Information Processing and Management 53 (2017) 705–720

Contents lists available at ScienceDirect

Information Processing and Management

journal homepage: www.elsevier.com/locate/infoproman

Intellectual structure of knowledge in iMetrics: A co-word analysis

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ARTICLE INFO

Article history:
Received 13 August 2016
Revised 1 February 2017
Accepted 2 February 2017
Available online 13 February 2017

Keywords:
iMetrics
Information metrics
Co-word analysis
Strategic diagram
Knowledge structure

ABSTRACT

As an iMetrics technique, co-word analysis is used to describe the status of various subject areas, however, iMetrics itself is not examined by a co-word analysis. For the purpose of using co-word analysis, this study tries to investigate the intellectual structure of iMetrics during the period of 1978 to 2014. The research data are retrieved from two core journals on iMetrics research (*Scientometrics*, and *Journal of Informetrics*) and relevant articles in six journals publishing iMetrics studies. Application of hierarchical clustering led to the formation of 11 clusters representing the intellectual structure of iMetrics, including "Scientometric Databases and Indicators," "Citation Analysis," "Sociology of Science," "Issues Related to Rankings of Universities, Journals, etc.," "Information Visualization and Retrieval," "Mapping Intellectual Structure of Science," "Webometrics," "Industry–University–Government Relations," "Technometrics (Innovation and Patents), "Scientific Collaboration in Universities", and "Basics of Network Analysis." Furthermore, a two-dimensional map and a strategic diagram are drawn to clarify the structure, maturity, and cohesion of clusters.

1. Introduction

Metric studies have been developed as a subsidiary branch of Library and Information Science over time. Various concepts of the field, such as bibliometrics, scientometrics, informetrics, webometrics, and technometrics are found in LIS journals. As proposed by Milojevic and Leydesdorff (2013), these concepts have similar goals and methods, and can be grouped under a research subset titled *information Metrics* or *iMetrics*. Using co-citation, bibliographic coupling, and co-word methods for exploring research topics in LIS, Chang, Huang, and Lin (2015) found that iMetrics was the most significant topic in LIS subsets. As an independent trend, iMetrics is not only emerging, but is also evolving into its socio-cognitive nature (Milojevic & Leydesdorff, 2013). By the application of common techniques in iMetrics, one can collect and evaluate data onto research trends and researcher status in different disciplines while evaluating research output concurrently (Hunter, 2009; Stidham, Sauder, & Higgins, 2012; Webster, 2011; Weightman & Butler, 2012; Zyoud, Al-Jabi, & Sweileh, 2014). Due to its applications, iMetrics is also employed by researchers in other disciplines.

Considering the gradual emergence and development of iMetrics, a comprehensive macro image of research on iMetrics should be drawn, and its scientific development needs to be explored, in order to enquire into its advancement in a temporal

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http://dx.doi.org/10.1016/j.ipm.2017.02.001
0306-4573/

continuum. One of the techniques employed for analyzing the knowledge structure of diverse fields is studying the relation between words used in various parts of a document, including the title, abstract, keywords, etc. This technique is called "co-word" analysis, and is a well-established and effective approach, that can show the intellectual structure of a research field (Ronda-Pupo & Guerras-Martin, 2012). It is an approach used for establishing a subject similarity between two documents (Rokaya, Atlam, Fuketa, Dorji, & Aoe, 2008). Co-word analysis presumes that a group of aggregated keywords could indicate underlying themes, and that co-occurrences of keywords could show the associations with the underlying themes (Hu & Zhang, 2015). By employing co-word analysis, one can determine the major topics in a field, in addition to its semantic structure and evolution over the time. In co-word analysis, it is supposed that frequent words have more meaning of an effect on a field than the less frequent ones. It help in determining both the emerging and the developed subject clusters to suggest the research path in the future (Lee & Su, 2010).

The frequency of word occurrence is a principal measure in content analysis. This measure is used for exploring the major topics in a research field by giving attention to highly frequent words. In other words, the frequency of a given word is an indicator of the importance of the word and its notion. Keywords have the potential for effectively describing the contents of a paper. If two keywords occur simultaneously in a paper, they have a semantic relationship (co-word/co-occurrence). The higher co-occurrence frequency of two keywords implies the more correlative they are (Liu, Hu, & Wang, 2012).

Like other co-occurrence analyses, particularly that of co-citation, co-word analysis is one of the fundamental methods for demonstrating the relationship among concepts. It is used to determine research frontiers in academic disciplines and explore knowledge structures in various research fields (Hu, Hu, Deng, & Liu, 2013; Ravikumar, Agrahari, & Singh, 2015; Stegmann & Grohmann 2003; Xie, 2015). By studying and analyzing the co-occurrence of keywords in the papers of a certain field, one can draw an instant picture of interesting topics within the field (Ding, Chowdhury, & Foo, 2001). In other words, there are collections of concepts in each scientific and technological field that build its knowledge structure. These concepts are expressed as keywords that are made for describing and naming them. Exploring concepts and the relationship between them by means of word relations in documents eases the creation of a scientific map.

As stated earlier, co-word analysis is one of the commonest approaches to iMetrics which allows us to reveal the emerging thematic clusters and the changes of traditional thematic clusters in order to forecast the path of coming researches (Lee & Su, 2010), and to study it's conceptual and semantic relations (Leydesdorff & Welbers, 2011). In addition, the intellectual structure of scientific domains can be examined as forming a cluster via clustering techniques and multidimensional scaling (Cho, 2014; Yan, Lee, & Lee, 2015). The data relating to co-word analysis as well as the data relating to other co-occurrence analyses (such as co-citation and co-authorship) have the potential of being analyzed using multidimensional scaling, network and cluster analysis and to show the structure of knowledge in a given field (Allendoerfer, 2008).

Finally, the use of novel technologies in network analysis can reveal the ruling relationships in co-word analysis and deeply examine these complex relationships and depict the structure of knowledge in a specific field. Studying the knowledge structure can be fruitful for both researchers and science policymakers. Although co-word analysis is a kind of iMetrics technique, iMetrics itself is not examined through co-word analysis using relatively complete records. For this purpose, i.e. using co-word analysis, this study aims at investigating the intellectual structure of iMetrics during the period from 1978 to 2014. This paper tries to answer the following questions:

1. Can the intellectual structure of iMetrics be visualized and represented using hierarchical clustering?
2. Can the intellectual structure of iMetrics be visualized and represented using multidimensional scaling?
3. How are topics and clusters of iMetrics represented by the strategic diagram in terms of maturity and development?

2. Literature review

Since its introduction by Callon, Courtial, Turner, and Bauin (1983), numerous researchers have used co-word analysis to study various fields. Some of these fields include information system management (Culnan, 1986), information retrieval (Ding et al., 2001), robot technology (Lee & Jeong, 2008), aerosol research (Xie, Zhang, & Ho, 2008), obstructive sleep apnea (Huang, 2009), distance education (Ritzhaupt, Stewart, Smith, & Barron, 2010), solid waste (Fu, Ho, Sui, & Li, 2010), risk assessment (Mao, Wang, & Ho, 2010), global climate change (Li, Wang, & Ho, 2011), stem cells research (An, & Wu, 2011), library and information science (Astrom, 2002; Hu et al., 2013; Sugimoto, Li, Russell, Finlay, & Ding, 2011; Wang, Zhang, & Wei, 2011; Zong et al., 2013), economics (Vaughan, Yang, & Tang, 2012), consumer behavior research (Muñoz-Leiva, Viedma-del-Jesús, Sánchez-Fernández, & López-Herrera, 2012), digital libraries (Dong, 2009; Liu et al., 2012), competitive intelligence (Xiang, & Qiu, 2012), knowledge management (Sedighi, & Jalalimanesh, 2014), engineering (Wu, & Leu, 2014), human–computer interaction (Liu et al., 2014), sociology of science (Dehdarirad, Villarroya, & Barrios, 2014), domestic knowledge discovery (Wang, Liu, & Sheng, 2014), cancer research (Xie, 2015), creativity (Zhang, Zhang, Yu, & Zhao, 2015), social networks in marketing (Wang, Zhao, & Wang, 2015b), computer sciences (Hu & Zhang, 2015; Wang, Zhang, & Liu, 2015a), Internet of Things (Yan et al., 2015) and computer games (Melcer et al., 2015).

In spite of numerous research conducted by co-word analysis to diverse scientific fields, few have considered iMetrics and related fields on their own. In one of the first studies of its kind, Courtial (1994) studied iMetrics (scientometrics) by using co-word analysis for 595 papers published between 1988 and 1993. The results revealed some clusters including, among others, "databases", "citation analysis", "author productivity", "scientific evaluation", "law of scattering", "bibliometrics", "co-word analysis", and "journal impact factor". The results also showed that during 1988–1990, iMetrics developed