A Scientometrics Analysis on Brain-Inspired Intelligence

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Abstract. In recent years, brain-inspired intelligence has attracted increasing attention from both academia and industry. Although there are several literature reviews of brain-inspired intelligence research, they appear to be a lack of systematic quantitative and visual investigation. The purpose of this paper is to make insights into certain characteristics of brain-inspired intelligence research, and consequently to reveal the global trends as well as support researchers to determine future research directions. The data were retrieved from Science Citation Index Expanded (SCI-E) of core databases in Web of Science (WoS) and the global patent database of incoPat. Based on the aforementioned data and the scientometric techniques, we show the general characteristics of R&D (R&D) output, identify the research hotspots and the knowledge structure of brain-inspired intelligence and evaluate the R&D capability of countries, institutions. Finally, we conclude that (1) China, the United States, UK, Germany and South Korea are the main R&D forces in brain-inspired intelligence domain. (2) The researchers focus mainly on brain-computer interface, neuromorphic device, neuromorphic computing, and brain operation mechanism, and the R&D forces concentrate on the directions of G06N, G06F, A61B, G06K, H01L. (3) Major countries/regions pay more attention on academic cooperation and exchanges in brain-inspired intelligence. (4) America is leading in the basic research of brain-inspired intelligence. (5) China still has a big gap with the European and American countries in terms of industrial application.

1. Introduction
Brain-inspired intelligence is a kind of machine intelligence that inspired by brain neural and cognitive mechanisms, and can be implemented through software and hardware collaboration. Brain-inspired intelligence is called brain-inspired computing as well. In the late 1980s, American scientist Carver Mead first proposed the concept of brain-inspired computing. The idea of brain-inspired computing is to imitate the operation principle in the nervous system of human, and commit to develop a computing technology which is fast, reliable, and low-cost. Brain-inspired intelligence is the ultimate goal of artificial intelligence, but brain-inspired intelligence cannot replicate human brains. In recent years, brain-inspired intelligence has attracted increasing attention from both academia and industry, and has become a research hotspot for technological and theoretical innovation. By far, there is a large body of researchers doing research on brain-inspired intelligence [1], including spiking neural networks [2-3], non-volatile technologies [4-5], algorithm–hardware codesign [6-7], and so on.

Scientometrics is the analysis of the general characteristics of R&D output, the research hotspots, the intellectual structure, and R&D capability of countries/institutions in a certain field, by using the information of papers/patents such as titles, keywords, abstracts, texts, institutions, etc. Many researchers had used scientometrics to analyze various fields. Chaomei Chen et al did research and analysis the hot trends of regenerative medicine based on CiteSpace software, and successfully
predicted that Yamanaka team’s two papers would have excellent performance and important influence in regenerative medicine [8]. Based on the papers of China National Knowledge Infrastructure (CNKI), Wang Yuan et al used scientometrics method and visualization software to analyze the knowledge network and theoretical structure of Chinese blockchain research [9]. Based on SCI papers collected from WoS, Chuanjun Zheng et al. studied the evolutionary pattern and emerging trends in smart city through hybrid analysis and visualization techniques available in CiteSpace [10]. Cuiyun Xiang et al. provided a scientometrics review on nonpoint source pollution research by examining the perspectives of characteristics of publication outputs, co-operations of countries/territories and institutions, co-occurrence analysis of subject categories and keywords, and co-citation analysis of journals and References [11].

This paper aims to make insights into certain characteristics of brain-inspired intelligence research, and consequently to show the global trends as well as assist researchers to establish future research directions. More specifically, our analysis aims to (1) summarize general characteristics of R&D output and main subject categories; (2) identify the research hotspots and the intellectual structure of brain-inspired intelligence field;(3) evaluate the R&D capability of countries, institutions.

2. Data Acquisition and Methods

2.1. Data Acquisition

The paper data was retrieved from Science Citation Index Expanded (SCI-E) of core databases in Web of Science (WoS), and the patent data was retrieved from the global patent database of incoPat. These two databases are very important and widely used scientific databases in most fields. The details of retrieval setting are shown in table 1. The retrieval time span was from 2002 to 2019, and the retrieval date was September 30, 2019. According to the research content, some impurity documents and patents were washed out, and 17835 SCI papers and 5806 patents were ultimately obtained.

| Table 1. Details of retrieval setting. |
|________________________________________|
| TS= ((brain near/2 inspired) or (Brain near/2 computer interface*) or (Brain near/2 like intelligent) or (cognitive near/2 comput*) or (cognitive near/2 brain comput*) or (Artificial near/2 synapse) or (neuromorphic near/2 comput*) or (neural near/2 interface) or (neural near/2 robot*) or (brain near/1 like chip) or (multimodal perception) or (cognitive near/2 synapse) or (neuromorphic near/2 comput*) or (Neuromorphic near/2 device) or (neural near/2 network chip) or (neural near/1 coding) or (Neuromorphic near hardware) or (brain near/2 inspired comput*) or (Neuromorphic*) or (“deep neural network”)) |
| TIAB= ((brain (2w) inspired intelligence) or (brain (1w) computer interface) or (brain (2w) like intelligent) or (brain (2w) like comput*) or (cognitive comput*) or (cognitive brain computat*) or (brain-inspired) or (artificial synapse) or (neuromorphic comput*) or (brain-like chip) or (brain (2w) inspired chip) or (neuromorphic (2w) device) or (neural (2w) network chip) or (neural cod*) or (neuromorphic hardware) or (multimodal perception) or (neural (2w) comput*) or (neural (2w) interface) or (neural (2w) robot*) or (brain (1w) machine interface) or (neuromorphic*) or (deep neural network*)) |

2.2. Methods

To extract keywords and research hotspots from such a massive data set, visual analysis must be more efficient than other analysis ways. In order to offer readers comprehensive and systematic information about brain-inspired intelligence research, this paper utilizes method of visual and statistics analysis to implement scientometrics analysis. CiteSpace, VOSviewer and Gephi are well-known visual analysis tools, which are widely used in scientometrics analysis field. Compared to Citespace, VOSviewer is more suitable for the cases that high requirement of co-occurrence [12], and it is more effective to
analyze WoS data [13]. WoS is the data source of this paper, and the size of data is quite large. Therefore, in order to get better analysis results, we chosen to use the VOSviewer software.

3. Results and Discussions

3.1. Trends of R&D Output

In order to grasp the trend of R&D in brain-inspired intelligence, the papers and the patents involved in brain-inspired intelligence are statistically analyzed from 2002 to 2018. The results are shown in figures 1 and 2. Brain-inspired intelligence is one of the important directions in artificial intelligence. The number of SCI papers and patents in the field of brain-inspired intelligence is on the rise, indicating that R&D of brain-inspired intelligence is gradually being valued. However, the output of papers and patents is relatively small now. It indicates that the brain-inspired intelligence technology is still in the theoretical exploration stage, and there is still a large gap between research and large-scale applications.

![Figure 1](image1.png)

**Figure 1.** Distribution of papers related to brain-inspired intelligence by publication year.

![Figure 2](image2.png)

**Figure 2.** Distribution of patents related to brain-inspired intelligence by publication year.

The Logistic prediction model is used to predict the output of paper and patent related to brain-inspired intelligence. The prediction results are as shown in figures 3, 4 and table 2. From the perspective of Logistic model prediction, the fastest growth period of paper publication and patent application is 2018 and 2019 respectively. The number of patents and papers will reach a round of
saturation in 2026 and 2027 respectively. It is predicted that we may encounter some technical bottlenecks in brain-inspired intelligence around 2027. As a result, R&D of brain-inspired intelligence slow down, and at the same time there will be a certain scale of application in the industry.

![Figure 3. Trend prediction for published papers in brain-inspired intelligence.](image)

![Figure 4. Trend prediction for published patents in brain-inspired intelligence.](image)

| Data Type | Growth factor | Saturated value | Saturated year | Half-life period | Total number in 2018 |
|-----------|--------------|----------------|----------------|-----------------|---------------------|
| paper     | 0.244        | 3878           | 2026           | 2018            | 2218                |
| Patent    | 0.249        | 2295           | 2027           | 2019            | 880                 |

3.2. Hotspot Analysis of R&D

If a large amount of literature contains a certain research topic, then we can say that this topic is one of the research hotspots in this field during this period. In addition, to a large extent, keyword represents the core idea of the topic. Therefore, we can summarize the research hotspots in this field to a certain extent through statistical analysis of keywords in research topics of the field.

In this paper, we analysed SCI papers collected from WoS in years 2017-2019 by VOSviewer software and obtained a map of keyword co-occurrence network and the high-frequency keywords in
brain-inspired intelligence domain. The keyword co-occurrence network is shown in figure 5. Top 30 high-frequency keywords are list in table 3. As we can see in figure 5 and table 3, the high-frequency keywords of papers in brain-inspired intelligence domain mainly include brain-computer interface, electroencephalogram (EEG), classification, system, memory, model, motor imagery, performance, communication, brains, neurons, plasticity, memristor, cortex, dynamics, device, perception, network, neuromorphic computing, mechanisms, etc. Therefore, it can be summarized that the research hotspots in brain-inspired intelligence domain at present mainly include brain-computer interface, neuromorphic device, neuromorphic computing, and brain operation mechanism.

![Figure 5. Co-occurrence of keywords in the SCI papers related to brain-inspired intelligence.](image)

| Keyword                                      | Frequency | Keyword | Frequency | Keyword | Frequency |
|----------------------------------------------|-----------|---------|-----------|---------|-----------|
| Brain-computer interface/brain-computer interfaces/BCI | 1579      | neurons | 279       | attention | 179       |
| EEG                                          | 467       | plasticity | 253       | design | 179       |
| Classification                               | 449       | memristor | 211       | networks | 176       |
| System/Systems                               | 411       | cortex | 203       | stimulation | 165       |
| Memory                                       | 410       | dynamics | 200       | recognition | 163       |
| Model                                        | 317       | device | 192       | devices | 152       |
| Motor imagery                                | 306       | perception | 189       | rehabilitation | 152       |
| Performance                                  | 295       | network | 188       | responses | 149       |
| Communication                                | 282       | neuromorphic computing | 184       | signals | 147       |
| Brain                                        | 281       | information | 183       | mechanisms | 146       |
International Patent Classification (IPC) is a hierarchical system composed of language-independent symbols, which is usually used to classify patents and utility models of different technical domains. By analyzing the IPC classification number of patents in a specific technical domain, we can perceive the popular direction of engineering development in this domain. By statistically analyzing the IPC of patents related to brain-inspired intelligence, we obtain figure 6 and table 4. From figure 6 and table 4, we can see that engineering development of brain-inspired intelligence domain in the past three years has mainly concentrated on branches of G06N (computer system based on specific models), G06F (electric digital data processing), A61B (diagnostics; surgery; appraisal), G06K (data identification; data representation; record carrier; record carrier processing), H01L (semiconductor device; electro-solid-state device), etc. It shows that brain-inspired intelligence related technology mainly involves in the domains of component, computer, data processing, and biomedicine, which is consistent with the current status of engineering development in brain-inspired intelligence domain.

3.3. Major Countries/Regions Analysis

3.3.1. Country/Region Distribution Analysis. In order to understand the R&D competition situation of brain-inspired intelligence, we statistically analyzed the country/region distribution of relevant papers. The results are shown in figure 7 and table 5. As we can see, from 2017 to 2019 publication year, the top 10 countries/regions of SCI paper output in brain-inspired intelligence domain are the United States, China, the United Kingdom, Germany, South Korea, Italy, Canada, Australia, Japan, and France. Among them, the number of papers from China and the United States respectively accounted for 33.3% and 20.4% of the total number. They account for more than half of the SCI paper output together. This indicates that the United States and China are top 2 countries with the highest research interest in brain-inspired intelligence. We analyzed statistically the country/region distribution of relevant patents as well. The result is shown in figure 8. From 2017 to 2019 year, there were 2124 patent published in brain-inspired intelligence domain. Among them, the number of Chinese patents reaches 925, accounting for 43.52% of the total number of the global patents. It reveals that China is the backbone of patent output in brain-inspired intelligence. Other countries with superior output of patents include the United States (575), South Korea (125), and China Taiwan (37).

By Summarizing the country/region distribution of R&D, it can be discovered that China and the United States dominate in brain-inspired intelligence, with fewer countries in the middle and a large number of countries in the tail. Explained that brain-inspired intelligence is a cutting-edge technology, and research is concentrated on the major scientific and technological countries such as China, the United States, and South Korea.

![Figure 6. Composition of major patent branches in brain-inspired intelligence (2017-2019).](image-url)
Table 4. Main patent branches in brain-inspired intelligence field.

| IPC Number | Patent quantity | Main branch                                                                 | Patent quantity |
|------------|-----------------|-----------------------------------------------------------------------------|-----------------|
| G06N       | 988             | (Computer system based on specific model)                                   |                 |
|            |                 | G06N3/063 (Using electricity)                                               | 516             |
|            |                 | G06N3/04 (Architecture, for example, interconnect topology)                  | 406             |
|            |                 | G06N3/08 (Learning algorithm)                                                |                 |
|            |                 | G06N3/06 (Physical implementation, i.e. hardware implementation of neural networks, neurons or neuron parts) | 297             |
|            |                 | G06N3/02 (Using neural network model)                                        | 268             |
|            |                 | G06F3/01 (Input device or input and output combination device for interaction between user and computer) |               |
|            |                 | G06F9/30 (Designs related to the execution of machine instructions, such as instruction decoding) | 72              |
| G06F       | 650             | (Electric digital data processing)                                          |                 |
|            |                 | G06F17/30 (Information retrieval; database structure; file system structure) | 33              |
|            |                 | G06F17/27 (Automatic analysis, such as grammatical analysis, orthorectification) | 21              |
|            |                 | G06F17/16 (calculated by matrix or vector)                                   | 20              |
|            |                 | G06F17/50 (Computer Aided Design)                                            | 20              |
|            |                 | G06F9/50 (resource allocation, for example, of central processing unit [CPU]) | 16              |
| A61B       | 285             | (diagnosis; surgery; identification)                                        |                 |
|            |                 | A61B5/00 (measurement for diagnostic purposes; human identification)         | 123             |
|            |                 | A61B5/0476 (electroencephalography)                                         | 100             |
|            |                 | A61B5/04 (Measurement of bioelectric signals of human body or various parts of human body) | 82              |
|            |                 | A61B5/0484 (using induced response)                                          | 40              |
|            |                 | A61B5/0478 (electrodes specifically for electroencephalography)             | 38              |
| G06K       | 243             | (data identification; data representation; record carrier; record carrier processing) | 175             |
| H01L       | 146             | (semiconductor device; electric solid device)                               |                 |
|            |                 | H01L27/24 (including solid components for rectification, amplification, or switching without potential jump barriers or surface barriers) | 129             |
|            |                 | H01L29/78 (field effect produced by insulated gate)                         | 50              |
|            |                 | H01L43/08 (resistor for magnetic field control)                             | 15              |
3.3.2. \textit{R&D Trend of the Major Countries/Regions.} In order to understand the R&D trend of the major countries in brain-inspired intelligence field, the papers/patents from the major countries were analyzed statistically by publication year. The statistical results are plot in figures 9 and 10. From figure 9, we can see that the number of published papers in brain-inspired intelligence increases gradually, and the growth rate has accelerated in recent years. The United States and the United Kingdom started research earlier in brain-inspired intelligence, and the theoretical research strength of the United States always ranks first in the whole world. The number of Chinese SCI papers surpassed that of the United Kingdom in publication year of 2014 and became the second largest country in the study of brain-inspired intelligence theory. From figure 10, US patents involved in brain-inspired intelligence have emerged around 2000, while other countries have few related patents. Before publication year of 2016, the United States were a leader in R&D of brain-inspired intelligence. In publication year of 2016, the number of Chinese patents (262) exceeded that of the United States (252), ranking first.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{image1.png}
\caption{Country/region distribution of SCI paper output in brain-inspired intelligence (2017-2019).}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{image2.png}
\caption{Country/region distribution of patent output related to brain-inspired intelligence (2017-2019).}
\end{figure}
3.3.3. Paper Citations of the Major Countries/Regions. The proportion of the world’s paper output, the total citation, the average citation and the number of high citing papers represent the depth and quality of research to a certain extent. The aforementioned indicators of top 10 countries/regions with greatest SCI paper output are list in table 5. As can be seen in table 5, the average citation for the United States is 6.94, which is much higher than other countries. The total citation and the number of high citing papers are the greatest. It indicates that the United States has higher quality of papers and has great influence in basic theoretical research of brain-inspired intelligence.

3.3.4. International Technology Output. It is generally believed that the patents applied for protection of the Patent Cooperation Treaty (PCT) usually involves the applicant’s key R&D technology, and has high technical application value. At the same time, applying for protection of PCT generally means applying for patent protection in country member of PCT, thus PCT application can be considered as one of the indicators of measuring technology output. To get the technology output indicator of major countries/regions, this paper makes statistics on PCT applications related to brain-inspired intelligence domain. The result is shown in figure 11. From figure 11, we can see that PCT applications mainly concentrated in the United States, China, and the United Kingdom, their applications accounted for 54.33%, 16.14% and 10.24% of the global applications, respectively. It indicates that the United States is superior in the international technology output of brain-inspired intelligence domain, and the
technical application value of its patents is high. Although China has been active in the research of brain-inspired intelligence domain in recent years and the patent output grows rapidly, the number of PCT applications is relatively small. China needs to strengthen the international layout of patent in brain-inspired intelligence domain.

Table 5. Top 10 countries/regions of SCI paper output in brain-inspired intelligence (2017-2019).

| Country/Region | Paper Output | Output proportion | Number of high citing papers | Average Citation | Total Citation |
|----------------|--------------|-------------------|------------------------------|-----------------|---------------|
| USA            | 2039         | 33.344            | 55                           | 6.94            | 14192         |
| China          | 1249         | 20.409            | 23                           | 5.68            | 7089          |
| United Kingdom | 576          | 9.730             | 13                           | 6.95            | 4002          |
| Germany        | 544          | 8.88              | 6                            | 5.67            | 3085          |
| South Korea    | 402          | 6.574             | 6                            | 6.08            | 2444          |
| Italy          | 341          | 5.576             | 6                            | 5.53            | 1885          |
| Canada         | 279          | 4.563             | 3                            | 5.05            | 1408          |
| Australia      | 278          | 4.546             | 2                            | 4.92            | 1367          |
| Japan          | 267          | 4.366             | 9                            | 6.51            | 1739          |
| France         | 263          | 4.301             | 6                            | 6.95            | 1827          |

3.3.5. International Cooperation. In order to understand cooperation situation in the basic research of brain-inspired intelligence, we constructed a data set with the SCI papers of the top 50 countries with the greatest output, and then conducted a statistical analysis on cooperation among the top 50 countries/regions and drawn the national cooperation network by VOSviewer software. The result is shown in figure 12. In the collaboration network, the size of a country’s node indicates its cooperation strength with the rest countries, and the thickness of the edge represents its cooperation frequency with specific country. From figure 12, we can see that the cooperation network among major countries is very complex, and China and the United States have the most centralized networks and connect to most of the rest countries. It is easy to draw that China and the United States have carried out extensive international exchange and cooperation, and their collaborative research in the brain-inspired intelligence domain shows stronger leading role.

3.4. Major Institutions Analysis

The paper output, the total citation, the average citation and the number of high citing papers of a specific institution represent the depth and quality of its research to some certain extent. The aforementioned indicators of top 20 institutions with greatest SCI paper output are list in table 6. Among the top 20 institutions, we can see from table 6, 10 institutions come from the United States, 3 institutions come from China, 2 institutions are from the United Kingdom, and the institution numbers of France, Germany, Singapore, Switzerland, and South Korea are all 1. The number of US institutions is superior to the rest countries. From table 6, we find that universities are the main powers in basic theoretical research of brain-inspired intelligence. From the perspective of the research quality, we can see that the average citations of Stanford University, Nanyang Technological University, Tsinghua University, University College London, Max Planck Society, Harvard Medical School are the greatest. University of California, Stanford University, Chinese Academy of Sciences, Tsinghua University, and French National Research Centre have greater number of high cited papers, and they show that the research quality of brain-inspired intelligence at the University of California, Stanford University, and Tsinghua University is higher. The research topics of SCI papers in brain-inspired intelligence domain
mainly include brain-computer interface, neuromorphic computing, neural interface, artificial synapse, neural component, and brain operation mechanism.

Figure 11. Country/Region distribution of PCT applications in brain-inspired intelligence (2017-2019).

Figure 12. Collaboration network among the major countries in brain-inspired intelligence.

In order to understand cooperation situation among institution in the basic research of brain-inspired intelligence, we constructed a data set with the SCI papers of the top 50 institutions with the greatest output as well. Subsequently, we conducted a statistical analysis on cooperation among the top 50 institutions and drawn the institution cooperation network by VOSviewer software. The result is shown in figure 13. From figure 13, we can see that the institutional cooperation network is intricate, which indicates that there are more exchanges between institutions in the research of brain-
inspired intelligence and the frequency is very high. Among the top 50 institutions, the centrality
degrees of Chinese Academy of Sciences and Stanford University are relatively larger. This shows
that they value the exchanges and the cooperation with other domestic/foreign institutions.

**Table 6.** Top 20 institutions of SCI paper output in brain-inspired intelligence (2017-2019).

| Institution                                      | Country        | Paper Output | High cited papers | Average Citations | Citations | Research Topics                                                                 |
|-------------------------------------------------|----------------|--------------|-------------------|-------------------|-----------|---------------------------------------------------------------------------------|
| University of California                        | USA            | 297          | 9                 | 6.33              | 1880      | Brain-computer interface, memory hardware, cerebral cortex, EEG signal, neurons  |
| Chinese Academy of Sciences                     | China          | 226          | 5                 | 6.83              | 1544      | Memory, synaptic plasticity, brain-computer interface, memristor, neural components |
| CNRS                                             | France         | 147          | 4                 | 7.86              | 1155      | Brain-computer interface, EEG signal, operating mechanism, classification, movement representation |
| The Pennsylvania State University                | USA            | 116          | 0                 | 5.22              | 605       | Brain-computer interface, neuron, plasticity, classification, attention          |
| Harvard University                               | USA            | 115          | 2                 | 6.88              | 791       | Brain-computer interface, brain, communication, cortical motor area, cortical control, neural interface |
| University of London                            | UK             | 113          | 3                 | 7.83              | 885       | Brain-computer interface, information communication, cognition, decision-making, EEG signal |
| Stanford University                              | USA            | 101          | 7                 | 13.7              | 1384      | Brain-computer interface, cortical motor area, cortical control, network, adaptability |
| University of California, San Diego             | USA            | 97           | 2                 | 7.08              | 687       | Brain-computer interface, EEG signals, neurons, classification, model            |
| Chinese Academy of Sciences University          | USA            | 92           | 0                 | 4.55              | 419       | Memory, memristor, brain, synaptic plasticity, artificial synapse                |
| Tsinghua University                             | China          | 90           | 4                 | 9.37              | 843       | Memory, brain-computer interface, memristor, neural mimic computing, device      |
| University of Pittsburgh                        | USA            | 89           | 0                 | 5.74              | 511       | Brain-computer interface, neuron, performance, system, classification           |
| University College London                       | UK             | 81           | 2                 | 9.32              | 755       | Brain mechanism, communication, decision-making, brain-computer interface, neurons |
| University of Seoul                             | South Korea    | 75           | 0                 | 5.12              | 384       | Neuromorphology, synaptic device, neuromorphic system, pattern recognition, memory |
| Harvard Medical School                          | USA            | 73           | 2                 | 8.16              | 596       | Brain-computer interface, communication, cortical motor area, cortical control, brain |
| University of Texas                             | USA            | 73           | 1                 | 7.19              | 525       | Neural interface, brain-computer interface, stimulation, brain tissue, cerebral cortex |
To some certain extent, the patent output and the number of transferred patents in some specific institution represent the depth and quality of its R&D. The R&D indicators of TOP 20 institutions are list in table 7. Table 7 shows that most of the top 20 organizations with greatest output come from China (12), and 5 institutions are from US, 2 institutions from South Korea, and 1 institution comes from Germany. It reflects that China poses superior development ability of brain-inspired intelligence in recent years. Development topics of the top 20 institutions mainly focus on brain-computer interfaces, artificial nerve synapses, neural network chips, morphological operations, attention mechanisms, etc. Among top 20 institutions, 9 Chinese institutions are colleges and universities and the rest three Chinese institutions are enterprises.

It shows that the core technologies of brain-inspired intelligence in China are mainly concentrated in universities, and the R&D capability of enterprise is very weak. China have advantage in the number of patent output, but it had few transferred patents. In contrast to Chinese institutions, the institutions from the United States, South Korea, and Germany are all well-known technology companies, such as IBM, Intel, Samsung, Hynix, Google, HRL, Syntiant, Audi. They have considerable number of transferred patents. It shows that the United States, South Korea, and Germany are more successful in industry application. Therefore, Chinese institutions need to promote
the commercial application of patents and strive to increase the number of patent applications if they want to have advantages in international market competition.

| Institution | Country | Patent output | Number of transferred patents | Core branch | Development Topics |
|-------------|---------|---------------|-------------------------------|-------------|--------------------|
| IBM Corp.   | USA     | 156           | 109                           | G06N,G06F,H04L,H01L,G11C | Instruction scheduler, resistance memory, video capture, neuron circuit, ferroelectric layer |
| Shanghai Cambrian Information Technology Co., Ltd. | China | 67 | 0 | G06N,G06F,G06K,G06Q,G10L | Vector norm, operation instruction, data operation, neural network model |
| Intel Corp. | USA     | 48            | 13                            | G06N,G06F,G06T,G11C,H03M | Neural network technology, flow control, neural processor, artificial neuron |
| Samsung Electronics Co., Ltd. | South Korea | 36 | 18 | G06N,H01L,G11C,G06F,H03K | Neural network recognition; non-volatile memory; artificial neuron; electronic processor; morphological calculation |
| Beijing Guangnian Infinite Technology Co., Ltd. | China | 33 | 19 | G06F,G06K,G06N,B25J,G06T | Human-computer interaction, natural language understanding, emotional computing, intelligent robots |
| Hynix Corp. | South Korea | 32 | 19 | G06N,H01L,G11C,H03K,C01B | Inverter circuit, nerve synapse, carbon nanotube, convolutional neural network, memristor |
| Xi’an Jiaotong University | China | 32 | 0 | G06F,A61B,G06K,C12N,G06N | Steady-state visual evoked potential, virtual reality technology, EEG signal classification, dynamic adaptation, brain-computer interface |
| Tianjin University | China | 31 | 0 | G06F,G06K,A61B,G06N,A61N | Brain-computer interface, pattern recognition, EEG data, mind control, reconstruction control method |
| Google Inc. | USA | 29 | 6 | G06N,G06F,G10L | Neural network computing, neural network chip, computing system, memory, computer implementation |
| Beijing Zhongke Cambrian Technology Co., Ltd. | China | 29 | 0 | G06N,G06K,G06F,H04N | Neural network computing, neural network chip, machine learning, neural reflex, control system |
| HRL Laboratories LLC. | USA | 28 | 11 | G06N,G06K,G06F,H04B,G01R | Convolutional neural network, brain-computer interface, pattern recognition, morphology, neural network chip |
| Tsinghua University | China | 24 | 2 | G06N,G06F,A61B,G11C,B25J | Brain-computer interface, cerebral cortex, strategy control, neural network core, non-volatile memory |
| Institution | Country | H01L, G06N, G066, G06F, A61B | Area |
|-------------|---------|----------------------------|------|
| Nanjing University of Posts and Telecommunications | China | Brain-computer interface, memristor, neural network, EEG signal, neuron circuit |
| Syntiant Corp. | USA | Artificial neural networks, morphological operations, integrated circuits, support vector machine |
| Peking University | China | Neural network computing, neural network chip, target recognition, chat robot, artificial neuron |
| Institute of Computing Technology, Chinese Academy of Sciences | China | Brain-computer interface, neural network chip, neuron calculation, visual evoked potential, neural network algorithm |
| University of Electronic Science and Technology of China | China | Image data, morphological operation, neural reflex, vector engine, neural reflex |
| Institute of Automation, Chinese Academy of Sciences | China | Convolutional neural network, brain-computer interface, natural language understanding, visual positioning, visual positioning |

4. Conclusion
This paper employs method of scientometrics and visualization to evaluate R&D situation, identify R&D hotspots, and analyze major country/region distribution and the great-output institutions in brain-inspired intelligence domain, and offers a comprehensive scientometrics review. Some conclusions are drawn in this paper.

(1) China, the United States, UK, Germany and South Korea are the main R&D forces in brain-inspired intelligence domain, and always maintain a high degree of research interest. The United States is a strong leader in both the R&D effort and the R&D depth.

(2) From the analysis on keywords and hotspots, it is easily drawn that the researchers focus mainly on brain-computer interface, neuromorphic device, neuromorphic computing, and brain operation mechanism in recent years. The R&D forces concentrate on the directions of G06N (computer system based on specific models), G06F (electric digital data processing), A61B (diagnostics; surgery; appraisal), G06K (data identification; data representation; record carrier; record carrier processing), H01L (semiconductor device; electro-solid-state device).

(3) Major countries/regions pay more attention on academic cooperation and exchanges in brain-inspired intelligence. It shows that major countries are aware of the importance of academic cooperation and exchanges to promote the development of brain-inspired intelligence.
(4) The number of SCI paper output by American researchers ranks first in the worldwide, America is also superior in aspects of average citation, total citation and number of high citing papers. It shows that America is leading in the basic research of brain-inspired intelligence.

(5) China has the largest number of patent output in the worldwide, but China is significantly lower than European and American countries in number of transferred patents and PCT patents. It shows that the relevant patents in China still have a big gap with the European and American countries in terms of industrial application.

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