

KNOWLEDGE GRAPH VISUALIZATION OF INTELLIGENT EMERGENCY RESEARCH

HUI XU^{1,2} AND SHUXIU LI¹

¹School of Economics and Management
Chongqing University of Posts and Telecommunications
No. 2, Chongwen Road, Nanshan Street, Nan'an District, Chongqing 400065, P. R. China
xuhui@cqupt.edu.cn; S200701042@stu.cqupt.edu.cn

²Chongqing Innovation Center of Industrial Big-Data Co., Ltd.
National Engineering Laboratory for Industrial Big-Data Application Technology
No. 1, Xinmao Road, Beibei District, Chongqing 400707, P. R. China

Received December 2020; revised April 2021

ABSTRACT. *The knowledge map of intelligent emergency is analyzed and visualized in this study. The literature used in this paper is collected from two databases, CNKI and Web of Science. The date of publication, author co-occurrence, keyword co-occurrence, and emerging topics of relevant literature related to intelligent emergency were analyzed by using the bibliometric method and VOSviewer software. The knowledge map presents the current research status and research hotspots of intelligent emergency. It shows that the intelligent emergency research in China began in 1984 and the number of publications has been increasing since 2001. The research in foreign countries started in 1954 and the number of publications began to increase after 1994. The United States and South Korea are leaders in the intelligent emergency research field. The number of literature published by high contribution authors in this field is less, and it still lacks scholars who can make outstanding contributions. There are numerous cooperation teams, but the cooperation among different teams is weak. Besides, foreign literature emphasizes the establishment of intelligent emergency systems, the improvement of emergency industry technology and the intelligent emergency education. There are some deficiencies in these aspects in China, which can be improved in the future development.*

Keywords: Intelligent emergency, VOSviewer, Knowledge map, Visualization, Co-occurrence analysis

1. Introduction. In recent years, the unknown risks faced by cities have been increasing and the public safety has also been threatened. The emergencies are gradually showing a trend of frequent occurrence, which cause heavy casualties, huge economic losses and serious social damage. For example, the 2019 Corona Virus Disease is a typical emergency [1]. It has become a hot and urgent topic to improve the emergency management ability that can respond quickly to emergencies, so as to maintain social security and stability [2]. The intelligent emergency industry is formed through a combination of traditional emergency response and information technologies such as big data, Internet of Things, Internet, cloud computing, and artificial intelligence. Through the integration of various functions of the whole city, the intelligent emergency industry organizes and collects data on the entire life cycle of urban emergencies, so as to realize real-time awareness, rapid response and coordinated linkage of emergencies [3]. It provides intelligent emergency response and solutions for emergency monitoring and prevention, deployment and control, scheduling and processing, and subsequent investigation and repair. In recent years,

as the market's demand for intelligent emergency products increases, more attention is paid to the development of intelligent emergency industry. Intelligent emergency is an emerging research topic. Son et al. summarized and synthesized the literature that examined resilience in the context of emergency management [4]. Ibrahim et al. reviewed the intelligent evacuation management system in detail from the aspects of crowd monitoring, crowd disaster prediction, evacuation modeling and evacuation path guidance [5]. Purnomo et al. conducted a systematic and comprehensive investigation on indicators, methods and examples of smart city cases [6]. Chen et al. were committed to applying intelligent technologies such as genetic algorithm and swarm intelligence algorithms to different emergency management tasks [7]. Du et al. used the three-stage research framework to study the research trend of emergency management [8]. Although a lot of studies on emergency management have been conducted, the studies focusing on the field of intelligent emergency are still limited. Besides, there is no literature published on visualization of intelligent emergency research by constructing knowledge maps. Therefore, this paper adopts the method of constructing knowledge map and analyzes the literature of intelligent emergency systematically. The research aims to analyze four aspects of the intelligent emergency literature, including publication time, co-occurrence of authors, co-occurrence of keywords, and emerging topics. The knowledge map of intelligent emergency research is analyzed and visualized in this research. The differences between Chinese and foreign literature, the research hotspots, and the research trend of intelligent emergency will be explored.

The sources of the reviewed literature include CNKI and Web of Science. VOSviewer software is adopted for visual analysis. The paper is organized as follows. The first part is introduction. In the second part, the research methods and data sources are illustrated. The third part conducts the data analysis, including the visual analysis and interpretation of the number of literature, the distribution of the years, authors, keywords, and the emerging topics. In the fourth part, discussions on the analysis are shown. The last part is the research conclusion.

2. Research Methods and Data Sources. A review of the relevant literature on the research topic will help to find the development trend and mainstream direction of theoretical research [9]. In this paper, the method of bibliometrics is used to study the intelligent emergency related literature. VOSviewer is a common bibliometric and visual analysis software, which can be used to study the research status, hot spots and trends in a certain field [10]. This paper uses VOSviewer to build a visual map to quantitatively analyze Chinese and foreign intelligent emergency literature. The Chinese literature reviewed in this paper is collected from CNKI, and the foreign literature reviewed is collected from Web of Science. The publication time of the collected literature is in the period of 1954 to July 1, 2020. The retrieval formula of Chinese literature is “SU = (‘智慧’ + ‘智能’ + ‘人工智能’ + ‘大数据’ + ‘物联网’ + ‘互联网’ + ‘云计算’) × (‘应急’ + ‘应急管理’)” (“SU = (‘Wisdom’ + ‘Intelligence’ + ‘Artificial Intelligence’ + ‘Big Data’ + ‘Internet of Things’ + ‘Internet’ + ‘Cloud Computing’) × (‘Emergency’ + ‘Emergency Management’)”). The retrieval formula of foreign literature is “TS = (Wisdom OR Smart OR Artificial Intelligence OR Big Data OR Internet of Things OR Internet OR Cloud Computing) AND TS = (Emergency OR Emergency Management)”. A total of 24987 Chinese and foreign literature have been obtained. Non-research publications such as letters, case analysis, comments, news, information and patents were excluded. Totally, based on the visualization function of the VOSviewer software, 4383 Chinese literature and 5227 foreign literature were studied in four aspects: publication time, author co-occurrence, keyword co-occurrence, and emerging topics.

3. Main Results.

3.1. Analysis of publication time. Excel is used to study the publication time. The study of Chinese literature began in 1984. Researches in the field of intelligent emergency began to show a substantial increase until 2001. From 1984 to 2000, the number of literature was kept within 2 every year. The study of foreign literature first appeared in 1954 and the number began to increase in a large degree after 1994. Between 1954 and 1984, only five papers were published in foreign languages. Figure 1 shows the publication time of the Chinese and foreign literature on intelligent emergency after 1984. Overall, the number of intelligent emergency research literature shows an increasing trend. As shown in Figure 1, 612 Chinese literature and 679 foreign literature on intelligent emergency research were published in 2019. From January 1, 2020 to July 1, 2020, the number of literature published in Chinese is 363 and the number of literature published in foreign language is 380. It can be predicted that the number of intelligent emergency publications will continue to increase in the future. According to comparative analysis, domestic research on intelligent emergency started late and the development time was relatively short. The beginning time has lagged behind foreign countries for 30 years and the substantial increase publication time has lagged for 7 years. In general, the amount of published literature in both Chinese and foreign languages was very small and there were less scholars devoted to the field of intelligent emergency research in the early stage.

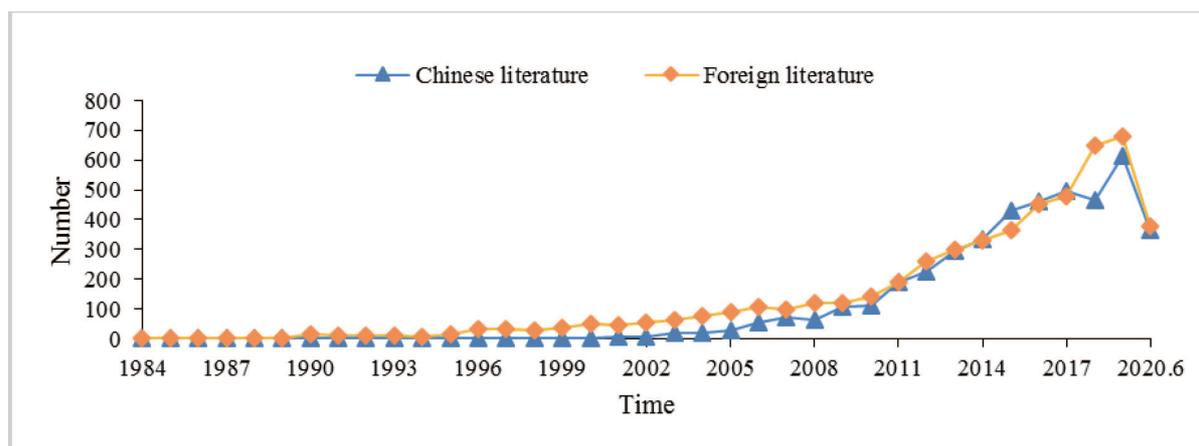


FIGURE 1. The publication time of literature

3.2. Visual analysis of author co-occurrence. The author co-occurrence visualization network can show the author’s publication volume and the cooperation relationship among authors. In this study, only authors with 3 or more papers would be chosen. In total, the information of 188 Chinese authors and 419 foreign authors was collected. The top ten high contribution authors are shown in Table 1.

Through analyzing the authors of Chinese and foreign literature, it can be found that Yang Li from the Center for Studies of Information Resources, Wuhan University in China published the largest number of Chinese literature of intelligent emergency response. The number of the published literature is 12, accounting for 0.27% of the Chinese literature included in the study. The author Young-jong Chung in South Korea has published the largest number of emergency foreign literature, the 13 articles accounting for 0.25% of the foreign literature. It shows that the amount of literature published by high contribution authors is small and it still lacks authors with outstanding contributions in the field of intelligent emergency research. Among the top ten foreign authors in terms of publication

TABLE 1. Information of the top 10 high contribution authors

No.	Chinese author	Institution	Publications	Foreign author	Institution	Publications
1	Yang Li	Center for Studies of Information Resources, Wuhan University	12	Young-jong Chung	Korea Atomic Energy Research Institute (KAERI)	13
2	Gang Li	Center for Studies of Information Resources, Wuhan University	11	Michelle Lin	University of Alabama at Birmingham	12
3	Wei Wang	Shanghai Municipal Engineering Design Institute	11	Christopher j. Lindsell	Vanderbilt University	10
4	Peng Zhang	Chinese People's Armed Police Forces Academy	9	Hyun-sik Park	Korea Atomic Energy Research Institute (KAERI)	10
5	Wangjie Chu	Anhui University	8	Brent Thoma	University of Saskatchewan, Canada	10
6	Tao Li	Hunan Agricultural University	7	Olof Beck	Department of Mediterranean Laboratory, Karolinska Institute, Sweden	9
7	Yang Liu	Tianjin University	7	Anders Helander	Department of Mediterranean Laboratory, Karolinska Institute, Sweden	9
8	Zhe Wang	Huazhong University of Technology	7	W Brian Gibler,	University of Cincinnati	8
9	Chunxia Guo	School of Management, Anhui University	6	Marcus Eng Hock Ong	Singapore General Hospital	8
10	Chunnian Liu	Nanchang University	6	Man Gyun Na	Korea University in Gwangju, South Korea	8

volume, 3 are from South Korea and 3 are from the United States, indicating that the United States and South Korea are relatively the leaders in the field of intelligent emergency research. Both the top one Chinese author Yang Li and the top two Gang Li are from the Center for Studies of Information Resources, Wuhan University. In addition, among the foreign authors, the top one Yong-jong Chung and the top four author Hyun-sik Park, are both from the Korea Atomic Energy Research Institute (KAERI). It shows that the Information Resource Research Center of Wuhan University and Korea Atomic Energy Research Institute are the leading research institutions at home and abroad.

A total of 31 cooperation teams were formed by 188 Chinese authors (a team includes 2 or more authors). As shown in Figure 2(a), the largest cooperation team consists of 12 authors, which is headed by Wei Wang from Shanghai Municipal Engineering Design and Research Institute. 25 teams only have 3 or fewer authors and 90 authors have not joined any team. Besides, 78 cooperation teams have been formed by the qualified 419 highly productive foreign authors. As shown in Figure 2(b), the largest team consists of 22 authors, led by Michelle Lin from the University of Alabama in Birmingham, USA, and Thoma, Brent from the University of Saskatchewan in Canada. The number of authors of 46 teams is 3 or less. The authors within the team are relatively closely connected and each team has relatively prominent research in the field of intelligent emergency response. However, the research conducted by each team is relatively independent. The cooperation among the teams is obviously less. There are 88 foreign authors who have not joined any team. The independent research among scholars contributes less to the development of the field of intelligent emergency research. Therefore, it is necessary to strengthen the cooperation and exchange between scholars from different regions.

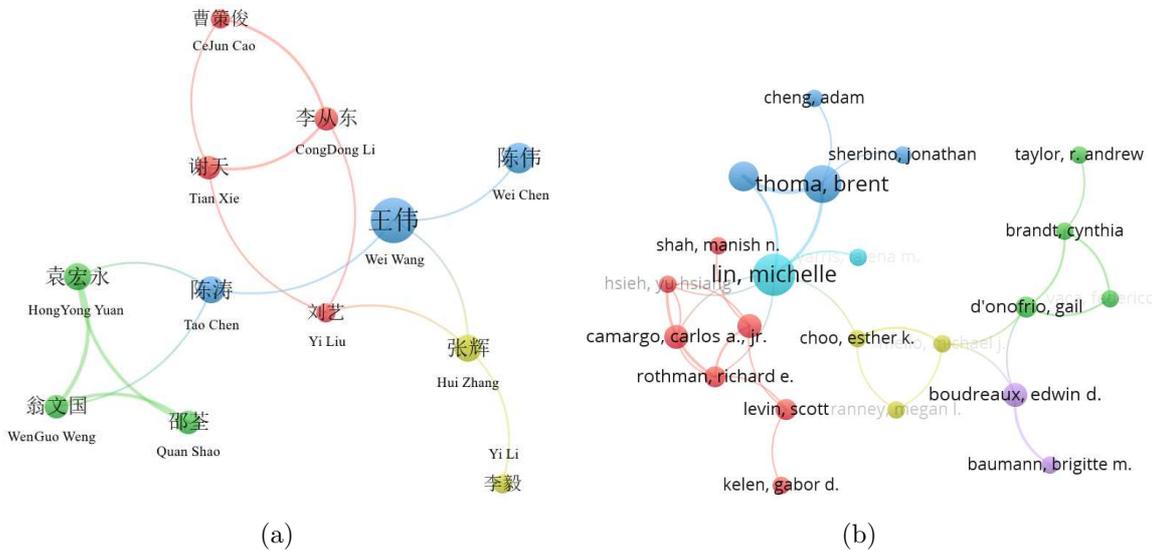


FIGURE 2. (color online) The largest cooperative team of Chinese and foreign authors

3.3. Visual analysis of keyword co-occurrence. Keyword co-occurrence visualization analysis network could be used to reveal research hotspots and trends. The frequency of occurrence of each keyword was set more than 20 times. As a result, 10506 Chinese keywords and 18110 foreign keywords were chosen. Keywords that are not closely related to the topic of intelligent emergency research were deleted. For the keyword clustering, some keywords with similar themes were merged. Finally, 75 Chinese literature keywords

TABLE 2. Statistics of high-frequency keywords

No.	Chinese keywords	Occurrence frequency	Foreign language keywords	Occurrence frequency
1	The Internet of Things	342	Internet	353
2	Emergency management	329	Management	271
3	Big data	319	System	235
4	Emergency rescue	161	Care	205
5	The emergency	155	Model	198
6	Smart city	137	Emergency	163
7	Emergency command	129	Information	154
8	Cloud computing	116	Big data	142
9	Emergency measure	100	Impact	135
10	Emergency decision	74	Social media	130

and 196 foreign literature keywords were obtained. The top ten keywords abstracted from the published intelligent emergency literature are shown in Table 2.

3.3.1. *Keyword co-occurrence and cluster analysis.* The occurrence frequency of 75 keywords in Chinese literature was grouped into six clusters. The relationship among the six clusters is close. The research topics of each cluster are intelligent emergency technology and method (red), emergency rescue (green), emergency decision making (blue), emergency communication (yellow), emergency command (purple), and smart city (gray). Specific keywords contained in each cluster are shown in Figure 3(a). Correspondingly, the research hotspots include emergencies, emergency command, emergency management, emergency rescue, emergency response, big data, Internet of Things, cloud computing and other artificial intelligence technologies. As the management object of intelligent emergency response, emergencies rank the fifth in the frequency of occurrence of keywords in Chinese literature. In recent years, emergencies have gradually entered a period of high frequency. Emergencies in China involve a wide range of areas, which are destructive and pose a great threat to public safety. With the development of science and technology, scholars have gradually realized that the use of science and technology to respond to emergencies is the basic guarantee for realizing social public safety. Therefore, artificial intelligence (AI) technology has become the focus of emergency research. In addition, among the six themes, emergency communications, emergency command, emergency management, and emergency rescue respectively correspond to the deployment and control, scheduling and handling of emergencies, and the investigation and repair afterwards. In order to meet the needs of the market, both of them have gradually become research hotspots for intelligent emergency response.

A total of 196 keywords in foreign literature were divided into four clusters. The topics of each cluster are intelligent emergency technology and method (red), emergency medical (green and purple), emergency education (blue), emergency response (yellow). Each cluster contains specific keywords, as shown in Figure 3(b). The topic of intelligent emergency technology and methods include 67 keywords, which focuses on the research of algorithms, design, systems, performance, optimization and other intelligent emergency technologies and methods. The emergency medical care contains 78 keywords and focuses on diseases, medicine, prevention, emergency medicine treatment, etc., emphasizing public health and safety. Emergency education mainly emphasizes the teaching and training of intelligent emergency related knowledge. It contains 25 keywords. Emergency response includes 26 keywords and the main themes are disaster management and response. Different from

the past decade are epidemic prevention and control, intelligent fire control, drone, and big data. As shown in Figure 4(b), keywords in foreign literature are COVID-19, deep learning, smart city, big data, and Internet of Things.

In April 2018, China officially established the emergency management department. The professionalization, standardization and modernization of emergency management became new hotspots [11]. The outbreak of novel Coronavirus at the end of 2019 has aroused increasing public attention. According to the survey results, artificial intelligence, big data, cloud computing and other digital technologies combined with traditional emergency management methods have played a considerable role in the monitoring and analysis of the epidemic, drug research and development, medical assistance and resumption of work and production [12]. It makes COVID-19, epidemic prevention and control, and artificial intelligence (AI) technologies became hotspots in both foreign and Chinese literature on intelligent emergency response in 2020 [13]. Besides, the establishment of smart cities and the realization of intelligent management and sustainable development of cities are the common themes of the study in domestic and foreign countries in recent years. Especially, deep learning has been a hot topic in recent two years [14].

4. Discussion. Through the visualization function of knowledge map, it can be seen that the research topics of intelligent emergency response in Chinese and foreign literature are slightly different. In addition to artificial intelligence technology, Chinese literature studies the entire life cycle of emergencies. Although Chinese scholars have done research on industrial technology, the innovation ability of intelligent emergency industry is still insufficient. Therefore, in order to improve China's ability of risk prediction and inference, it is necessary to constantly improve the technology of intelligent emergency response industry and keep innovating. Foreign literature emphasizes the development of emergency education and emergency medical care. It also attaches importance to the establishment of emergency systems. Vigorously developing emergency education can increase the public's attention to first aid knowledge. More attention to the development of emergency medical care can reduce the harm of emergencies to the society, politics, economy and people's lives. The establishment of the intelligent emergency system and platform can prevent and handle emergencies effectively. In general, foreign literature mainly emphasizes the ability to prevent and infer risks and the development of the intelligent emergency system. However, it still lacks scholars with outstanding contributions in the field of intelligent emergency response. Scholars from different regions should strengthen cooperation and exchanges, learn from each other and conduct in-depth research, so as to promote the rapid development of the intelligent emergency research [15].

5. Conclusions. This paper mainly uses VOSviewer software to analyze the intelligent emergency research literature in the database of CNKI and Web of Science from four aspects: publishing time, co-occurrence of authors, co-occurrence of keywords and emerging topics. Then the development status and research hotspots of intelligent emergency research are analyzed. It is helpful for scholars to find the differences and weak points between Chinese and foreign literature research on intelligent emergency, so as to provide reference for the development of intelligent emergency research.

There are still some deficiencies in this study. The data sources are limited to CNKI and Web of Science. Besides, in the co-occurrence visualization network of authors, there may be authors with the same name from different institutions. In the future, the study for different intelligent emergency dimensions and relevant technology will be conducted.

Acknowledgment. This research was conducted with the support of the Key Humanities and Social Science Research Program of Chongqing Municipal Education Commission (Grant No. 21SKGH061); the Science and Technology Research Program of Chongqing Municipal Education Commission (Grant No. KJQN202000631); the National Natural Science Foundation of China (Grant No. 71801026); and the Innovative Project of Chongqing Oversea Study Innovation Program (Grant No. cx2020035). The authors also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

REFERENCES

- [1] N. Li, P. T. Wang, X. Y. Wang et al., Molecular diagnosis of COVID-19: Current situation and trend in China (Review), *Experimental and Therapeutic Medicine*, vol.20, no.5, p.13, 2020.
- [2] X. Jiang, X. N. Su and X. W. Liu, A probe into unexpected events-driven emergency decision knowledge base structure, *Information and Documentation Services*, no.1, pp.25-29, 2015.
- [3] G. Li and Y. Li, Research on smart emergency in view of intelligence: Introduction of entropy theory, *Library & Information*, no.1, pp.66-71, 2015.
- [4] C. Son, F. Sasangohar, T. Neville et al., Investigating resilience in emergency management: An integrative review of literature, *Applied Ergonomics*, vol.87, 2020.
- [5] A. M. Ibrahim, I. Venkat, K. G. Subramanian et al., Intelligent evacuation management systems: A review, *ACM Trans. Intelligent Systems and Technology*, vol.7, no.3, 2016.
- [6] F. Purnomo, F. L. Gaol, H. Prabowo, S. H Supangkat and Meyliana, A systematic literature review on smart cities: Indicators, methods, and case studies, *ICIC Express Letters*, vol.14, no.11, pp.1113-1120, 2020.
- [7] N. Chen, W. J. Liu, R. Z. Bai and A. Chen, Application of computational intelligence technologies in emergency management: A literature review, *Artificial Intelligence Review*, vol.52, no.3, pp.2131-2168, 2019.
- [8] L. Du, Y. B. Feng, L. Y. Tang et al., Networks in disaster emergency management: A systematic review, *Natural Hazards*, vol.103, no.1, pp.1-27, 2020.
- [9] H. Lee, M. S. Cha and T. Kim, Text mining-based mapping for Kano quality factor, *ICIC Express Letters, Part B: Applications*, vol.12, no.2, pp.185-191, 2021.
- [10] N. J. van Eck and L. Waltman, Software survey: VOSviewer, a computer program for bibliometric mapping, *Scientometrics*, vol.84, no.2, pp.523-538, 2010.
- [11] Y. Li and J. J. Sun, Construction of an intelligence resource support capability for smart emergency management, *Journal of the China Society for Scientific and Technical Information*, vol.38, no.12, pp.1310-1319, 2019.
- [12] Artificial Intelligence Industry Development Alliance, *Research Report on Artificial Intelligence for COVID-19 Prevention and Control*, http://pdf.dfcfw.com/pdf/H3_AP202003301377165861_1.pdf, 2020.
- [13] W. M. Li, N. Su, M. Y. Shang et al., Visualization analysis and interpretation of domestic scientific researches on coronavirus disease 2019, *International Journal of Laboratory Medicine*, vol.41, no.9, pp.1025-1029, 2020.
- [14] A. Shrestha and A. Mahmood, Review of deep learning algorithms and architectures, *IEEE Access*, vol.7, no.1, pp.53040-53065, 2019.
- [15] Y. Li and G. Li, Practice and application of intelligence engineering oriented to the emergency decision-making under the background of smart city, *Library and Information Service*, vol.60, no.11, pp.81-85, 2016.