IOP Conference Series: Earth and Environmental Science

PAPER • OPEN ACCESS

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To cite this article: Shuran Lyu *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **295** 042067

The Knowledge Map of Marine Energy

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Abstract. In order to analyze the research hotspots of marine energy, the Citespace III software was used to visually analyze marine energy. The database was collected on the criteria of marine energy as the keyword, and time span extended from 2007 to 2016 on the basis of the "Web of Sciencetm core collection database". The scientific knowledge maps analysis of marine energy has been conducted based on the Citespace III software, and analyzes the active countries/regions, institutions and research hotspots in related research fields. Active countries/regions, institutions and research hotspots of relevant research areas have been studied, and University of Chinese Academy of Sciences is at the first place of whole research institutions in marine energy field. Keywords co-occurrence analysis results show that coast, corrosion, kinetics, evolution and sediments have the highest centralities which are the focal keywords in marine energy research field. The results of the co-citation analysis show that wave energy, tidal stream energy, tidal stream turbines, and the microalgae biofuels are the hotspots in marine energy research field.

1. Introduction

As the world's energy consumption continues to rise, traditional energy is becoming scarce, and all coastal countries are to focus on the development of marine energy. Predictability of marine energy helps to prevent large-scale blackout accidents. It's vital to guarantee energy security and optimize energy structure for exploring and developing marine energy actively, therefore, marine energy research is the focus of scientific research at present stage, and it is particularly necessary to comb the research hotspot of marine energy research.

Scientific knowledge map, as an emerging research method, regards scientific knowledge as a measurement object, through data mining, information processing and graphics rendering to reveal the process of knowledge development and structural relationships. Chen[1] did visualization research to acquire the trends and the key nodes of knowledge development in regenerative medicine via CiteSpace. Kim [2]and Chen[3] analyzed the research literature on the recommender system from 1992 to 2014 based on CiteSpace, and the landmark articles in this field have been figured out. Mora[4] used CiteSpace to analyze the development of heat integration and heat e-gold network, and made a prediction of future research directions.

The remaining of the paper is organized as follows: In Section 2, the data and method were introduced. In Section 3, the analysis results were shown. In Section 4, we discussed the status of marine energy research. Finally, conclusion was drawn in Section 5.

2. Material and Methods

Firstly, we collected the data from the Web of Science database. Search conditions are as follows: the Web of Science Core Collection as a database[5]; "marine energy" as a keyword of topic, time span is from 2007 to 2016; literature type is "article"; subject category is "oceanography", "environmental sciences", ""geology", "green sustainable science technology", "engineering chemical", "engineering environmental", "thermodynamics", "nuclear science technology", "engineering marine", "engineering mechanical"[6]. Eventually, 3019 records are retrieved. We did a preliminary analysis via Histcite software which shows that there are 8880 authors, 290878 citations and 14403 keywords in 3019 records. Secondly, bibliometric and visual analysis has been done via CiteSpace III software database collected.

3. Results

3.1. The articles distribution of countries / regions and institutions

Figure 1 is a heat map which shows the geographical distribution of research institutions in marine energy research. The geographic information is generated through function of "Geographical" in CiteSpace III software and the map is drawn in Google Fusion Tables. As the map shows, USA, Europe and China are the most active areas as for marine energy research. It is clear that America, Europe and China are leading the study in this field.

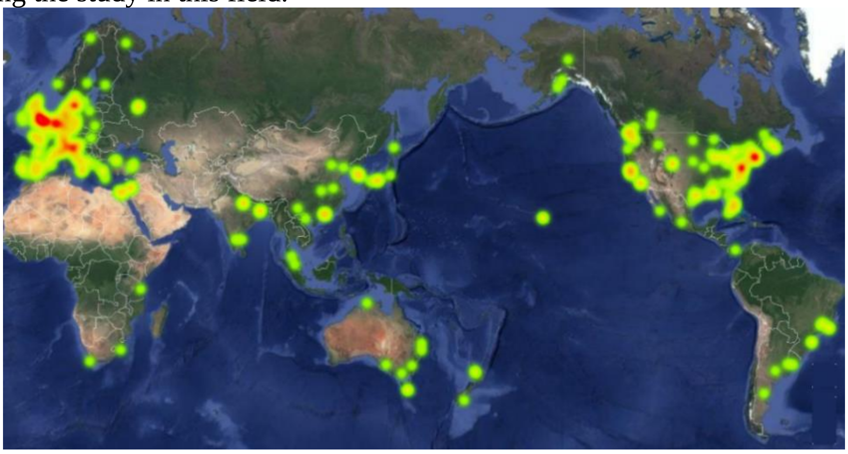

Figure 1: Geographical distribution of scientific research institutions

The top 10 countries with the most publications are shown in Table 1. The top 10 institutions of publications are shown in Table 2.The first three countries are the United States of America (624), China (465), and Britain (391). As is shown, top 3 countries are ahead of the publications than others. While the first three institutions are University of Chinese Academy of Sciences (73), Oregon State University (40), and Harbin Engineering University (38).

Table 1: Rank of countries of issued amount

Rank	Country	Amount
1	United States of America	624
2	China	465
3	Britain	391
4	Italy	173
5	Spain	156
6	France	141
7	Canada	137
8	Australia	107
9	Japan	103
10	Germany	102

Table 2: Rank of institutions of issued amount

Rank	Institutions	Amount
1	University of Chinese Academy of Sciences	73
2	Oregon State University	40
3	Harbin Engineering University	38
4	University of Southampton	38
5	University of Exeter	33
6	Plymouth University	32
7	University of Edinburgh	31
8	University of Michigan	31
9	Norwegian University of Science and Technology	30
10	Tsinghua University	27

3.2 Research hotspot in the field of marine energy

The each indexed article will be added a topic label which includes a total of 151 tags as a certain category on web of science. The research hotspot can be excavated under the detection of nodes through the function of Citation burst in CiteSpace III. We figure out the hotspots subjects and keywords by the method mentioned above.

3.2.1. The co-occurrence analysis of keywords

We chose threshold at criteria as top 200 per year and map generating method of "minimum spanning tree". The analysis result is shown in Figure 2, 1071 nodes and 1816 lines of the co-occurrence patterns are drawn. The results of clustering are reasonable since the value of Q is 0.4255 (bigger than 0.3) and the value of S is 0.5602 (bigger than 0.5).

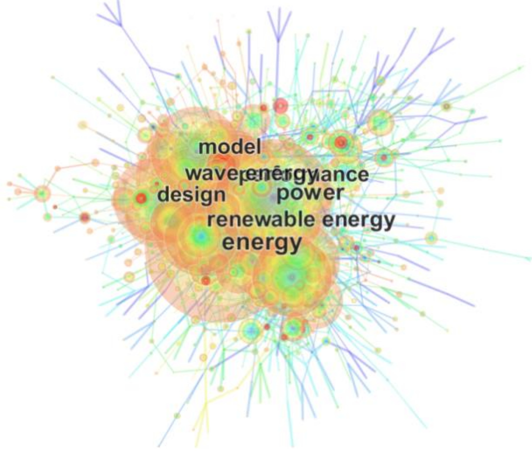

Figure 2: Keywords co-occurrence patterns.

The top 20 centrality keywords are coast, corrosion, kinetics, evolution, sediments, growth, power, wave energy, systems, dynamic fracture, microalgae, marine-sediments, temperature, basin, renewable energy, performance, design, flow, life-cycle assessment and efficiency. Coast, corrosion, kinetics, evolution and sediments are the hotspot keywords in the field of marine energy since they have the highest centrality among all the keywords[7]. Top 20 centrality keywords are shown in Table 3.

Table 3: Rank of institutions of issued amount

Rank	Centrality	Frequency	Keywords	Rank	Centrality	Frequency	Keywords
1	0.12	16	coast	11	0.06	85	microalgae
2	0.1	35	corrosion	12	0.06	39	marine-sediments

3	0.09	24	kinetics	13	0.06	35	temperature
4	0.08	41	evolution	14	0.06	34	basin
5	0.08	35	sediments	15	0.05	109	renewable energy
6	0.08	35	growth	16	0.05	95	performance
7	0.07	120	power	17	0.05	88	design
8	0.07	98	wave energy	18	0.05	44	flow
9	0.07	77	systems	19	0.05	44	life-cycle assessment
10	0.07	6	dynamic fracture	20	0.05	33	efficiency

3.2.2. The co-occurrence analysis of articles
As the database is collected from 2007 to 2016, we do the further analysis setting time slice as 1 year. The results as shown in Figure 3are that the value of N in the citation co-citation map is 1473, the value of E is 1766 and the density is 0.0016[8]. The clustering result is reasonable for the value of Q is 0.5371 (bigger than 0.3) and the value of S is 0.5688 (bigger than 0.5).

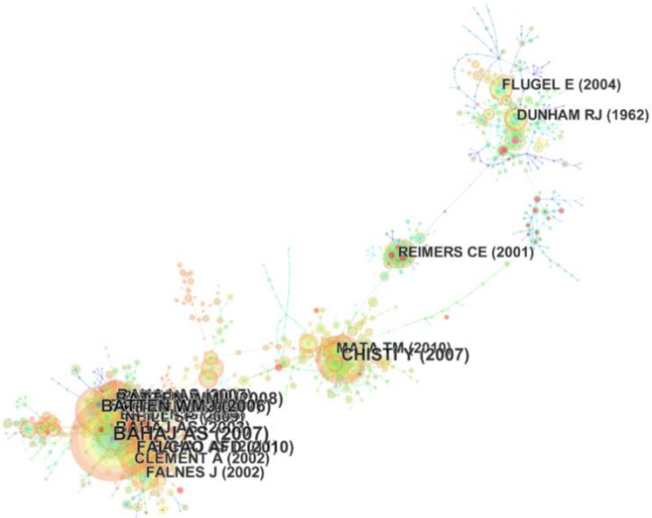

Figure 3: Citation co-citation map

4. Discussion
We tried to locate the hot spot of marine energy research via the function of “burst detection”. The co-citation analysis result shows that 60 of 1473 nodes have appeared burst[9]. The citation burst results are sorted in descending order according to the intensity. Top 10 articles of burst from 2007 to 2016 are shown in Table 4.

Table 4: Top 10 articles of burst from 2007 to 2016

No.	Articles	Intensity	Begin	End
1	Impact of tidal energy converter(TEC) arrays on the dynamics of headland sand banks	4.3534	2014	2016
2	Performance assessment of tidal stream turbines: A parametric approach	3.4620	2014	2016
3	The impact of tidal stream turbines on large-scale sediment dynamics	3.4548	2014	2016

4	Marine renewable energy: The ecological implications of altering the hydrodynamics of the marine environment	3.3611	2014	2016
5	A review of wave energy converter technology	3.3180	2014	2016
6	Assessment of the impacts of tidal stream energy through high-resolution numerical modeling	3.3180	2014	2016
7	A 10 year installation program for wave energy in Ireland: A case study sensitivity analysis on financial returns	3.1662	2014	2016
8	An outlook on microalgal biofuels	2.8742	2012	2014
9	Biomethanation potential of macroalgaeUlva spp. and Gracilaria spp. and in co-digestion with waste activated sludge	2.8684	2014	2016
10	Wave energy potential along the Death Coast (Spain)	2.8606	2014	2016

3 of the top 10 articles are related to the wave energy (No.5, No.7, and No.10).

·Article No.5 introduced the status of wave energy utilization, evaluated the efficiency of the wave energy converter technology, and made some suggestions for the future development of the wave energy[10].

·Article No.7 assessed the supply-demand rate of wave energy in Ireland, and calculated the economic benefits of the installation of wave energy devices.

·Article No.10 analyzed the wave energy resources of the death coast based on the SIMAR-44 data set. Measured the near shore wave energy by using the model of coastal wave propagation, and evaluated the wave energy potential along the death coast[11].

2 of the top 10 articles are related to the tidal stream energy (No.1, No.6).

·Article No.1 studied the effect of large-scale exploitation of the tidal stream resource on the dynamics of headland sand banks through a series of model experiments.

·Article No.6 simulated the power generation under the high flow and the low flow by using the high-resolution model, and analyzed the effect of hydrodynamics on the tidal stream energy.

2 of the top 10 articles are related to the tidal stream turbines (No.2-3).

·Article No.2 proposed a parametric method to evaluate the performance of tidal stream turbines, and presented a procedure to compare the performance of different tidal stream turbines.

·Article No.3 simulated the effect of tidal stream turbines on sediment dynamics between the regions of strong tidal asymmetry and the tidal symmetry[12].

2 of the top 10 articles are related to the microalgae biofuels (No.8-9).

·Article No.8 took a comparative analysis of the biochemical methane potential of 4 species of Ulva and Gracilaria genus, and analyzed the effect of anoxic marine sediment on methane production.

·Article No.9 introduced the industrial production technology of the microalgae biofuels, and proposed a sustainable and economical way to develop it[13].

The article No.4 elaborated the wide range of renewable energy resources in the marine environment, and analyzed the ecological implications of marine renewable energy installations on the marine environment[14].

In summary, the hotspots of marine energy mainly centralized in the wave energy, tidal stream energy, tidal stream turbines, and the microalgae biofuels .Furthermore, the hotspots of wave energy research contain the wave energy potential measuring, the wave energy economic benefit analysis, and the efficiency calculation of wave energy converter; the hotspots of tidal stream energy research contain the influencing factors of tidal stream energy, and the effect of large-scale exploitation of the tidal stream resource on sediment dynamics; the hotspots of tidal stream turbines research contain the performance evaluation of tidal stream turbines, and the effect of tidal stream turbines on marine sediment dynamics; the hotspots of microalgae biofuels contain the microalgae biofuel potential analysis, and the industrial production technology of the microalgae biofuels.

5. Conclusions

The paper drew the scientific knowledge maps of marine energy research, and the research status has been analyzed. Conclusions are as follows.

(1) The USA, Europe and China are in the leading position in the field of marine energy research, and the University of Chinese Academy of Sciences, Oregon State University, and Harbin Engineering have played a significant role in the research and development of university energy research field.

(2) Coast, corrosion, kinetics, evolution and sediments have the highest centrality in keywords co-occurrence analysis which is the focal keywords in marine energy research field.

(3) The hotspots of marine energy research field are energy, tidal stream energy, tidal stream turbines, and the microalgae biofuels at present.

Acknowledgment

This study is supported by "Beijing Natural Science Foundation of China (Grant: 9162001)" and Capital University of Economics and Business, Graduate Technology Innovation Project.

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