Visualization Analysis for Aqueduct Researches Based on CiteSpace

GONG Li¹, WANG Zhonghui*, LU Yekun¹, KANG Chuntao¹

¹School of Civil Engineering, Lanzhou Jiaotong university, Lanzhou730070, China
*Corresponding author’s e-mail: 903892370@qq.com

Abstract. In order to learn the aqueduct researches situation in China, we analyze the published literature about aqueduct from 1988 to 2017 in the CNKI database, and process on the CiteSpace visual analysis software. The scientific knowledge maps are obtained to tease out the changes of the literature about aqueduct researches, the cooperation relationship between authors and the institutions, and the keywords about hot spots. They visually reflect the complex relationships among the knowledge groups of aqueduct researches, such as network, structure and crossover, and clarify the current research situation and development trend of aqueduct researches. This study indicates that there are relatively few research literature about aqueduct; The number of authors researching on aqueduct is large, but the number of prolific ones is relatively small. Meanwhile, the collaboration between authors is relatively dispersive, since it does not form close relation. The distribution of research institutions is centralized which is not beneficial to mutual cooperation between research institutions and research institutions. The analysis of keywords shows that the researches about aqueduct are mainly in the aspects of internal stress, external stress, structure and construction technology.

1. Introduction
Aqueducts are long distance systems consisting of bridges and tunnels, or channels and groove. It’s generally used for irrigation and water transport and navigation. With the implementation of many water conservancy projects and diversion projects, aqueduct, as a kind of water conveyance building, has been constructed in large quantities [1]. The aqueduct has been widely studied and applied during the construction of the south-to-north water diversion project [2]. With the development of society, the rational utilization of water resources becomes more and more important, and aqueduct as an important building for water transfer project has become a key research direction. Since the introduction of scientific knowledge mapping in 2005, the application of scientific knowledge mapping in some fields in China has achieved considerable development [3], but the research progress and research hotspots in the aqueduct field are rarely analyzed based on the knowledge mapping system. After the retrieval of the CNKI database, the knowledge map of the research status, research cooperation and research hotspots of the aqueduct were analyzed intuitively based on the visualization tools [4], so as to provide scientific reference for the research of aqueduct engineering.

2. Research methods and data sources

2.1. Research methods
The software CiteSpace, which has some characteristics in the research of knowledge map visualization, is used as the data analysis tool. CiteSpace presents the structure, regular and
distribution of scientific knowledge through visualization [5]. It generates a rich visual map according to provides co-word analysis of keywords and subject words and co-occurrence analysis of authors, institutions and countries [6], which avoids the influence of researchers’ subjective judgment on the analysis results and enhances the objectivity of the results [7]. This study used CiteSpace 5.1.RB.SE to analyze the data of research literature on aqueduct.

2.2. Data sources
In order to better reflect the research problems in the aqueduct research field, the data are collected from the CNKI database, the keyword is "aqueduct" limited from 1988 to 2017, and journals are chose from SCI source journals, EI source journals, core journals and CSSCI for retrieval. There are almost 562 available papers obtained from the 737 retrieved papers after delete data that unknown of directory, profile, meeting and signature, and export the data in Refworkd format.

3. The condition of literatures output
The change of the number of literatures reflects the actual progress in this field. According to draw broken line chart in the aqueduct field from 1988 to 2017 can directly reflect the changing trend of aqueduct research. We can see from the figure.1 that the number of literatures of aqueduct research showed an obvious upward trend. In April 1991, the fourth session of the seventh National People's Congress included the "south-to-north water diversion" in the "eighth five-year plan" and the "ten-year plan". From 1992 to 2001, the average annual output of 5.6 articles, showed a relatively slow speed. Since 2002 when the south-to-north water diversion project was approved and officially started, the research on aqueduct has been developing rapidly. However, it can be seen from the literature output that the average annual papers output are low and fluctuate greatly. Thus the research in the aqueduct field is still relatively slow.

![Figure 1. Literatures output trend of aqueduct area in 1988 to 2017](image)

It can be found from the change of literature output trend that the output of papers in 2001 to 2002 and 2007 to 2008 increased significantly compared with other years. There are totally 34 papers were published in 2002, one of the paper which talk about the applicability of Housner model in aqueduct seismic calculation published by Liu Yunhe from Xi'an university of technology was cited 57 times, the results of this paper have important reference value for the follow-up research of Housner model in aqueduct seismic and deepening fluid-solid coupling [9]. In 2008, there are totally 40 papers were published, and the vertical seismic effect analysis of large aqueduct published by Li Yuchun of Tongji university has the highest number of citations. For the aqueduct with different structural types, it puts forward a specific analysis with proper consideration of vertical seismic effect in the case of seventh-degree seismic fortification[10]. There were the highest output year is 2010 with 51 papers published, the highest cited one is published by Li Zhengnong from Hunan university which put idea of that the horizontal seismic response analysis of aqueduct structure with pile-soil dynamic interaction, and calculated that in aqueduct seismic research and design pile-soil interaction cannot be neglected[11].

Through the above analysis, it can be concluded that the outstanding of aqueduct research is that aqueduct seismic design and seismic response research.
4. Co-occurrence analysis of scientific research cooperation

4.1. Authors’ co-occurrence analysis

Co-occurrence analysis of authors can reflect core authors in the research field, their cooperation and inter-citation relationship [8]. In Citespace, "TimeSlicing" was set from 1988 to 2017, time slice value is three and "NodeTypes" in the function and parameter Settings area set as Author, and in order to optimize the network that "Pruning" is set to Pathfinder. After running the software we can obtain the co-occurrence network map of the author, as show in figure 2. We can see from the figure that there are a total of 180 nodes and 177 connections, and the network density is 0.011. In this figure, the size of the node represents the number of articles published by the author. Based on the analysis of the graph, there are formed a authors' cooperative network graph with Wang Bo, Bai Xinli, Li Zhengnong, Ji Richen and Mo Haihong.

![Figure 2. Co-occurrence map of authors’ cooperation in aqueduct research](image)

The authors and organizations within the partition are shown in table 1. The authors in area a1 are all from the same organization and have close cooperation with each other. The output of this area is account 44.8% in the five regions, thus the output of each other ranks in the forefront, it plays a good guiding role in the theoretical research of the aqueduct field and promotion and takes a leading position in the domestic aqueduct research. The representative author of area a2 is Bai Xinli, he has 23 articles published but the number of co-authors is small. The volume of cooperation output in a3 area is second in all areas and it only behind in a1 area, accounting for 28.4% of the five areas. The representative authors of area a4 and area a5 are Ji Richen and Mo Haihong, but the number of its cooperation output is less and has same situation with area a2. The author group of aqueduct research is scattered on the whole and the weak cooperation among various research teams is not conducive to the development of research in the aqueduct field.

| Area | Author                 | Output | Centrality | Institution                                      |
|------|------------------------|--------|------------|-------------------------------------------------|
| a1   | Wang Bo                | 36     | 0.00       | Zhengzhou University                            |
|      | Xu Jianguo             | 33     | 0.00       | Zhengzhou University                            |
|      | Chen Huai              | 21     | 0.00       | Zhengzhou University                            |
| a2   | Bai Xinli             | 23     | 0.02       | North China university of water resources and hydropower |
| a3   | Li Zhengnong           | 21     | 0.02       | Hunan University                                |
|      | Li Yuchun              | 20     | 0.01       | Tongji University                               |
|      | Lou Menlin             | 16     | 0.01       | Tongji University                               |
| a4   | Ji Richen              | 18     | 0.00       | Lanzhou Jingtong University                      |
| a5   | Mo Haihong             | 13     | 0.00       | South China university of technology             |
4.2. Institutional co-occurrence analysis

Research in the aqueduct field is mainly universities and research institutes. The co-occurrence map of institutional cooperation generated by CiteSpace is shown in figure 3. The institution that have largest output is North China institute of water resources and hydropower, the second is Zhengzhou University, Hohai University and Lanzhou Jiaotong University. We can see from the figure that the node connection that closely connected institutions are basically located in the same region or adjacent regions. For example: North China institute of water resources and hydropower, Zhengzhou University, Hohai University and Yellow River conservancy technical college have a close connection; the same as Lanzhou Jiaotong University, Xi 'an university of technology and institute of cold and dry areas, Chinese academy of sciences; And Tongji university and Wenzhou university as well, etc. However, general speaking, the cooperation among institutions is scattered and the cross-regional cooperation is weak, which does not constitute a good cooperative relationship in this field and is not conducive to the establishment the good academic cooperative relationship.

![Figure 3. The collaborative network map of cooperate institutions in aqueduct research](image)

5. Co-occurrence analysis of keywords

Keywords are a high generalization of the subject of scientific literature. According to extraction of keywords from aqueduct research, using visualization method excavate the hot spots and trends of this research field. In CiteSpace sofware, the "NodeTypes" in the function and parameter setting area were set as Keyword, and obtained the keyword co-occurrence network map. As shown in figure 4 there are 115 hot keywords were generated in the network map. The frequency of distribution can determine the research focus, distribution and structure of the discipline, in order to better control the hotspot and trend of aqueduct research, key words with frequency is ten or more were screened out. As shown from the figure 4, the main content of the research in the aqueduct are respectively "aqueduct", "fluid-structure interaction", "finite element", "middle route of south-to-north water transfer project", "temperature stress", "seismic response", "aqueduct structure", "large aqueduct", "prestress" and "south-north water diversion project".

It can be fond from table 2 that the centrality of keyword "finite element" is 0.55, with the highest centrality. This condition indicated that "finite element" plays a bridge role in the research field of aqueduct and has a good correlation with the research of other problems. It has laid a foundation in the research on the structure, seismic analysis, monte-carlo simulation and temperature simulation of the aqueduct by using the finite element theory [12].
After running "LLR" (log-livelihood ratio) do keyword clustering, we obtained 10 clustering terms as shown in figure 5. In the practical process of aqueduct research, firstly, using finite element analysis to study the aqueduct structure. Secondly, doing further analysis for influence of a series of external factors (water flow, temperature and earthquake, etc.) on the aqueduct. Finally, according to simulate and optimize through external influencing factors to make the operation of the aqueduct safer and more reliable [13-16].

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diversion project".

The burst intensity of "aqueduct" is 7.5335, and the burst time is from 1998 to 2001. Mainly focuses on the problems in the process of aqueduct construction.

The bursting strength of "prestressed concrete" is 3.9266, and the bursting duration is the longest and from 1999 to 2004. Mainly studied in the aspect of material application.

The outburst strength of "aqueduct structure" is 3.7545, and the outburst time is from 2004 to 2006. Mainly surrounding the effects of external factors such as finite element, dynamic performance, seismic response, monte-carlo simulation reliability and seismic analysis on the internal stress of the aqueduct were studied.

The outburst intensity of "Shahe aqueduct" is 4.6353, and the outburst time is from 2012 to 2014. Shahe aqueduct is a key project of the middle route of south-to-north water diversion project, its maximum height is 9.6m [17]. Meanwhile, Large-span thin-wall bidirectional prestressed structure has complex spatial stress and great difficulty in erection, which is mainly studied in terms of construction technology [18].

The bursting intensity of the "middle route of south-to-north water diversion project" is 5.9522, and the bursting time is from 2013 to 2015. Aqueduct is an important long distance water conveyance tool in the south-to-north water diversion project. It mainly researched based on the water filling test, safety monitoring and stress analysis of the rectangular aqueduct, drainage aqueduct, crossing the river aqueduct and Shahe aqueduct to water test, safety monitoring and stress analysis.

### Top 5 Keywords with the Strongest Citation Bursts

| Keywords          | Year | Strength | Begin | End  |
|-------------------|------|----------|-------|------|
| Aqueduct          | 1988 | 7.5335   | 1998  | 2001 |
| Prestressed concrete | 1988 | 3.9266   | 1999  | 2004 |
| Aqueduct structure | 1988 | 3.7545   | 2004  | 2006 |
| Shahe aqueduct    | 1988 | 4.6353   | 2012  | 2014 |
| The middle route of the south-to-north water diversion project | 1988 | 5.9522   | 2013  | 2015 |

Figure 6. Keywords emerging map in aqueduct research

### 6. conclusion

By using CiteSpace software, this paper visualized and analyzed the literatures with the theme of "aqueduct" collected in CNKI database from 1988 to 2017. The results showed that:

1. Literature output. From 1992 to 2017, the number of literature output showed an overall growth trend, but the average annual literature output changed greatly, showing a scattered state and without a steady growth, which was affected by the construction of water conservancy industry. Since the start of South-to-north water transfer project in 2002, the study of the aqueduct obviously rise, but when the project enter a stage of full implementation in 2005, the aqueduct research significantly lower. Along with the running of the project, the aqueduct research is obviously increasing in 2008, until the year of 2015, the research trend of stable every year, and after the issue of formal water run of south-to-north water transfer project, research in the field of aqueducts is declining rapidly. It shows that the research on aqueduct is obviously influenced by the national water conservancy engineering construction policy, and the research on aqueduct field fluctuates greatly.

2. Research cooperation. In terms of author cooperation, the research teams formed among the authors are small and scattered. In addition to the close cooperation between the respective team authors, the cooperation among the teams is scattered, and the tree branches are sparse, without a good cooperative relationship. In terms of institutional cooperation, north China institute of water resources and hydropower is outstanding, with more institutions cooperating with it, forming a good research cooperative relationship, which has played a significant role in promoting the research in the aqueduct
field. However, from the overall distribution of institutional cooperation, institutional cooperation is mainly concentrated in the more developed areas of water conservancy construction in China, and inter-regional cooperation is obviously relatively backward. It shows that the overall distribution of research cooperation in aqueduct research is not uniform, and the connection is relatively not very close.

(3) Hot research. By analyzing the key words of aqueduct research, it can be found that the stress, structure and construction technology of aqueduct are the main aspects. And the study of internal and external stress of aqueduct plays an important role in the study of its structure and construction. Keywords further emergence analysis shows that the emergence of the words are mainly specific engineering examples, it is indicated that aqueduct research problems and practical engineering problems are relatively close, targeted and the actual application of the research results prominent. With the development of research in aqueduct field, the research direction of aqueduct is gradually developing towards the research on the influence of external environmental factors on aqueduct and the research direction of self-optimization design.

Through the above analysis and research, the paper makes a specific analysis of the literature output, author cooperation, institution cooperation and keyword research of aqueduct research, and concludes that the research in the aqueduct field in China is generally scattered with poor cooperation. Academic research close to practical engineering makes aqueduct research lack of motivation. Therefore, it is necessary to strengthen the close cooperation in research, and the academic research should be ahead of the actual engineering construction policy to make the research of aqueduct develop innovatively.

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Reference
[1] Xu, J.G., Wang, B., Chen, H., Huang, L., Zhou, H. (2012) Study on seismic nonlinear collision of double-groove aqueduct structures. Engineering seismic resistance and reinforcement, 34(06):38-44.
[2] Xiong, P.F., Jiang, Y., Peng, G. (2014) Dynamic response analysis of flume under the equivalent mechanical model. China rural water conservancy and hydropower, (03):71-73+77.
[3] Chen, Y., Liu, Z.Y. (2005) Atlas of scientific knowledge quietly rising. Science of science research, (02):149-154.
[4] Chen, Y, Chen, C.M., Liu, Z.Y., Hu, Z.G., Wang, X.W. (2015) Methodological functions of CiteSpace knowledge mapping. Science of science research, 33(02):242-253.
[5] Chen, C.M., Hu, Z.G., Liu, S.B., Zeng, G.H. (2012) Emerging trends in regenerative medicine: a scientometric analysis in CiteSpace. Expert Opinion on Biological Therapy, 12(5).
[6] Zhang, H.W., Li, H., Wei, B.G., Zhou, T.H., Gong, L., Yang, H. (2017) Visualization map analysis of international soil and water conservation research. China soil and water conservation, (03):44-50+69.
[7] Zhang, H.W., Li, H., Wei, B.G., Zhou, T.H., Gong, L., Yang, H. (2017) Comparative econometric analysis of soil and water conservation research at home and abroad based on WoS platform. Soil and water conservation bulletin, 37(01):212-218+349.
[8] Wang, X.Y., Zhang, Q.S., Chen, W.Y. (2017) Visualization analysis of agricultural mechanization research based on CiteSpace. Chinese journal of agricultural mechanization, 38(02):145-149+158.
[9] Liu, Y.H., Hu, B.Z., Yan, J.W., Wang, K.C. (2002) Applicability of Housner model in seismic calculation of aqueduct. Chinese journal of hydraulic engineering, (09):94-99.
[10] Li, Y.C., Lou, M.L., Zhou, C. (2008) Vertical seismic effect analysis of large aqueduct. Earthquake engineering and engineering vibration, (02):102-107.
[11] Li, Z.N., Zhang, P.P., Zhu, X.P., Zhou, Z.G., Lu, J. (2010) Horizontal seismic response analysis of aqueduct structure considering pile-soil dynamic interaction. Chinese journal of civil engineering, 43(12):137-143.

[12] Bai, X.L., Wang, S.F., Wu, Z.Y., Ma, B. (2014) Analysis on the influence of thermal insulation plate on the temperature stress of large aqueduct structure. China rural water conservancy and hydropower, (06):154-157.

[13] Motta, D., Keenan-Jones., Garcia, M.H., Fouke, B.W. (2017) Hydraulic Evaluation of the Design and Operation of Ancient Rome's Anio Novus Aqueduct. Archaeometry, 59(6).

[14] Wang, B., Xu, J.G., Ren, K.B., Huang, L. (2010) Study on semi-active control of aqueduct structure considering fluid-structure coupling. Journal of Zhengzhou university, 31(04):89-92.

[15] Farshad Madani,Charles Weber. (2016) The evolution of patent mining: Applying bibliometrics analysis and keyword network analysis, 46.

[16] Francisco Javier Suarez,Rafael Bravo. (2014) Historical and probabilistic structural analysis of the Royal ditch aqueduct in the Alhambra (Granada). Journal of Cultural Heritage, 15(5).

[17] Zhai, Y.J., Zhu, T.S., Feng, G.W. (2013) Research and application of key technologies of Shahe aqueduct on the middle route of south-to-north water diversion project. People's Yangtze river, 44(16):1-6.

[18] Chen, H., Li, X.J., Yue, C.J. (2013) Analysis on the origin of cracks on the pier of Shahe aqueduct in the middle route of south-to-north water diversion project. China rural water conservancy and hydropower, (10):64-67.