanwhile, the research and application of new technology and AI has a significant role in promoting the development of countries and societies [22–26].

A considerable number of scholars have been engaged in research on big data, data mining, smart city, education, knowledge management, innovation network, policy-making, and other areas related to AI, as well as many journal articles, research topics, and research conferences on AI [25–35]. The special issue on "Human Centered Web Science" from the journal *World Wide Web* is to explore how humans could keep up with the current trend toward authorizing users to collectively decide on the usage of web-based information and services in the new era of Internet and AI, and to study and discuss how to master human-driven features of Web-based systems, conduct high-level governance policies and so on [36]. These studies discuss how to adapt to the new era and new trends, and explore the corresponding ideas and solutions. The special issue "Knowledge Management, Innovation and Big Data: Implications for Sustainability, Policy Making and Competitiveness" of the journal *Sustainability* is another typical representation [37]. A considerable number of articles have explored the new era of big data, knowledge management, and innovation. Integration would result in policy driven at a higher level of abstraction; many related scholars believe that the diffusion and development of these multidisciplinary characters and innovations will be based on critical and radical diffusions of smart machines and AI. This research was based on the special issue "Artificial Intelligence and Cognitive Computing: Methods, Technologies, Systems, Applications and Policy Making", and explored the interactive relationship between the hotspots of China's AI international research and national-level policy keywords.

Many scholars have explored the diverse effects, problems, and implications of AI. From the perspective of social science, Miller combed and proposed the development of interpretable artificial intelligence [38]. Lytras, Hassan, and Aljohani believed that in a new era of collective human wisdom, the intelligent library would be one of the important representations and composition systems of AI and the smart city; this kind of personalized and intelligent service and technology-integrated data mining, scientometrics, computer science, AI, and other technologies, and, in the future, library and information science, combined with AI, smart cities and other concepts could help humans to better make scientific and sensible decisions in the face of complex networks and big data [39]. Rajan and Saffiotti discussed the development status and practice of the emerging field of integrated AI and Robotics [40]. Chui, Lytras, and Visvizi discussed the various ways in which AI and big data could offer important support during the process of attaining energy sustainability in smart cities [41].

Some scholars have discussed the impact of AI on scientific research, the expansion of scientific discoveries, and the economic impact of AI in last few years [42,43]. Visvizi, Lytras, and co-workers conducted research on smart cities, big data, education, knowledge management, and AI, explored the comprehensive impact of related technology and service, and discussed the relationship between policy-making and academic research, focusing on existing research and technological innovation [44–47]. In recent years, AI has gradually become a national strategy in China, and relevant policies and designs at the central and local levels have been introduced. Chinese scholars' research on domestic and international AI applications has gradually deepened and expanded. This research includes not only the comprehension of relevant policies and industrial trends of AI in China [19,48–51] and the comparative analysis of AI development strategies and situations domestically and abroad [52–54], but also the discussion of AI development and application to specific fields [55–57]. Over the past five years, more articles have been published on the internal and external governance, construction path and social impact of AI [58–60]; meanwhile, more and more econometric analyses have been conducted in certain fields of AI [61–63].

In general, there are two parts to the research into China's AI policy and China's AI research hotspot. The first part is the research on AI policy. For example, some scholars have discussed the policy quantification of AI [63,64], and there are studies on the development policy and strategic layout of China and other countries in the overall field or specific field of AI [53,65–67]. The other part is research on the field and hotspots of artificial intelligence research in China, such as the analysis of the academic pedigree of scholars in the field of AI research [63], and the comparative study of research hot spots and frontier trends between China and other countries [68], but the comparative study of Chinese academic research hotspots and political policy priorities has been relatively sparse.

As some members of the China AI Development Report 2018 research group, the team of this research participated in the sorting and analysis of the policy part of the report. After the completion of the report, the team members wanted to further explore the relationships and interactions between the content of China's AI policy concerns and Chinese scholars' research concerns, hoping to further enrich such comparative studies and provide corresponding suggestions to political and academic circles.

This research was based on Chinese scholars' international research on artificial intelligence and the relevant hotspots, keywords in English articles, and the comparison of hotspots and keywords in Chinese government policy literature. By tracing the hot topics and key words of Chinese scholars' international studies and domestic political circles, this study was able to track the interaction between domestic policies and international research, and then provide certain implications, references, and theoretical bases for the internationalization of AI research in China, the internationalization of relevant domestic policies, and the relationship between academia and policies.

2. Knowledge Map Visualization Analysis of International Research Evolution of Artificial Intelligence in China

A knowledge map is an image of a knowledge domain and shows the relationship between the development process and structure of scientific knowledge. Citespace visualization software is one of the representative tools used for the visualization of scientometrics and knowledge map [69–71]. Through an international analysis of Chinese scholars in the field of artificial intelligence and visual analysis of the knowledge maps of English articles, this study explored the network structure and evolution of related research hotspots and keywords of Chinese scholars in the field of AI [69–72]. By analyzing the hotspots and keywords of international research in a certain field, scholars can provide necessary reference and identify implications for the development direction, policy formulation, knowledge base, and frontier trends of the field [73–76]. In addition to scientometrics and knowledge mapping, many scholars and experts also use other algorithms and technologies to study AI, such as data extraction, features fusion, and classification and recognition technologies [77–84]. Based on these studies, from the perspective of evolution and cooperation, this study used the methods of scientometrics and knowledge map visualization to research, which is helpful for further enrichment of the field and gives this research a certain uniqueness and novelty.

We chose to download and obtain the corresponding literature data from the "Web of Science Core Collection" of ClarivateAnalytics's Web of Science database (http://www.isiknowledge.com/). Most of the research team members were members of the China AI Development Report 2018 report research group for policy analysis, and they were not very familiar with many specific AI technologies due to the wide range of artificial intelligence research. To ensure that the literature was pertinent and reflected the targeted situation, this study only selected "Artificial Intelligence" as "Topic", "China" as "Address", and "2009–2018" as "Timespan" in the research literature in the Web of Science Core Collection, so as to carry out a comparative analysis of China's national-level AI policies between 2009 and 2018. Therefore, the sample selection of this study had certain limitations, and the literature trend chart (Figure 1) had a certain one-sidedness and misleading nature; it only showed that the research on AI by Chinese scholars is increasing year by year, and that research literature presents a certain significant growth trend with policy encouragement and financial support.

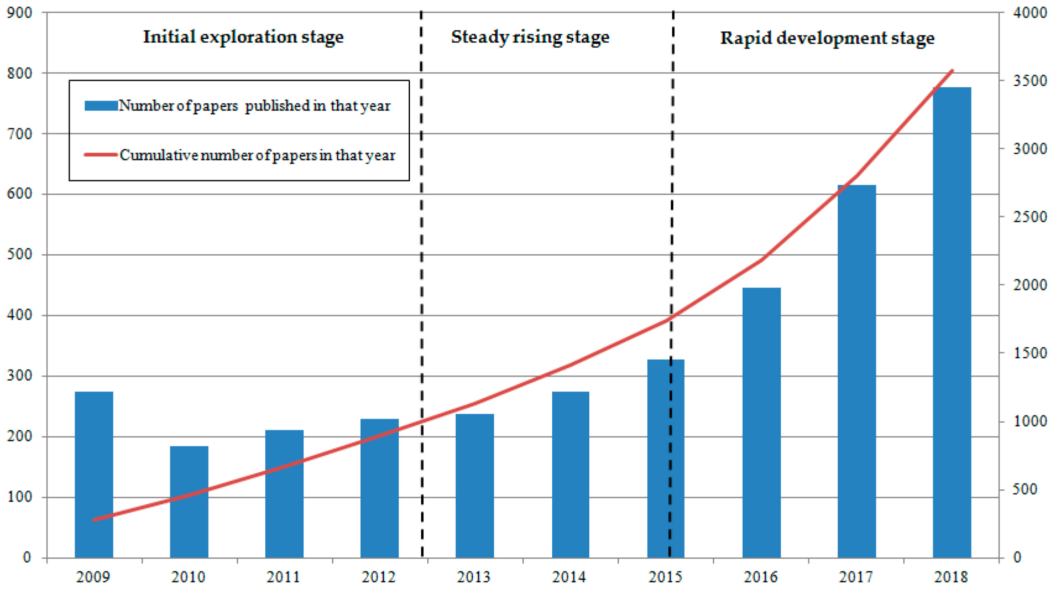

Figure 1. The annual number and stage distribution of China's international artificial intelligence (AI) research (2009–2018).

As mentioned above, this paper selectd the relevant papers of Chinese scholars from the core collection of ClarivateAnalytics's Web of Science database from 2009 to 2018, and used "Artificial Intelligence" and its key keywords for searching and selecting. A total of 3746 related papers were collected, and the three types of papers (1762 articles, 1830 proceedings papers, and 112 review; 3577 in total) which best reflected the international research of artificial intelligence were selected and served as samples for data and visualization analysis in this study. After sorting and screening, 3577 articles were collected for further analysis.

2.1. Distribution of AI International Research Results

The growth regularity and trend of papers published in international high-level journals as well as conferences are important indicators of knowledge accumulation or change in research fields [26]. After screening the topic paper data of China's AI international research, classifying and sorting them by year, the number and change trend of Chinese research papers on AI in 2009–2018 was obtained, as shown in Figure 1. Figure 1 has two coordinate systems. The left coordinate system corresponds to the blue column (number of papers published in that year), and the right coordinate system corresponds to the red curve (cumulative number of papers in that year).

It can be seen from Figure 1 that although the publication of international AI research papers fluctuates, in general, the growth with time showed a trend of increasing year by year. The cumulative number of papers over the year showed a very stable year-on-year growth trend, and the growth process was divided into three stages: (1) Stage 1 is the initial exploration stage (2009–2011). The number of relevant papers in this stage was around 100–200, among which the number of papers in 2009 was relatively large, and the overall situation was relatively stable. (2) Stage 2 is the steady rising stage (2012–2015). The number of papers was growing at this stage, fluctuating slightly, and the number of papers gradually increased from more than 200 to more than 300. (3) Stage 3 is the rapid development stage (2016–2018). The number of papers in this stage grew relatively rapidly, from 300 or 400 in 2015–2016 to 777 in 2018.

Regarding the division of the literature into these three stages: on the one hand, the division was based on the sorting and growth trend of the literature in the studied years, and, on the other hand, it was based on the three-stage division of China's national-level policy in 2009–2018 in the China AI

Development Report 2018 [19], so as to use the keywords of the three-stage literature and the keywords of the three-stage policy documents for comparative analysis.

2.2. Distribution of High-Yield Countries/Regions and Institutions with AI International Research Cooperation

Based on the relevant international research articles on AI, the refinement statistics of "Countries/Regions" represented the countries and regions that have cooperated with Chinese institutions or scholars to conduct AI research. The number and percentage of total publications from these countries or regions in cooperation with Chinese scholars is shown in Table 1. From Table 1, the top 15 aside from China were the United States (250 articles, accounting for 6.99%), the United Kingdom (82 articles, accounting for 2.99%), Australia (68, 1.90%), Canada (62, 1.73%), Singapore (52, 1.45%), Japan (42, 1.17%), France (24, 0.67%), Iran (23, 0.64%), India (19, 0.53%), Italy (18, 0.50%), Spain (16, 0.45%), Saudi Arabia (15, 0.42%), South Korea (15, 0.42%). Among them, the United States was the first group, with 250 papers in cooperation; the second group was concentrated in other developed countries and regions in the field of AI in other continents, such as the United Kingdom (traditional powers), Australia in Oceania, Canada in North America, Singapore in Southeast Asia, etc.

Table 1. The high-yield countries/regions distribution of China's AI international research cooperation (2009–2018).

No.	Country/Region	Paper Number	Percentage
1	China	3572	99.86%
2	USA	250	6.99%
3	UK	82	2.99%
4	Australia	68	1.90%
5	Canada	62	1.73%
6	Singapore	52	1.45%
7	Japan	42	1.17%
8	Taiwan	34	0.95%
9	France	24	0.67%
10	Iran	23	0.64%
11	India	19	0.53%
12	Italy	18	0.50%
13	Spain	16	0.45%
14	Saudi Arabia	15	0.42%
15	Korea	15	0.42%

Based on the relevant international research articles on AI, the refined statistics of "Organizations" were calculated for countries and regions that cooperate with China, as shown in Table 2. The first 15 universities in the first group began with the Chinese Academy of Sciences (331 articles), in which research benefits from the Chinese Academy of Sciences' long-standing research in this field, and the huge research institutes under the Chinese Academy of Sciences. The second group included China's Ministry of Education and China's high level universities, such as the Ministry of Education of China (140 articles), Tsinghua University (111 articles), the University of Chinese Academy of Sciences (101 articles), the Hong Kong Polytechnic University (99 articles), Beihang University (96 articles), Zhejiang University (81 articles), Wuhan University (76 articles), Huazhong University of Science and Technology (73 articles), and Shanghai Jiaotong University (72 articles), which were all over 70. Among them, traditional science and engineering and defense science colleges had an advantage, and many other comprehensive universities also had good performance.

Table 2. The high-yield institution distribution of China's international AI research (2009–2018).

No.	Organization	Paper Number	Percentage
1	Chinese Academy of Science	331	8.37%
2	Ministry of Education China	140	3.54%
3	Tsinghua University	111	2.81%
4	University of Chinese Academy of Science CAS	101	2.56%
5	Hong Kong Polytechnic University	99	2.50%
6	Beihang University	96	2.43%
7	Zhejiang University	81	2.05%
8	Wuhan University	76	1.92%
9	Huazhong University of Science Technology	73	1.85%
10	Shanghai Jiao Tong University	72	1.82%

2.3. Research Hotspots of China's AI International Research

In this study, the topics and keywords in the literature were used to explore the hot topics and hotspots of Chinese scholars in the field of AI in 2009–2018. It is generally believed that keywords are highly condensed and concise in the topic and research hotspots; with the assistance of the knowledge map of co-occurrence keywords drawn by CiteSpace software, this study quickly elucidated the structure, network distribution, and frequency of co-occurrence of related articles keywords, so as to clarify the research hotspots in the field [73–76]. Through the visualization analysis of 3577 related papers collected in this paper, a knowledge map of the international research hotspots of China's AI by node type and time-zone type was obtained. The two maps are shown in Figures 2 and 3.

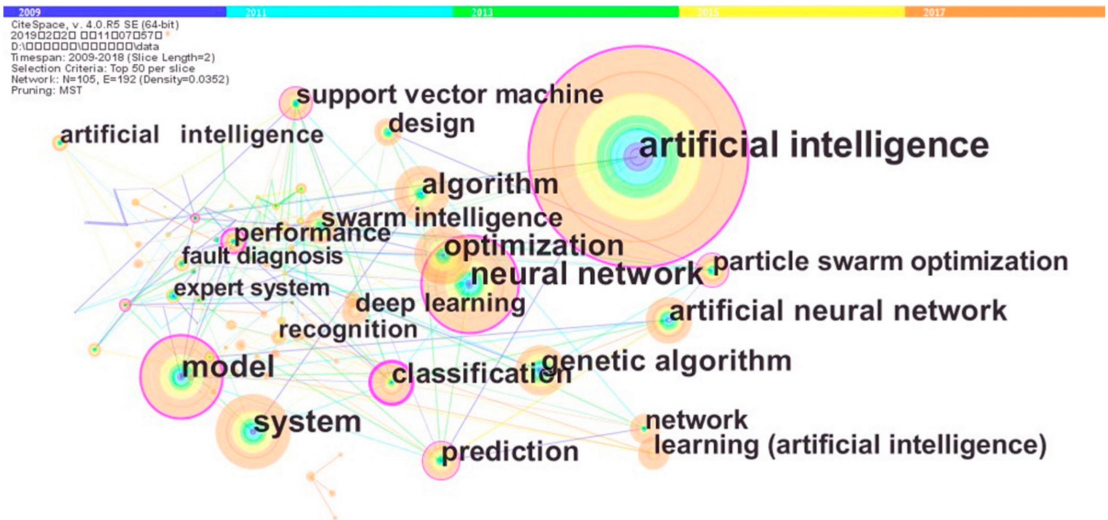

Figure 2. The knowledge map of China's international AI research hotspots (node type) (2009–2018).

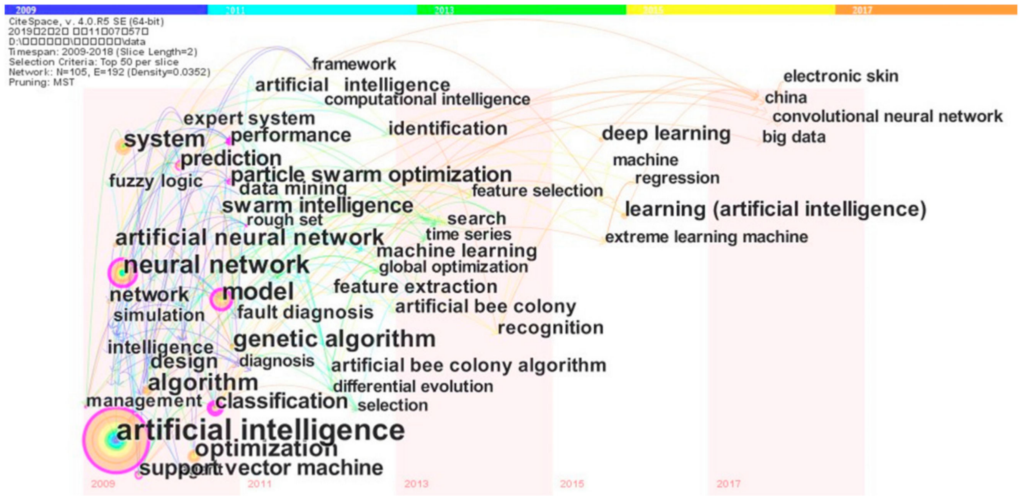

Figure 3. The knowledge map of China's international AI research hotspots (time-zone type) (2009–2018).

The keywords in the knowledge maps shown in Figures 2 and 3 represent the nodes in the network, and the connections between the network nodes represent their co-occurrence relationships. The larger the nodes, the more rings, indicating that the co-occurrence frequency of the keywords is higher. Figure 2 shows that besides the node of "artificial intelligence" (673 times), the nodes with high frequency were "neural network" (307 times), "model" (261 times), "system" (244 times), "optimization" (202 times), "genetic algorithm" (172 times), and "cloud computing" (97 times), etc. Furthermore, new keywords and research hotspots of "China" (32 times), "extreme learning machine" (29 times), "big data" (29 times), "face recognition" (25 times), "electronic skin" (28 times) and other nodes emerged 2015. By reviewing the keywords and subject words that have appeared over the years, the hotspots and interests of Chinese scholars' research on AI can be understood. In the initial exploration stage of AI, Chinese scholars relied on "artificial neural networks" and "genetic algorithms" to conduct research and gradually formed models and systems, and then transferred focus to "cloud computing" and "data sharing" in the steady rising stage. In recent years, hot topics such as "China", "big data", "face recognition", and "electronic skin" have been closely related to the frontier areas of AI, or closely related to current policies and social concerns. In addition, some experts mentioned new functions of AI applications in different fields, such as pattern tracking, data classicization, neural network, deep mining, etc. [85–91], which are worthy of further attention in this study. The organic connection and quantitative comparative analysis between the hot spots of AI international research in the past ten years and policy keywords at the national level is discussed in the following sections.

3. Quantification Analysis of China's AI National-Level Policy Documents

3.1. Stage Division of China's AI National-Level Policy

The quantification analysis of policy documents is based on the analysis of policy documents; on the basis of collecting policy documents and constructing subject words, it further integrates the information contained in the documents, and carries out co-occurrence analysis, clustering analysis, and trend evolution analysis of relevant information, keywords and subject words from multiple dimensions and multiple angles. Starting from the quantitative law of inductive document attributes, it puts forward deeper policy suggestions and reflections based on the combination of qualitative and quantitative research [92–95].

This study established a dataset of AI policy analysis. First, based on the word frequency statistics of AI documents, it identified and constructed the list of initial AI keywords, which were mainly about "AI", and "deep learning", "big data", and "cloud computing", etc. The research team further asked experts in the corresponding field to judge and screen the keywords. Based on the keywords, the pre-search was conducted in the Government Documents Information System (GDIS) of the School of Public Policy and Management of Tsinghua University, and the title and text of policy documents containing the above-mentioned search terms were selected and screened. A total of 262 pieces of China's central-level or national AI policy documents were retrieved. The relevant policy documents were initially sorted and classified according to their years of publication, and the policy trend as well as a stage division map was drawn (shown in Figure 4).

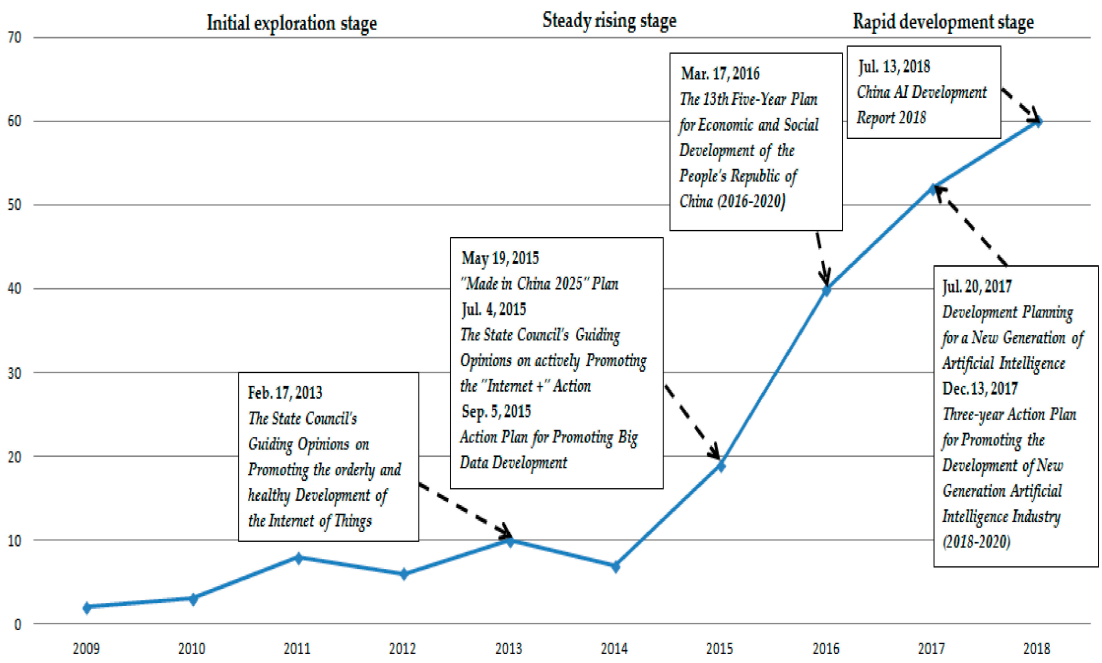

Figure 4. The trends and stages of China's national-level AI policy (2009–2018). Source: According to References [19,51].

The collection of policy documents and reports, especially the China AI Development Report 2018 and Domestic and Foreign AI Policy Analysis Report 2018 was combined with the three-stage distribution of AI international research hotspots discussed in Section 2. In order to maintain the consistency and contrast of the analysis, this study roughly sorted the national AI policy into three groups: (1) the initial exploration stage of 2009–2012, where there were fewer national-level policies for AI; (2) the steady rising stage of 2013–2015, when the development of AI gradually increased to the level of national strategy, and policy documents were issued more quickly and steadily; and (3) the rapid development stage of 2016–2018, representing the upsurge of AI development, in which the national-level AI policies became more comprehensive, the top-down design was further enhanced, and the follow-up policies and plans at all levels in various fields were more targeted and specific.

3.2. Quantification Analysis of National-Level Policy Documents on AI and Comparative Analysis between International Research Hotspots and Policy Keywords

Word co-occurrence is one of the most commonly used analytical methods for bibliometrics. Two keywords appear in one document and are recorded as one co-occurrence of the topic. The more co-occurrences, the closer the relationships between the two words and the stronger the correlations; analyzing the co-occurrence relationships of keywords in existing policy documents can cluster the subject words and identify the core theme of the field; thus, the co-occurrence network of the keywords in each period and stage can be constructed, and the stages can be identified [19,51]. After integrating and modifying the co-occurrence map of AI reports, a three-stage theme co-occurrence map of AI development was obtained, as shown in Figures 5–7.

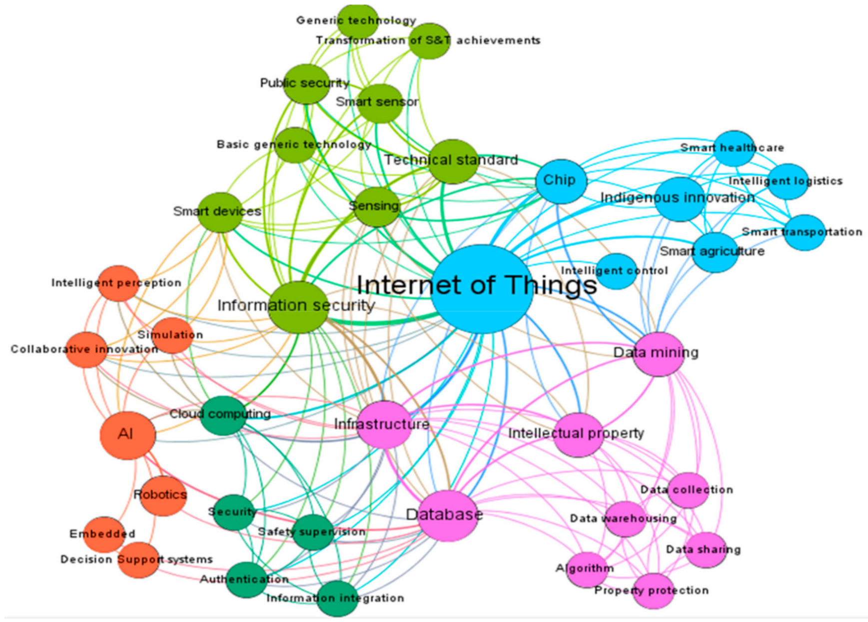

Figure 5. The initial exploration stage keywords co-occurrence map of China's national AI policy (2009–2012). Source: According to References [19,51].

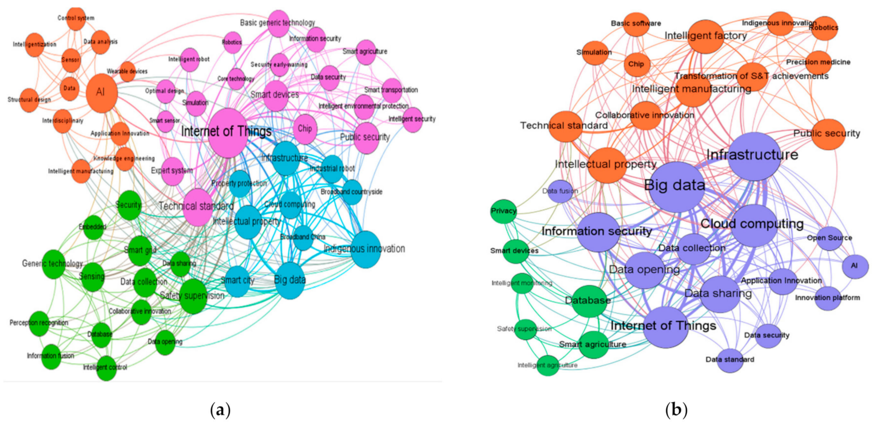

Figure 6. The steady rising keywords co-occurrence map of China's national AI policy (2013–2015). (**a**) (2013–2014); (**b**) (2014–2015). Source: According to References [19,51].

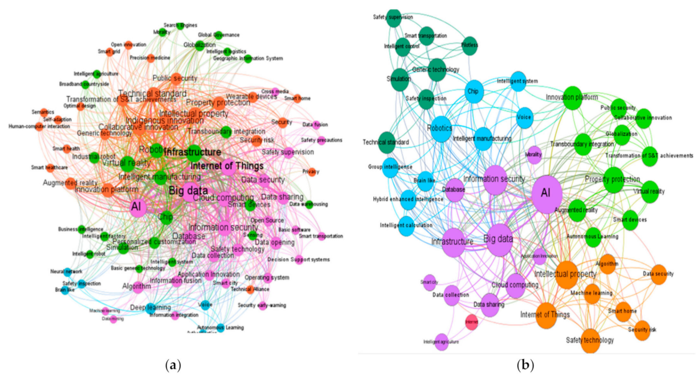

Figure 7. The rapid development keywords co-occurrence map of China's national AI policy (2016–2018). (**a**) (2016–2017); (**b**) (2017–2018). Source: According to References [19,51].

In the initial exploration stage of AI policy (2009–2012), as shown in the co-occurrence map of policy keywords in Figure 5, "AI", "infrastructure", "information security", "technical standards", and "Internet of Things" were the core themes of relevant policies. These were closely related to the social development at that time. During this period, the Internet of Things was just beginning to emerge, and infrastructure construction about AI was ineffective, especially in some aspects such as data collection, data mining, and database construction. However, at this stage, national-level and central-level policies directly related to AI and the Internet of Things had not yet been introduced, resulting in drawbacks in intellectual property rights, property rights protection, technical standards, information security, and public safety.

At this stage, the hotspots of international research on AI in China were "artificial intelligence", "artificial neural network", "genetic algorithm", "group intelligence", "return", "model", "system", "standard", "recognition", "predict", "data mining", and others. It can be seen that there are differences between the two. For example, many hotspots of international research focused on specific technique and frontier exploration of AI (such as "artificial neural network", "genetic algorithms", "recognition", etc.), while policy keywords and hotspots were "Internet of Things", "Infrastructure", "Information Security", and so on. However, there were subtle similarities and connections, such as "data mining", "identification", "prediction", and so on, which were the foundation and prototype of policy keywords in terms of "infrastructure", "Internet of Things", "database construction" and "intelligent industry chain". The exploration of "model" and "system" in research hotspots is the exploration and foundation of future policies on "technical standards". It can be seen that in the initial exploration stage of 2009–2012, the hotspots of international research on AI in China had a certain alienation from the AI policy at the national level, because at this time, there were not many national-level policies on AI. At the same time, international research hotspots and policy keywords had a certain degree of connection. The research hotspots contained the technical basis and prototypical exploration of the current and future policies.

In the steadily rising stage of AI policy (2013–2015), as shown in the co-occurrence maps of policy keywords in Figure 6a (2013–2014) and Figure 6b (2014–2015), "AI", "Internet of Things", "big data", "infrastructure", and "information security" were the core keywords of relevant policies. In this period, China had a certain foundation in the application of big data technology and the development of the internet of things industry, and the knowledge of AI had become more and more mature, and then turned to the basic technology of AI and related practical applications. In 2015, "Made in China 2025" was released, deploying "intelligent manufacturing" in a holistic way and implementing the strategy of manufacturing power; in the same year, the guidelines for the "Internet +" Action were released, clarifying that AI was one of the 11 key development areas for the formation of the new industrial model, promoting the development of AI to the national strategic level. During this period, the hotspots of international research on AI in China were "deep learning", "feature selection", "face recognition", "artificial bee colony algorithm", "time series", "regression", "China", "strategy", and so on. From a macro perspective, the international research on AI in China gradually increased the research and analysis of "China" and "strategy" level; at the micro level, the discussions on the technology and application of AI were more specific and cutting-edge, being inseparable from the policy promotion and keywords of this period, and many specific technologies were built on the basis of AI infrastructure, big data, and databases deployed in China. Compared with the alienation relationship in the initial exploration stage of the previous period, the specific technology and application of AI in this period began to be reflected in policy formulation and social life, that is to say, the hotspots of AI international research began to be closely integrated with the keywords of national policy, but research hotspots focused more on the exploration and application of technology, and national policy was more macroscopic, representing the overall embodiment of hotspots and technologies.

In the rapid development stage of AI policy (2016–2018), as shown in the co-occurrence maps of policy keywords in Figure 7a (2016–2017) and Figure 7b (2017–2018), "AI" became the largest keyword in this stage, while "big data", "infrastructure", "Internet of Things", and "technical standards" were still relevant policy keywords. It should be noted that the keywords such as "robot", "intelligent manufacturing", and "deep learning" also appeared and increased, and the related words of "intellectual property" and "property rights protection" also began to appear. In 2016, the National 13th Five-Year

Plan of China proposed to break through AI technology. During this period, the development of virtual technology, intelligent commerce, industrial robots, and other fields marked the gradual establishment and improvement of the AI industry system, and the state began to attach importance to the intellectual property rights and property rights protection of AI. The release of the New Generation Artificial Intelligence Development Plan in 2017 marked the beginning of the new era of AI in China. At present, China has systematically arranged AI from the national level, and the Report of 19th National Congress of China put forward "promoting the deep integration of the Internet, big data, AI and the real economy" and strengthened the comprehensive support of AI for science and technology, economy, social development, and national security [4,36]. During this period, the hotspots of international research on AI in China focused on specific frontier technologies and practical commercial application technologies such as "big data", "convolution neural network", "electronic skin", "image classification", "sensors", "movies", "electronic games", and "applications", which is in line with the current policy advocating integration of artificial intelligence and the real economy at the national level. At the same time under the promotion and accumulation of previous research hotspots, current research hotspots began to closely integrate with current policy topics. There are two reasons for this: on the one hand, the planning and top-down design of policies are constantly strengthened, and the contents and keywords of policy documents often cover most of the hotspots and keywords of AI research; on the other hand, the hotspots of AI international research in this period also indicate that more scholars began to pay attention to expanding their research topics and directions to cover policy strategies and commercial applications. Therefore, in this period, the international research hotspots of AI in China were closely integrated with the characteristics of national policies, and they were deeply integrated with and covered by with each other.

In this part, some experts suggested that the research team could continue to use new algorithms and systems to further enhance performance values, e.g., HMM, modified HMM, embedded HMM, GMM, etc. [96–101], and these need to be further expanded upon by the research team in follow-up studies.

4. Discussion and Conclusions

First, this paper adopted the methods of mathematical statistics to carry out simple historical statistics and stage division of relevant Chinese scholars' papers on China's international AI research downloaded and screened from Web of Science database. According to the number and growth trend of articles published, the international research on AI in China was roughly divided into three stages, namely the initial exploration stage (2009–2012), the steady rising stage (2013–2015), and the rapid development stage (2016–2018). Subsequently, the high-yielding countries/regions and institutions of AI international research were analyzed, and the CiteSpace software was used to process related papers. Hotspot knowledge maps of international AI research were drawn, the relevant research topics, keywords, and hotspots are found, and the network results and distribution of research hotspots were obtained. Hotspots and keywords included "artificial intelligence", "neural network", "model", "system", "optimization", "genetic algorithm", "cloud computing", and so on according to the frequency. In the past three years, new hot topic words have included "China", "extreme learning machine", "face recognition", and "electronic skin", etc.

Based on the theory and method of quantitative analysis of policy documents, 262 central-level AI policy documents were collected and screened from the Government Document Information System (GDIS); the documents were also sorted by quantity and distributed into stages. Based on the documents themselves and the previous division of research hotspot stages, the documents were also divided into three stages according to the time of publication: the initial exploration stage (2009–2012), the steady rising stage (2013–2015), and the rapid development stage (2016–2018), which were the same as the research hotspot stage for comparative analysis. On the three-stage co-occurrence maps of China's national-level policy keywords, this study made a preliminary quantitative analysis of policy documents and carried out a comparative analysis of the evolution of AI international research hotspots.

In terms of stages, in the initial exploration stage (2009–2012), China's international AI research hotspots and national-level policy keywords had a somewhat alienated relationship; research hotspots were more frontier, while national level policies were few, but research hotspots formed the technical basis and embryonic exploration of the current and future policy keywords. In the steady rising stage (2013–2015), the AI research hotspots were more closely related to the national level policy keywords; the research hotspots focused more on the exploration and application of technology, and the national level policy was the overall collection of hotspots and technologies. In the rapid development stage (2016–2018), the characteristics of China's international AI research hotspots and national level policies were closely integrated, and they were deeply integrated and covered.

In general, research hotspots often focus on exploring the frontiers and technologies of AI. With the development of the times and the progress of policies, research hotspots gradually began to integrate with policies: research hotspots expanded from frontier exploration to the applications of technology and attention was paid to strategies and policies, while policies at the national level began to pay more attention to top-down design and bottom-level promotion, and the overall strategy and planning layout of research hotspots and technological frontiers were also relatively in place, being more targeted strategically and overall.

Although this research had a certain novelty in comparing and analyzing the hot spots and keywords of policy and academic circles, and involved scientometrics and knowledge map visualization analysis of relevant academic literature and policy documents, there are still many limitations and weaknesses related to the opinions of some experts and reviewers. First, the selection of academic literature and policy documents had certain limitations and could be misleading. This study only shows the general situation of China's AI research and policy-making from one side or one general trend. It is possible that different sample selections would reflect different situations and outcomes, clarification of which will require greater sample sizes in the future or more sample selections from other perspectives. Secondly, experts also suggested some novel algorithms and systems in AI, which the research team need to further study, reference, and apply to enrich the research on AI development. Future studies need to select samples scientifically, and use more new algorithms, new systems, and a variety of research methods to comb and study the development and research of AI in China and the world.

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