Research Hotspot and Evolution Analysis of ECG from the Perspective of Knowledge Map

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Abstract. In this paper, knowledge mapping technology is used to analyze the relevant literature of ECG research in China, and the research status, research hotspot and trend in this field are statistically analyzed. CiteSpace V is used to carry out data visualization analysis on the literature retrieved from CNKI database. Through the analysis, we can see that the research of ECG based disease diagnosis has achieved sustainable development in recent years, but the high influential authors pay less attention to the research in this field. The core of the research is mainly focused on wavelet transform, feature extraction, classification and recognition, and the research strength in this field still needs to be strengthened.

1. Introduction
According to the statistics of the World Health Organization, the death toll caused by cardiovascular disease (CVD, also known as circulatory system disease) is up to 17 million worldwide every year, accounting for 1/3 of the total death toll in the world [2]. In China, cardiovascular disease is a serious threat to people's health. According to the report of China cardiovascular disease report (2018), China's cardiovascular disease shows a trend of prevalence. It is estimated that there are 290 million people suffering from cardiovascular disease, including 13 million stroke, 11 million coronary heart disease, 5 million pulmonary heart disease, 4.5 million heart failure, 2.5 million rheumatic heart disease, 2 million congenital heart disease and 245 million hypertension. Among them, cardiovascular disease mortality still ranks first. In 1884, German neurophysiologist Emile discovered the electrical activity of the heart, which started the research of ECG signal; in 1887, British physiology Professor Waller recorded the fluctuation of ECG with capillary electrostatic agent; in 1903, Dutch physiologist Hofen developed the first string electrocardiograph, which used the ammeter to receive the signal on the surface of human body to describe the ECG Recorded on the photographic film, this method produced a great sensation in the medical field at that time after the first clinical application in rescuing patients; after 1961, with the wide use of dynamic electrocardiogram, medical experts all over the world combined the two fields of computer and medicine to study the ECG recognition and classification technology. Electrocardiography (ECG) is a kind of medical technology that records the electrophysiological activities of the heart in time and records them by electrodes. ECG contains a lot of pathological and physiological information, which is an important basis for detecting human heart disease. It can show the health of human heart. According to the signal waveform of patients' ECG, doctors can make targeted treatment. However, a large number of ECG data will increase the workload of doctors, and the experience level of doctors will also affect the results of arrhythmia analysis.
2. Research Methods and Data Sources

2.1. Data Sources
In this paper, CiteSpaceV knowledge map software is used to analyze the knowledge map of CNKI database "ECG signal" and "ECG recognition". The data is based on the published papers with the theme of "ECG signal recognition" and "ECG recognition". The time span is 1996-2019 (up to December 2019), which more comprehensively reflects the development of ECG recognition Situation and research trend. Through data screening, the irrelevant literature such as reviews, reviews, reports, etc. were eliminated, and 316 papers on the subject of "ECG signal" and "ECG recognition" were obtained.

2.2. Research Method
In this paper, CiteSpaceV knowledge map software is used to study the data of ECG related topics. Based on the method of word co-occurrence, the frequency of keywords appearing in the same group of documents is statistically analyzed, so as to judge the close degree of relationship between documents, and also reflect the co-occurrence frequency of the relationship between author cooperation and organization cooperation. CiteSpaceV, a knowledge map analysis tool, is a scientific document analysis tool jointly developed by Dr. Chen Chaomei and Dalian University of technology. It can classify, summarize and statistically analyze the documents in specific fields, and analyze the research hotspot and research trend in the field intuitively by drawing. CiteSpace software reflects the core authors, institutions, journals and high-frequency citations and other information in specific fields through the historical research on the published literature included in CNKI database and CSSCI database. In recent years, CiteSpace software has been widely used in the research of knowledge map in various fields [3].

3. Analysis of the Characteristics of ECG Signal Research Literature

3.1. Annual Analysis of Published Quantity
The research on ECG signal recognition technology can be traced back to the 1980s. In 1982, mark et al. introduced the construction of MIT-BIH arrhythmia database for the first time. Since then, the research work of arrhythmia recognition based on ECG signal has been carried out in succession at home and abroad. The annual distribution chart of the number of papers published with ECG signal recognition as the research content is shown in Figure 1. From Figure 1, it can be found that the number of papers in this field has an overall upward trend during 1996-2019. Relevant research has been carried out in 2004-2005, 2006-2009, 2012-2018 There has been a certain trend of growth. Since 1979, with the increasing research on ECG signal, a set of standard process has been formed for the research of ECG signal, including signal pre-processing, sample feature selection and classification model selection and optimization [3-23].

![Figure 1. Annual statistics of number of literature published](image-url)
3.2. Analysis of the Author

Based on the knowledge map analysis of the authors of 316 papers, it can be clearly seen in Figure 2 that the representative co-authors in the field of ECG research include Zhang Haihong, Wang Zhizhong, Cai Liyu, Zhang Kun [20-27], etc. The communication and cooperation among the author groups can reflect the dissemination and exchange of academic achievements. Effective communication and cooperation play an important role in promoting the development and progress of the discipline. However, the density of the cooperation network of the authors in this field is low, and there are few nodes in the cooperation network, which leads to the lack of a high cohesive cooperation group in this field. ECG signal recognition research academic exchanges and achievements sharing in this field continue to be further enhanced.

![Figure 2. Cooperation network of authors](image)

On the other hand, through the statistics of high cited authors, we can analyze the high cited authors in the field of ECG research. Due to the limited number of papers published on the subject of ECG recognition, it is impossible to get better high cited visualization results. As shown in Table 1, most of the high cited authors in this field rank top by virtue of a high cited paper, and most of the articles written by these authors are before 2012, which shows that the follow-up research in this field still needs to be deepened, and the research on ECG signal recognition analysis has not formed a certain research system.
Table 1. High cited authors of ECG research

| Paper                                                                 | Author      | Time | Citation times |
|----------------------------------------------------------------------|-------------|------|----------------|
| EEG signal recognition method based on wavelet packet Transform and clustering analysis | Baoguo Xu   | 2009 | 73             |
| Research and Implementation of Wearable System for Physiological Parameters Monitoring | Wei Guo     | 2012 | 69             |
| EEG signal recognition method based on improved CSP algorithm A Surface EMG Signal Identification Method Based on Short-time Fourier Transform | Mingai Li   | 2009 | 66             |
| Recognition algorithm and program design of QRS wave in ECG          | Zhizhong Wang | 2000 | 66             |
| A Wearable Mobilehealth Care System Supporting Real-time Diagnosis and Alarm monitoring | Jiewen Zheng | 2008 | 62             |
| Surface EMG Signal Classification Method Based on Wavelet Transform  | Liyu Cai    | 2000 | 59             |
| The Study on the Key Technology of ECG Signal Intelligent Analysis | Cheng Yao   | 2012 | 58             |
| The Algorithms Research of ECG Signals Intelligent Detection & Analysis for Mobile Cardiac Telemonitoring System | Lingyun Zhu | 2003 | 54             |

3.3. Analysis of Research Institutions

It can be seen from Figure 3 that there is cooperation in this field. However, the research institutions in the field of ECG signal research have the same problems as the authors. From the figure, we can see that the density of cooperation network in this field is also low, the cooperation between research institutions needs to be further improved, and no systematic research results have been formed in this field.

Figure 3. Analysis of cooperation network of research institutions

On the other hand, through the statistics of the number of papers issued by the research institutions, we can analyze that the main research institutions in the field of ECG signal research are Hangzhou University of Electronic Science and Technology (23 articles), Jilin University (16 articles), Zhejiang
University (16 articles), Tianjin University of Technology (13 articles), Harbin University of Technology (12 articles), Chongqing University (11 articles), Beijing University of Posts and Telecommunications (11 articles), Shanghai Communications University (10 articles), Southwest University (10 articles). Since 2009, Hangzhou University began to study the recognition methods of EMG signals, and then studied the recognition methods of other kinds of body signals, mainly including ECG signals, eye signals, EEG signals, finger ECG signals, etc., and achieved some research results. Jilin University and Zhejiang University take ECG as the research object. At present, they mainly use neural network to realize ECG recognition by using different methods of feature extraction.

Table 2. Statistics of published quantity of research institutions (unit: article)

| Research Institute                                      | Number of published papers |
|---------------------------------------------------------|-----------------------------|
| Hangzhou University of Electronic Science and technology| 23                          |
| Jilin University                                        | 16                          |
| Zhejiang University                                     | 16                          |
| Tianjin University of Technology                        | 13                          |
| Harbin Institute of Technology                           | 12                          |
| Chongqing University                                    | 11                          |
| Beijing University of Posts and Telecommunications       | 11                          |
| Shanghai Jiaotong University                            | 10                          |
| Southwestern University                                 | 10                          |
| National University of Defense Science and technology    | 9                           |
| Shandong University                                     | 9                           |
| Chongqing University of Posts and Telecommunications     | 7                           |
| Yanshan University                                      | 6                           |
| South China University of Technology                     | 6                           |
| Guangdong University of Technology                       | 6                           |
| East China University of Science and Technology          | 6                           |
| Yunnan University                                       | 5                           |
| Zhengzhou University                                    | 5                           |
| Chongqing University of Posts and Telecommunications     | 5                           |
| University of science and technology of China            | 5                           |
| Nanjing University of Posts and Telecommunications       | 5                           |
| Lanzhou University of Technology                        | 5                           |
| Beijing University of Technology                        | 5                           |

4. Analysis of the Core Topics of ECG Signal Research

4.1. Keyword Analysis
By analyzing the key words of the literature, we can express the content of the literature clearly and directly reveal the main research content of the research topic, which lays the foundation for the hot spot and frontier in the research field. Through the co-occurrence analysis of keywords in ECG research papers, we can clearly see the distribution of high-frequency keywords in this field. Figure 4 can be obtained through statistics. It can be seen from Fig. 4 that the high-frequency keywords in the field are ECG signal, wavelet transform, feature extraction, support vector machine, etc.
Through the frequency statistics of keywords, we get the keyword frequency statistical chart as shown in the figure below. According to the chart, the higher frequency of keywords in the field of ECG research is: 108 times of ECG, 56 times of wavelet transform, 36 times of feature extraction, 34 times of support vector machine, 20 times of identity recognition and 16 times of pattern recognition.

**Table 3.** Keyword frequency statistics

| Frequency statistics | Influence factor | Publication time | Keywords                      |
|----------------------|------------------|------------------|-------------------------------|
| 108                  | 0.35             | 1986             | ECG signal                    |
| 56                   | 0.27             | 2000             | wavelet transform             |
| 36                   | 0.24             | 2009             | feature extraction            |
| 34                   | 0.35             | 2007             | Support vector machine        |
| 20                   | 0.04             | 2013             | Identity recognition          |
| 16                   | 0.11             | 2000             | pattern recognition           |
| 15                   | 0.07             | 2014             | Motor imagery                 |
| 14                   | 0.05             | 2013             | EEG signal                    |
| 12                   | 0.01             | 1997             | Classification and recognition|
| 12                   | 0.03             | 2012             | electrocardiogram             |
| 11                   | 0.00             | 2000             | neural network                |
| 11                   | 0.21             | 2007             | Brain computer interface      |
| 10                   | 0.02             | 2003             | classification                |
| 10                   | 0.01             | 2009             | Emotion recognition           |
| 9                    | 0.14             | 2017             | Deep learning                 |

**Figure 4.** Keyword analysis

**Figure 5.** Keyword frequency statistics
According to the statistical analysis of the frequency of key words in the relevant literature of ECG signal research, the research focus in this field is mainly focused on classification and recognition. In signal preprocessing, wavelet transform, EEMD method, wavelet analysis and other methods are used to denoise and form a sample set. Then, machine learning, deep learning, support vector machine and other methods are used to extract QRS of ECG signal. The wave shape feature points in the wave are used for identification, heart disease identification (arrhythmia, myocardial infarction), etc.

4.2. Research Trend Analysis

Through the analysis of keyword knowledge map of ECG research, we can understand the focus of ECG research in different historical stages. According to the analysis of keyword knowledge map in different periods, we can get the map analysis results as shown in Figure 6.

![Figure 6. Research topic analysis](image)

According to figure 6, since 1979 - In 1986, ECG signal was gradually studied in China; during 1995-2004, the classification based on ECG signal gradually appeared in the research field, and the research topics such as wavelet transform, neural network and pattern recognition gradually appeared; in 2007-2013, the research on ECG signal in China mainly focused on feature extraction, feature selection, wavelet analysis, etc., to realize the purpose. After 2014, with the increasing demand for data analysis in various industries in the era of big data, acquiring knowledge efficiently through machine learning has gradually become the main driving force for the development of machine learning technology. This kind of research mainly focuses on how to use information effectively, and how to obtain hidden, effective and understandable knowledge from huge amount of data. Therefore, since 2016, machine learning and deep learning have been gradually used for feature extraction, feature recognition and other aspects of ECG signals, especially in heart disease judgment and identity recognition. With strong learning ability of machine learning and deep learning, parallel data can be run at high speed, parameters can be corrected through a large number of training, feature values can be enhanced, and more abundant features can be described. Data information to improve the accuracy of classification and recognition.

5. Conclusion

In recent years, arrhythmia has become a great threat to people's life and health, and ECG can reflect people's health status in real time. In order to prevent and diagnose heart disease in time, it is very important to identify ECG effectively, which has great clinical application value. It is imperative to research and develop the automatic recognition technology of ECG based on machine learning and deep learning. In the future research, we can analyze and research from the aspects of network structure, parameter adjustment and model optimization, and introduce larger data set and more complex network model to further study ECG signal.
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