

Bibliometric Analysis of International Research Situation of BCI Based on SCI Papers

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Abstract: In recent years, the research of brain computer interface has developed rapidly and its application has been expanding. This paper uses bibliometrics to analyze the global brain computer interface literature, and reveal the macroscopic situation of brain computer interface research from the overall situation, high-frequency keyword analysis, important literature and other aspects.

1. Introduction

Brain-Computer Interface (BCI) aims to achieve the technology of information interaction and function integration between neural system and external devices by establishing a direct connection path between human brain nerves and external devices (such as computers, robots, etc.). It is a computer-based system that can acquire and analyze brain signals in real time and convert them into output commands to realize the control of external devices [1-2]. Since 1973, Jacques Vidal published the first article on brain computer interface based on EEG signal, and first proposed the concept of BCI [3]. With the continuous development of neuroscience, computer science, sensor technology, material science and other technologies, BCI technology has become mature increasingly, and its application field has been expanded from the initial medical rehabilitation to all aspects, and caused a wide concern in the whole world. For example, DARPA issued the "Next generation non-surgical neurotechnology" (N3) project request in March 2018, aiming to develop a high-resolution non-surgical bidirectional neural interface, and it can read and write signals to the brain [4]. In July 2016, Elon Musk, the founder of Tesla, invested and founded Neurolink, a brain computer interface company for neural prosthesis applications and future human-computer communication. European Union, Japan, China and other governments also released relevant research plans. In order to further understand the current situation of brain computer interface research, analyze the current situation of brain computer interface research scientifically, and benefit the future research, this paper will use bibliometric analysis method to research and analyze the general situation and research topics of brain computer interface field.

2. Data Sources and Methods

2.1 Date Source

The data of this paper is from Science Citation Index Expanded (SCIE) database of Clarivate Analytics company, through the keyword retrieval strategy of brain computer interface, relevant research papers are searched in the database. The selected literature types include article, review and proceedings paper, and 5142 research papers have been obtained up to 2018.

2.2 Research Method

Bibliometric analysis is a method to understand the research status and development trend of the research field from a macro perspective [5]. From the perspective of literature statistics and summary of research trends, core institutions, research hot spots, etc., we can quickly understand the overall situation of research in this field, and provide a macro reference for the future research work. The analysis tools used in this study are: WOS platform, InCites database, CiteSpace

software.

3. Analysis of the Overall Situation of Brain Computer Interface Research

3.1 Annual Change Trend of the Number of Research Paper

According to the results of SCI retrieval, the number of papers published by BCI was less than 100 before 2007; the growth trend of the annual circulation is obvious, showing a rapid growth trend since 2008; and it began to enter a rapid growth period since 2011.

In the past decade, BCI theory and technology have made great progress, benefiting from the rapid development of neuroscience, cognitive science, computer science and control science.

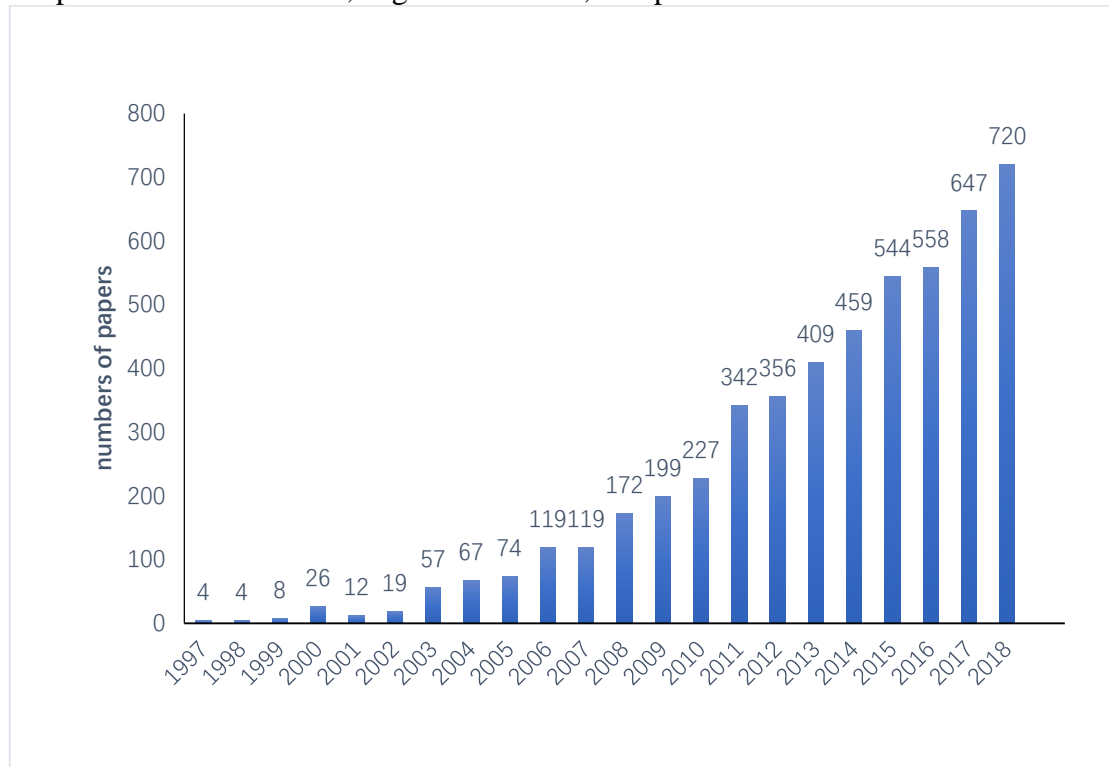


Figure 1 The chronological distribution of BCI paper output.

3.2 Comparison of Paper Output in Major Countries

A total of 85 countries / regions around the world have conducted BCI related research, and the top 15 countries with the largest number of publications are USA, CHINA MAINLAND, GERMANY, UNITED KINGDOM, JAPAN, ITALY, SOUTH KOREA, SPAIN, CANADA, AUSTRIA, FRANCE, SWITZERLAND, NETHERLANDS, CHINESE TAIWAN, AUSTRALIA, which is shown in Table 1. The United States has a very significant advantage in BCI research, accounting for 33.5% of the number of papers in the world; the total cited frequency is twice that of China, which ranks the second; and international cooperation is the largest.

Among the 15 countries, Australia and Germany are cited the most frequently, while Italy and Switzerland have the best share of international cooperation papers. Compared with other 15 countries, China's research output scale and influence are good, but it has a poor-performance in international cooperation.

Table 1 Top 15 countries/regions in BCI.

Country/ region	Numbers of papers	Times cited	Cites/ papers	International Collaborations	International Collaborations (%)
USA	1722	84712	49.19396	644	37.39837
CHINA MAINLAND	720	15179	21.08194	258	35.83333

GERMANY	711	41788	58.77356	464	65.2602
UNITED KINGDOM	395	11159	28.25063	262	66.32911
JAPAN	348	6949	19.96839	146	41.95402
ITALY	321	17449	54.35826	233	72.58567
SOUTH KOREA	293	6854	23.39249	122	41.63823
SPAIN	246	6046	24.57724	136	55.28455
CANADA	231	6540	28.31169	107	46.32035
AUSTRIA	227	19942	87.85022	142	62.55507
FRANCE	204	8203	40.21078	106	51.96078
SWITZERLAND	167	7738	46.33533	121	72.45509
NETHERLANDS	152	5214	34.30263	88	57.89474
CHINESE TAIWAN	139	2435	17.51799	36	25.89928
AUSTRALIA	120	2832	23.6	71	59.16667

3.3 Research Institution

There are 1689 institutions around the world that have conducted BCI related research, including 387 institutions in the United States, 161 in China, 90 in Japan, 78 in Italy, 77 in France, 75 in South Korea, 65 in Germany and 61 in Spain. It shows that the U.S. has the largest research investment in this field and has obvious advantages. The institutions with the highest volume of papers are University of California System, Eberhard Karls University of Tübingen, EBERHARD KARLS UNIVERSITY HOSPITAL, Graz University of Technology, etc.

The top 20 institutions in the world of the volume of BCI research publications are shown in Table 2. Among these 20 institutions, there are 10 in the United States, 4 in Germany, and 1 each in Australia, France, Japan, China, and Switzerland.

4. High Frequency Keyword Analysis

CiteSpace software is used to make statistics and Analysis on keyword fields of papers in brain computer interface field, and the high frequency keyword distribution is shown in Figure 2. Among them, the circle size indicates the frequency of keyword occurrence, and the line thickness between circles indicates the strength of co-occurrence relationship between keywords. From the keyword analysis of BCI literature, the current brain computer interface research is mostly non implanted, mainly focused on the recognition and processing of EEG signals, including P300, motor imaging, etc.

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5. High Cited Papers

Cited frequency is an important index used to measure the academic influence of academic papers in bibliometrics. The h index of papers in the field of brain computer interface is 179, 25 papers have been cited more than 500 times, and 6 papers have been cited more than 1000 times. The top 10 cited papers are shown in Table 3.

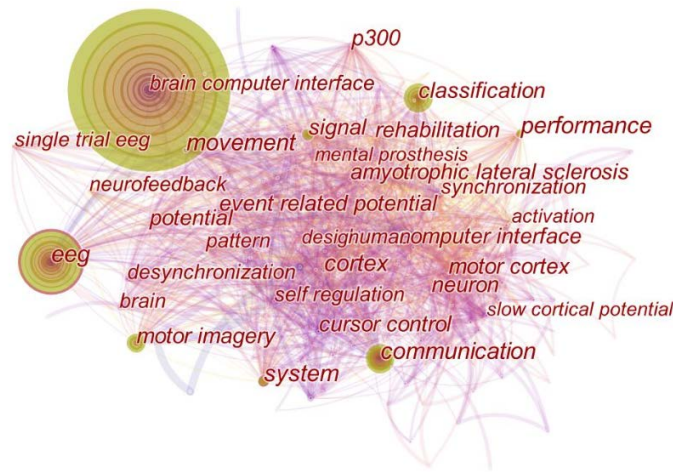


Figure 2 The distribution of high frequency keywords

The most cited paper is a review titled "Brain-computer interfaces for communication and control" published by Wolpaw, JR, etc. of Wadsworth Center in 2002, published in CLINICAL NEUROPHYSIOLOGY. In this paper, the brain-computer interface technology, its research progress and application are discussed. It was cited 99 times from June to December 2019, indicating that this paper is still has a high influence 17 years after its publication.

Table 3 The 10 papers with the highest citation frequency in the field of BCI.

Title	Author	Main work unit	Cited frequency
Brain-computer interfaces for communication and control	Wolpaw, JR, etc.	New York State Dept Hlth, Wadsworth Ctr, Lab Nervous Syst Disorders	3948
Neuronal ensemble control of prosthetic devices by a human with tetraplegia	Hochberg, Leigh R.; Donoghue, John P, etc.	Brown Univ, Dept Neurosci,	1872
Beyond mind-reading: multi-voxel pattern analysis of fMRI data	Norman, Kenneth A, etc.	Princeton Univ, Dept Psychol	1239
A review of classification algorithms for EEG-based brain-computer interfaces	Lotte, F, etc.	INRIA Rennes	1240
BCI2000: A general-purpose, brain-computer interface (BCI) system	Schalk, G, etc.	New York State Dept Hlth, Wadsworth Ctr, Lab Nervous Syst Disorders	1158
Optimal spatial filtering of single trial EEG during imagined hand movement	Ramoser H, etc.	Graz Univ Technol, Inst Biomed Engn, Dept Med Informat	1171
Brain-computer interface technology: A review of the first international meeting	Wolpaw, JR, etc.	New York State Dept Hlth, Wadsworth Ctr, Lab Nervous Syst Disorders, Albany, NY 12201 USA	1044
Cortical control of a prosthetic arm for self-feeding	Velliste, Meel; Schwartz, Andrew B, etc.	Univ Pittsburgh, Sch Med, Dept Neurobiol, E1440 BST, Lothrop St, Pittsburgh, PA 15213 USA.	961
Optimizing spatial filters for robust EEG single-trial analysis	Blankertz, Benjamin, etc.	Tech Univ, Berlin, Germany.	953
Brain-machine interfaces: past, present and future	Lebedev, Mikhail A.; Nicolelis, Miguel A. L.	Duke Univ, Dept Biomed Engn, Durham, NC 27710 USA	900

6. Conclusion

BCI is an interdisciplinary subject involving neuroscience, psychology, computer science, biomedical engineering, mathematics, clinical medicine, signal detection, signal processing. Through the econometric analysis of BCI literature, we can see that BCI research has increased significantly in 2003, 2008 and 2011, and has entered a rapid growth stage since 2011. The U.S. has obvious advantages in BCI research, in terms of the number and strength of research institutions, the number and quality of paper output. At present, the research of global BCI is mainly non-implantable, focusing on the recognition and processing of EEG signals. There is still a lot of space for future BCI research, especially for its application. This field is still very young. With the development of computer technology, neuroscience, material science and other disciplines, BCI technology will become more and more mature.

References

- [1] McFarlandDJ, WolpawJR. Brain-computerinterfaceuseisa skill that user and system acquire together [J]. PLoS Biology, 2018, 16(7):e2006719.
- [2] Wolpaw J.R., Birbaumer N., Mc Farland D.J., et al., Brain-computer interfaces for communication and control[J]. Clinical Neurophysiology, 2002, 113 (6): 767–791.
- [3] Vidal, Jacques J., Real-time detection of brain events in EEG [J]. Proceedings of the IEEE, 1977, 65 (5): 633–641.
- [4] Nonsurgical neural interfaces could significantly expand use of neurotechnology [EB/OL]. (2018-03-16). <https://www.darpa.mil/news-events/2018-03-16>.
- [5] JunPing Qiu, Bibliometrics [M]. Scientific and Technical Literature Publishing house, 1988. (In Chinese)