Research on Damage Identification of Civil Engineering Structures based on CiteSpace

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Abstract. With the continuous innovation of technology and building materials, civil engineering has been rapidly developed. However, due to various reasons, China's in-service building structure is or will usher in the peak of structural damage. This paper aims to study the development stage of structural damage identification in civil engineering, and find out the research hotspot and development trend in recent ten years. Based on Web of Science (WoS) platform, the damage identification methods of civil engineering structures in recent ten years are studied by CiteSpace software. The results show that: through the literature feature analysis, the words with the highest frequency are "damage identification", "model", "frequency", and "crack detection". The word with the strongest burst is "wavelet transform," and the word with the longest duration is "Kalman filter." This paper offers a theoretical basis and reference value for the research hotspot and development trend of damage identification of civil engineering structures.

Keyword. Structural damage identification, CiteSpace, WoS, Visualized maps.

1. Introduction

In the process of operation and use, civil engineering structures are inevitably affected by environmental erosion, material aging and other factors. In-service structures may degrade over time, causing major accidents that endanger people's lives and property. In recent years, building collapse accidents in China are prone to occur frequently, and the safety situation is not optimistic. According to the data released by the Ministry of Housing and Urban-Rural Development, in 2019, there were 23 accidents with greater production safety or above in housing municipal projects across the country, of which 13 were building collapse accidents, accounting for 56.52% [1]. For example, on April 29, 2022, a massive landslide occurred in Changsha, Hunan Province. The accident investigation team found that the direct cause of the accident was the illegal construction of poor construction quality, unreasonable structure, low bearing capacity, illegal expansion to 8 floors (local 9 floors). As a result, the columns and walls on the east side of the second floor exceeded the ultimate bearing capacity, and eventually caused the overall collapse of the house. [2]. Once a collapse accident occurs, it will not only bring huge economic losses to the government, construction enterprises and individuals, but also may endanger people's lives. Therefore, it is necessary to detect damage during the use of the structure and take measures to avoid accidents. Based on the research on the damage identification methods of civil engineering structures in the past ten years using CiteSpace software by Web of Science (WoS), this paper summarizes the research hotspots and development trends in this field.

2. Research Method

CiteSpace is a visual document analysis software. It can analyze the literature retrieved in a variety of databases, such as China National Knowledge Infrastructure (CNKI) and WoS. At the same time, it can summarize and classify the literature data in the database by year, author, author institution, journal type, etc. By visualizing the deep knowledge and research focus in the literature, and visualizing the results with data and graphs, readers can have a more intuitive understanding of this research field.

Of these databases that CiteSpace can analyze, WoS is the most authoritative. The WoS Core Collection database contains more than 12,000 authoritative academic journals in various fields

around the world and includes references cited in papers and is compiled into a unique citation index by cited author, source, and year of publication [3, 4]. All the data in this paper are from the core collection of WoS database, and the journal papers on the topic of information behavior are selected as the object of bibliometric analysis. A total of 2528 articles were obtained from December 31, 2013 to December 31, 2023. The search field was "Structural damage identification", the article type was article, and the language was English.

3. Results and Discussions

3.1. Literature Feature Analysis

3.1.1 Chronological analysis of the literature

The growth statistics and trends of the literature from 2014 to 2023 are shown in Fig. 1. During this period, the number of articles increased steadily, from 166 to nearly 373, indicating that the study of structural damage identification was highly valued by scholars during this period.

Due to aging buildings and construction quality problems, China's housing construction is facing a peak of structural damage. Through the identification of structural damage, the existing building structures can be scientifically evaluated for durability and remaining life prediction, avoiding large-scale maintenance after damage expansion [5]. Structural damage identification technology can also help maintain the integrity of the structure and extend its lifespan.

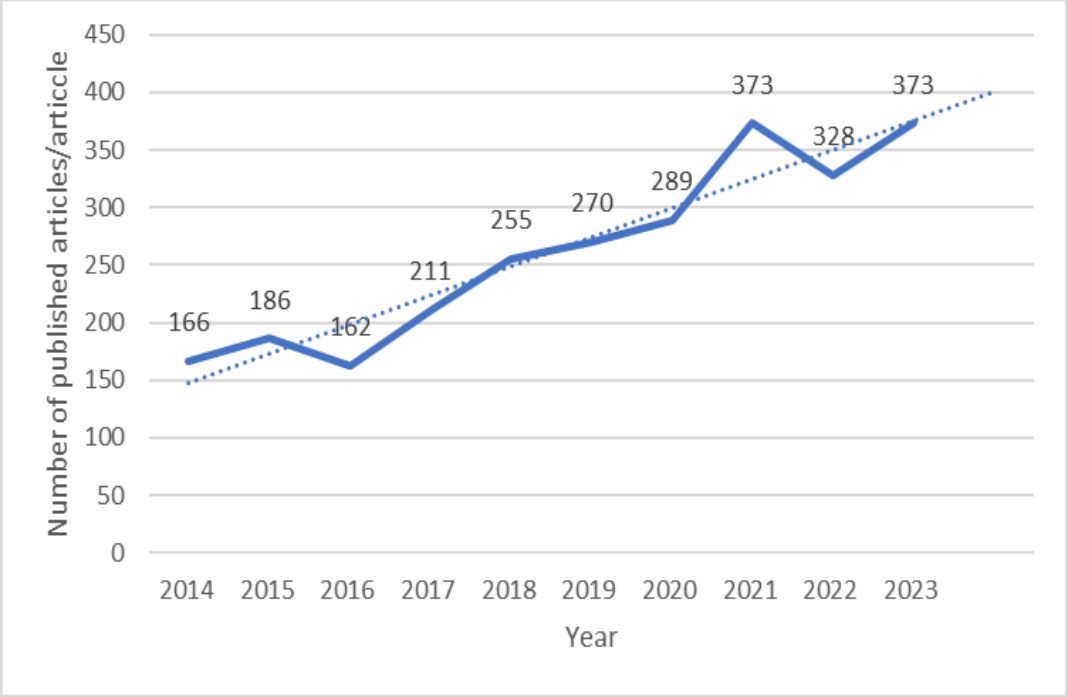

Fig. 1 Temporal distribution of the number of core journals in foreign structural damage identification research from 2014 to 2023

3.1.2 Documentation institution analysis

The top 10 institutions in the field of structural damage identification from 2014-2023 are shown in Table 1. Fig. 2 shows the number of CiteSpace publications and collaborative networks in the field of structural damage identification, forming a community centered around universities such as Tongji University, Hong Kong Polytechnic University, Dalian University of Technology, Southeast University, among which collaboration between international universities is more common.

Table 1. Top 10 institutions in the field of structural damage identification from 2014 to 2023

Rank	Name of the institution	Country	Number of published articles
1	Tongji University	China	94
2	Hong Kong Poly technic University	China	72
3	Dalian University of Technology	China	66
4	Southeast University-China	China	64
5	Harbin Institute of Technology	China	60
6	University of California System	America	45
7	Curtin University	Singapore	42
8	Xiamen University	China	37
9	Polytechnic University of Milan	Italy	34
10	Guangzhou University	China	29

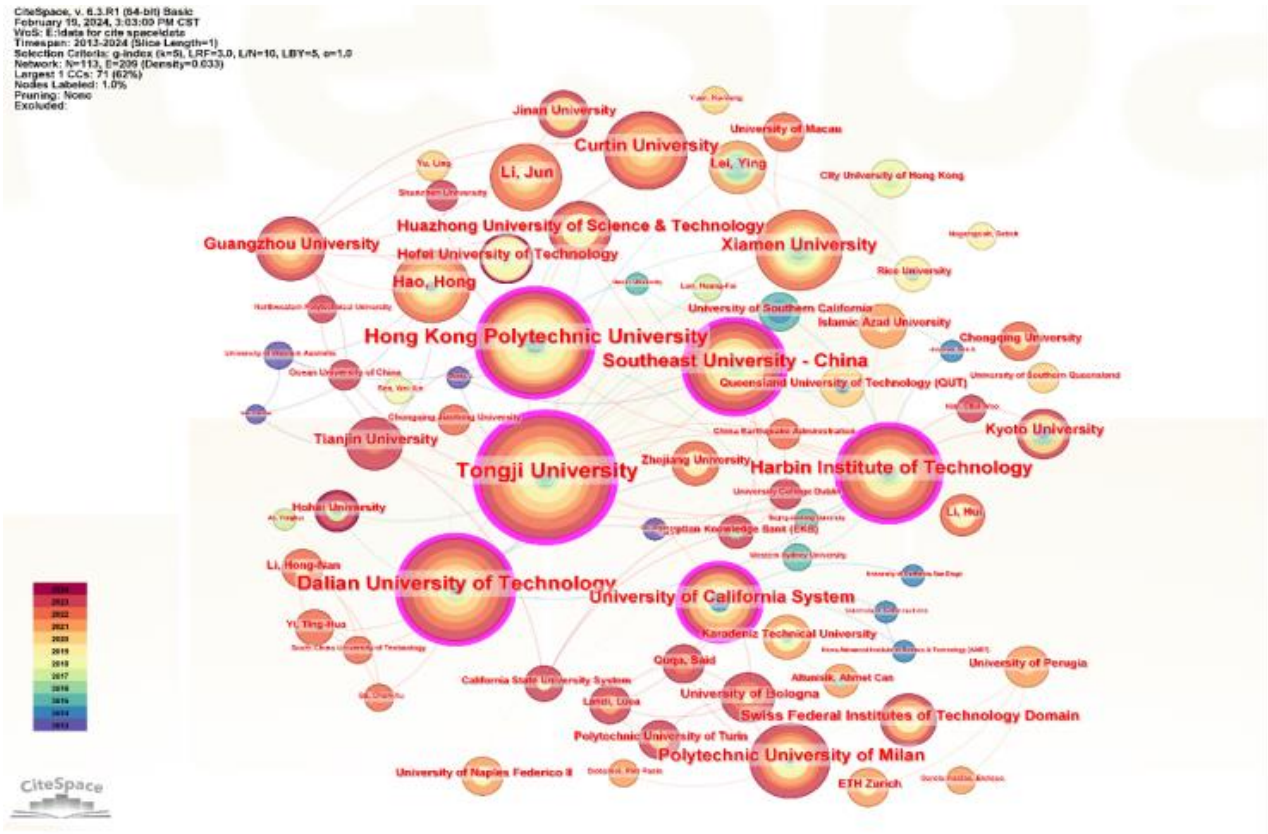

Fig. 2 Institutional Cooperation Network in the Field of Structural Damage Identification from 2014 to 2023

3.2. Literature Citation Feature Analysis

The timeline from 2014 to 2023 was divided into 10 time periods in the software, and the co-cited network was generated by selecting the literature with no less than 4 citations, as shown in Fig. 3.

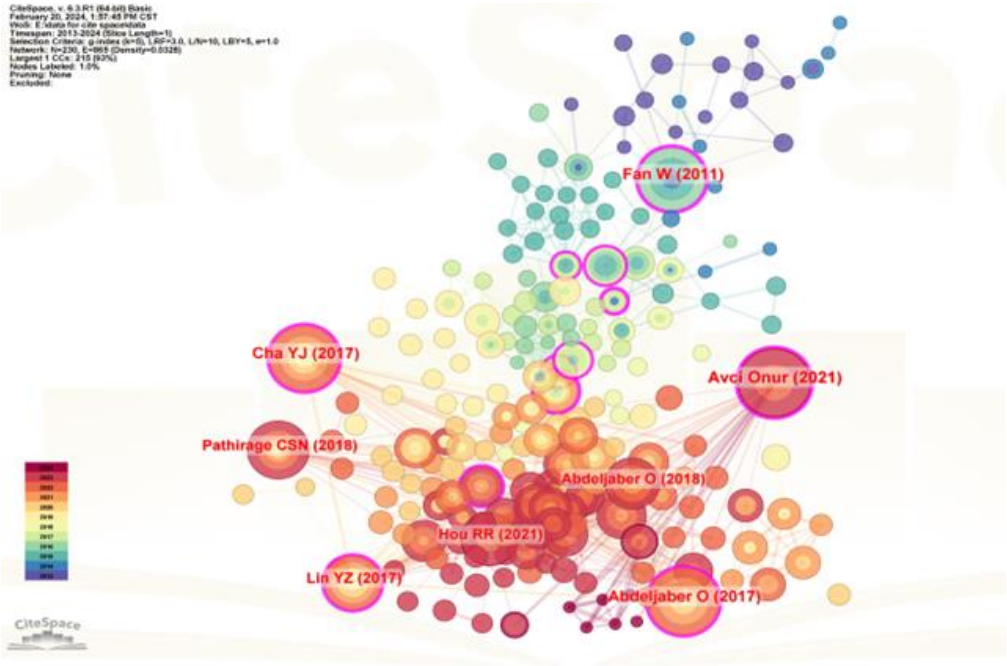

Fig. 3 Literature co-citation network in the field of structural damage identification

3.3. Keyword Feature Analysis

3.3.1 Keyword frequency of analyze hot spots

Keywords can visually express the subject content of the literature, as well as the research direction and theme. The topic "Structural damage identification" was used as the search field, and the publication time of the paper was from December 31, 2013 to December 31, 2023.

As shown in Table 2, the words with the highest frequency were "damage identification", "model", and "frequency", and the words with the highest centrality were "model", "model analysis", "frequency", "diagnosis", and "crack detection", which were 0.08, 0.08, 0.06, 0.06, 0.06.

Table 2. Keyword frequency analysis table

Rank	Frequency	Centrality	Keywords
1	261	0.08	model
2	59	0.08	modal analysis
3	202	0.06	frequency
4	72	0.06	diagnosis
5	59	0.06	crack detection
6	352	0.05	damage identification
7	163	0.05	algorithm
8	161	0.05	vibration
9	67	0.05	beams
10	178	0.04	system identification
11	129	0.04	localization
12	112	0.04	model updating
13	57	0.04	sensitivity
14	39	0.04	methodology
15	36	0.04	genetic algorithm
16	36	0.04	classification
17	111	0.03	modal identification
18	108	0.03	structural damage
19	106	0.03	structural damage detection
20	91	0.03	parameters performance

3.3.2 Strong emergent keyword analysis and forecast

The analysis of strong emerging keywords can help researchers identify research focus in this field, understand the changes in the activity and research interests of the research field, and predict future trends.

As can be seen in Table 3, the word that appears most frequently is: wavelet transform. Wavelet transform has important research value in damage identification of civil engineering structures. The response signals of civil engineering structures are often non-stationary. The multi-resolution characteristics of wavelet transform can place vibration signals in different frequency bands for real-time analysis, so as to monitor structures and determine damage locations [6, 7]. In addition, wavelet transform can better consider the uncertainty factors in the identification process and improve the stability of the structure [7].

Table 3. The top 10 mutation words in the literature

Keywords	Year	Strength	Begin	End	2013 - 2024
wavelet transform	2013	7.23	2013	2016	
genetic algorithm	2013	6.71	2013	2017	
extended kalman filter	2013	5.73	2013	2018	
location	2013	4.63	2013	2017	
wavelet neural network	2015	15.16	2015	2016	
flexibility	2015	6.77	2015	2018	
modal analysis	2013	5.67	2016	2017	
ambient vibration test	2017	9.37	2017	2018	
simulation	2017	5.68	2017	2019	
modal parameters	2018	5.97	2018	2020	

The word that lasts the longest is “Carl Manfeldt”. First of all, because the Kalman filter can eliminate random interference errors and obtain useful information that approximates the real situation, the accuracy of structural damage identification can be gradually improved by modifying the model, which is crucial for the small damage of the structure [8]. With the deepening of research, the Kalman filter algorithm is constantly improved and optimized to adapt to more complex engineering structures and more diverse damage situations. Secondly, measurement data often contain noise and uncertainty. Kalman filter can improve the stability and accuracy of structural damage identification by reducing the influence of some noise.

With the research of digital image technology, computer vision technology is increasingly regarded as a key means to promote the development of detection technology in the field of structural damage identification in civil engineering [9]. By analyzing the surface features of the structure captured by digital images, it is possible to detect corrosion, cracks, and other forms of damage to the steel structure. This facilitates early detection of problems and appropriate maintenance measures [10]. Computer vision technology can also accurately inspect critical areas such as welded joints and bolted joints to identify fatigue cracks or other defects.

4. Conclusion

This paper systematically analyzes the research fields of structural damage identification in recent years based on the visual literature analysis function of CiteSpace software, and draws the following main conclusions:

(1) Based on the research results of structural damage identification methods in civil engineering in WoS database in the past ten years, this paper summarizes and prospects the research hotspots in this field. Through the analysis of literature features, it is found that the words with the highest frequency are "damage identification", "model", "frequency" and "crack detection", which have the

highest centrality. The word with the strongest burst is "wavelet transform," and the word with the longest duration is "Kalman filter."

(2) In summary, it can be predicted that the damage identification of civil engineering structures will be closely combined with the computer field to jointly promote the trend of intelligent, digital and sustainable development. These changes will also bring new challenges and opportunities to the industry. It could also be a key factor in improving the quality of cities and infrastructure. At the same time, the sustainable development and intelligent trend of the industry will provide new opportunities and challenges for practitioners.

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