Research in the field of smart wearables from 2006 to 2019: a bibliometric analysis and visualization based on citespace

Tingting Guo

1.Institute of textile and clothing, Shanghai University of Engineering Sciences, Shanghai 201600, China

Abstract. Smart wearable devices have been developing rapidly in recent years. Based on the core database of Web of Science, a total of 4313 literatures from 2006 to 2019 were screened out to make a comprehensive review. Citesea was used for graph metrology analysis. The main findings are as follows: first, the most important developments occurred in China, the United States, and South Korea. China, in particular, has dominated the theory, with the most records and close cooperation with many countries or regions. Second, several universities and research institutions play important roles in collaborative networks, and the most influential central author is Zhonglin Wang. Thirdly, the research focus has changed from high concentration to diversification, and the existing research fields are extensive. Finally, through direct reference analysis, co-citation analysis and co-citation cluster evolution analysis, key literature, milestones in the history of theoretical development, research hotspots and trends are identified and visualized. Through sorting out the dynamic evolution process of knowledge cluster, this empirical study is of great significance to construct the prospect of intelligent wearable theory.

1. Introduction

Smart wearable devices have become a hot topic in recent years, especially widely used in medical field and sports field. There are a lot of scholars in this area has obtained certain research results, such as Zysset, c. et al, as early as 2012, put forward a kind of electronic technology in the textile fabric on the thread of integrating technology, flexible plastic substrate is cut into strips, used as a carrier of the electronic devices, including integrated circuits, thin film devices, interconnect and contact pads. These functional plastic stripes, called e-stripes, are woven into textiles. Conductive wires perpendicular to the e-stripes electrically interconnect devices on a single e-stripes. The integration of e-stripes and conductive threads into woven fabrics is compatible with commercial weaving processes and suitable for mass production. Zubair, m. et al. designed a health care smart bracelet based on skin conductance to detect psychological stress. The band continuously monitors the user's psychological stress and wirelessly transmits stress-related data to the user's smartphone. It not only helps users better understand their stress patterns, but also provides doctors with reliable data for better treatment; Zolyomi, a. et al. proposed A design scheme that could improve the social communication ability of intelligent and developmentally disabled patients (IDD) through intelligent wearable devices, and improve the quality of intelligent textiles to improve comfort. Also some scholars research for different types of wearable devices A periodic review, such as Betancourt, A 1997-2014 were summarized, FPV video analysis technology development, focus on the field the most commonly used features, methods, challenges and opportunities, Cheng, x. l. et al., in recent years were reviewed with enhanced physical and chemical properties and specific functions of GPEs in the progress of electrochemical energy storage, this paper mainly through the method of literature metrology research hotspot and trend in the field of wearable
system summary and thinking. Designed to provide a meaningful overview for those interested in studying smart wearables, aiming to develop a meaningful overview for scholars interested in studying smart wearable.

2. Data source and methodology

2.1 Data source
An important problem in analyzing information is to be information-rich and neutral. The data set in this paper comes from the science network (WoS), which is considered to be the most important and commonly used scientific database in many research fields. Because the WoS has strict screening mechanism, it is important to the information of global academic database. With natural science, engineering, biological medicine, social science, the authority of the arts and humanities, influential academic journals of more than 15000 kinds. According to Garfield's law of concentration of literature metrology, it only includes many disciplines and important academic papers in the field of research. Science citation index network by science citation index expanded (Sci -E) and social science citation index (SSCI), humanities and science citation index Arts & humanities citation index (A&HCI), meeting records (CPCI - S) citation index - science, meeting records citation index - social sciences & humanities (CPCI - SSH), emerging resources citation index (ESCI). Please note that there are many other database can be considered, such as Google scholar, therefore, in this article, the focus will be on the WoS.

Search the WOS database. Search terms TS = 'Smart wearable' or 'intelligent wearable', index sci-core journals, but due to resource constraints, we can only get data from 2006 to now. A total of 4,313 literature records were obtained, and the data were downloaded as full-record plain text format. The plain text information downloaded to the target file was imported into Citespace. 4224 remaining document records were deprocessed. Time partition is set from 2006 to 2019.

2.2 Research methodology
In this paper, using the method of literature metrology, the intelligent wearable were summarized. The method of literature metrology is the use of the principle of statistical method and literature metrology practice of quantitative model to indicate the forefront of scientific research. It is important to review the related literature, because the forefront of scientific research (1965) Price depends on the recent research results, therefore, scientific workers need to pay close attention to contemporary and his colleagues who work in the same field of research. The author, the country and the research institution were taken as nodes to draw the cooperative network map. After co-occurrence analysis with keywords as nodes, cluster analysis, time evolution analysis and Burst analysis were carried out. The cited literatures and cited journals were taken as nodes to draw the co-cited atlas, and the cited literatures were Burst analyzed. The correlation strength maintains the system default; Top N is selected for threshold setting. Different time partitions, threshold setting and clipping methods are selected according to the selected nodes to achieve the purpose of clear and intuitive drawing.
3. Large-scale assessment of smart wearable

3.1 Number of publications

Figure 1 shows the number of WoS publications from 2006 to 2019, including 2155 proceedings papers, 1955 articles, 208 reviews, 40 early accesses, 23 editorial materials, 10 Meeting Abstracts, 2 letters and book chapter, correction, Data paper, news item and Retracted Publication each have only one. As can be seen from the figure, from 2006 to 2013, the number of published articles kept a stable growth at a low speed. From 2014, the number of published articles increased exponentially and reached a peak of 888 articles in 2018.

3.2 Publication volume and cooperation chart of countries or regions

From figure 2 we can clearly see, the highest number in several countries are China, the United States and South Korea, China, in particular, in 1087 the number of leads, but in the mind of the highest ranked respectively, Spain, Britain, Australia, France, Germany and Italy, the higher the centrality embodies the literature for the higher the contribution in this field.

For the cooperation graph analysis of countries and regions, we obtained 67 nodes and 471 connections in cite space. The larger the font size of the country or region in the figure, the higher the centrality and the higher the contribution to the field. The denser the connection, the more cooperative the countries or regions are, and the thicker the connection, the closer the connection. We set the threshold to 50 to leave only the nodes with high impact for clearer judgment. As can be seen from figure 3, Australia, the UK, China, France and Italy are surrounded by dense connections, indicating that they have close communication with other countries or regions. At the same time, we can see that some countries such as India and Romania lack cooperation with other countries, and international academic cooperation may need to be strengthened by more and more countries or regions.
3.3 Productive institution and collaboration network

More than 280 institutions have conducted researches on the field of smart wearable. Table 1 shows the top 20 institutions in the world that have published the most papers on the methodological innovation and empirical application of smart wearable, among which Chinese Acad Sci ranks the first. Georgia Inst Technol, Tsinghua Univ, Donghua Univ, Univ by Chinese Acad Sci respectively. The top five in the top 20 universities in twelve from mainland China, a from its Hong Kong, China, three from South Korea, the United States, Italy, Singapore and Switzerland are each one. However, we can see that number and centricity is not absolute, such as Univ Chinese Acad tools. Although Sci ranked 5th with 55 articles, its centrality was zero, indicating that although the institute had done a lot of research, it had made little contribution to the field of intelligent wearable.

Table 1. Top 20 institutions in the field of smart wearables

| Institute                        | Count | Centrality |
|----------------------------------|-------|------------|
| 1 Chinese Acad Sci               | 159   | 0.17       |
| 2 Georgia Inst Technol           | 75    | 0.16       |
| 3 Tsinghua Univ                  | 57    | 0.16       |
| 4 Donghua Univ                   | 55    | 0.06       |
| 5 Univ Chinese Acad Sci          | 55    | 0         |
| 6 Nanyang Technol Univ           | 45    | 0.07       |
| 7 Korea Adv Inst Sci & Technol   | 39    | 0.07       |
| 8 Fudan Univ                     | 36    | 0.09       |
| 9 Peking Univ                    | 36    | 0.07       |
| 10 Soochow Univ                  | 34    | 0.02       |
| 11 Huazhong Univ Sci & Technol   | 34    | 0.07       |
| 12 Hong Kong Polytech Univ       | 33    | 0.02       |
| 13 Natl Univ Singapore           | 32    | 0.06       |
| 14 Swiss Fed Inst Technol        | 30    | 0.03       |
| 15 Univ Elect Sci & Technol China| 30    | 0.04       |
| 16 Yonsei Univ                   | 29    | 0.01       |
| 17 Univ Sci & Technol Beijing    | 27    | 0.02       |
| 18 Zhejiang Univ                 | 26    | 0.02       |
| 19 Univ Bologna                  | 26    | 0.02       |
| 20 Seoul Natl Univ               | 25    | 0.02       |
We will be filtered to top 50 institutions, sets the threshold to 30 frequency. Figure 4 shows the largest cluster composed of production organization. Most of them are located in China's universities. In the vast network, we can see that the three clusters, China's biggest cluster of colleges and universities. In the top left corner of the figure 3 has a smaller clusters, by CNR, Arizona State Univ of main composition and so on. In the network connecting said collaboration between nodes, the thickness of a link to express the degree of coordination between agencies node according to the size of the degree of coordination between agencies. Among them, by Chinese Acad Sci in collaborative networks play a role of bridge builders and leader. Also, you can see that in collaborative networks, some productive organization is seen as a contact, these findings suggest that some institutions may already be in the study of intelligent wearable established a stable partnership.

3.4 Author collaboration network

Co-author can share and spread of interdisciplinary knowledge, help the innovation, expand the influence of scientific research. We carried out based on the author as to the identity of the author collaboration network. Node size according to the author and other authors of the number of publications. If two nodes have joint authorship, then there will be a line between them. We get 712 nodes in cite space, 1089 wire. We set the threshold value is greater than 5, retained the 19 lead author collaboration network.
As can be seen from figure 5, the author's cooperative relationship is mainly divided into three clusters, with Zhonglin Wang, Haixia Zhang, and Wei Chen as the central distribution. In particular, Zhonglin Wang has published up to 35 articles and is closely related to other authors. His research focuses on flexible capacitor materials, which are the key factor in smart wearable devices. Haixia Wang mainly focuses on stretchable electronic devices with good elasticity, which can be used to detect the movement of different parts of the human body, and has a high impact in sustainable wearable devices, self-powered electronic skin and smart wireless sensor networks. Wei Chen mainly studies motion monitoring sensor system, which has been widely used in sports health, children detection and other fields, and has made great achievements in signal reception and processing.

4. Conclusion and future work

The results of this study show that in the past 15 years since 2006, the annual amount of research in the field of intelligent wearable has shown an explosive growth since 2014, and the research prospect of intelligent wearable is promising. The prolific author is represented by Zhonglin Wang, whose main focus is energy supply of intelligent wearable devices. High-yielding countries/institutions are Chinese universities and research institutes; The journal with the most literature and some influence is ADV MATER; In terms of research hotspot and hotspot evolution trend, the current hotspot keywords are activity classification, high sensitivity, smart e-health environment, etc., which may still be the research hotspot of smart wearable in the future, providing references for the continuity of topic selection and design.

Above results summarized the research status and development trend in the field of intelligent wearable, but there are still some limitations. For software design, and in order to ensure the quality of literature, the data collection and processing of selecting only a single database, can't use more than one database is analyzed at the same time, there are some limitations, so the overview of the field to be further improved.

References

[1] Liu, M.M., et al., High-Energy Asymmetric Supercapacitor Yarns for Self-Charging Power Textiles. Advanced Functional Materials, 2019. 29(41): p. 12.
[2] Xiao, Y., et al., Self-powered, flexible and remote-controlled breath monitor based on TiO2 nanowire networks. Nanotechnology, 2019. 30(32): p. 9.
[3] Chen, X.X., et al., An ultrathin stretchable triboelectric nanogenerator with coplanar electrode for energy harvesting and gesture sensing. Journal of Materials Chemistry A, 2017. 5(24): p. 12361-12368.
[4] Ansems, K., W. Chen, and L. Brown, Smart Photo Frame for Arousal Feedback Wearable sensors and intelligent healthy work environment, in Workshop Proceedings of the 7th International Conference on Intelligent Environments, J.C. Augusto, et al., Editors. 2011, Ios Press: Amsterdam. p. 685-696.
[5] Chen, H.Y., et al., A Review of Wearable Sensor Systems for Monitoring Body Movements of Neonates. Sensors, 2016. 16(12): p. 17.
[6] Ahmadi, A., et al., Toward Automatic Activity Classification and Movement Assessment During a Sports Training Session. Ieee Internet of Things Journal, 2015. 2(1): p. 23-32.
[7] Cherif, N., et al., Physical activity classification using a smart textile. 2018 Ieee Life Sciences Conference. 2018, New York: Ieee. 175-178.
[8] Chowdhury, M.E.H., et al., Wearable Real-Time Heart Attack Detection and Warning System to Reduce Road Accidents. Sensors, 2019. 19(12): p. 22.
[9] Duclos, M., et al., An acceleration vector variance based method for energy expenditure estimation in real-life environment with a smartphone/smartwatch integration. Expert Systems with Applications, 2016. 63: p. 435-449.
[10] Amara, S., et al., High-Performance Flexible Magnetic Tunnel Junctions for Smart Miniaturized Instruments. Advanced Engineering Materials, 2018. 20(10): p. 9.
[11] Baek, S., et al., Flexible Pressure-Sensitive Contact Transistors Operating in the Subthreshold Regime. Acs Applied Materials & Interfaces, 2019. 11(34): p. 31111-31118.

[12] Bai, S.L., et al., Enhancement of NO2-Sensing Performance at Room Temperature by Graphene-Modified Polythiophene. Industrial & Engineering Chemistry Research, 2016. 55(19): p. 5788-5794.