Theory Method and Principle of Metrics Science

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Abstract

Measurement is an integral part of modern science. This paper proposed a comprehensive statistical overview of the terms librametrics, bibliometrics, scientometrics, informetrics, webometrics and knowledgometrics refer to fields related to the study of the dynamics of disciplines as reflected in the production of their literature. These terms are used to describe similar and overlapping methodologies. The origins, historical survey, scope, application and development of each of these terms are presented in this study. Several method and principles of metrics studies have been discussed. Finally paper concluded that the main research areas of each stage concentrated on the major topic like citation analysis has been a core research area during every stage; research interest has shifted from theoretical research to applied aspect; visualization methods and scientific mapping have attracted more and more attention and will become a main research area of scientometrics. The inclusion of webometrics expands the field of bibliometrics, as webometrics inevitably will contribute to further methodological developments of web-specific approaches and knowledgometrics adds new concept to the field.

Keywords: *Bibliometrics, Scientometrics, Knowledgometrics.*

Introduction

Bibliometrics to Knowledgometrics refer to quantitative techniques applicable to measure the records of human communicated literature. Over the years,

several new terms have appeared on the horizon representing quantitative studies in library and Information Science.The History of comparative Anatomy Part-I: A Statistical Analysis by Cole and Eale (1917) is considered to be the first bibliometric study in 1917. Hulme (1923) was the first to use the expression 'statistical bibliography' in 1923; later several studies have been conducted. Gross and Gross (1927) study is considered to be the third study in the field based on citations. After Hulme, the term statistical bibliography was used by Henkle in 1938 in his article "The periodical literature of Biochemistry" and Gosnell (1944, 1943) in his dissertation in 1943, and later in his article 1944. The historical development of the term statistical bibliography has been traced by Witting (1978) in a foot note. As the term was considered very clumsy, not very descriptive, and can be confused with statistics itself or bibliographies on statistics.

Librametrics

In 1948 at the Aslib's (1949) conference in Lamington Spa, Ranganathan introduced the term Librametry for the first time. He suggested to develop librametry on the lines of biometry, econometry, and psychometry. His suggestions were avidly welcomed at the conference by Bernal and others. The term Librametrics has two roots: Libra and Metry. The word 'Libra' connotes 'library' and 'metrics' means measurement. Further, as the librarian of the Madras University Library, he practiced various librametric techniques way back in 1925, in order to solve day today library problems and to streamline the day-to-day library activities, services for their clientele and also for the betterment of library professional as a whole.Ranganathan (1969) in his paper presented in the DRTC 7th Annual Seminar (1969) suggested a few examples of statistics to library science. Based on his experience and the experiments carried out at the Documentation Research and Training Centre outlined the applications for Librametrics:

Determination of the strength of library staff; Disposition of library staff for circulation work during different library hours; Disposition of library staff for reference service during different library hours Organization of Library System; Establishing the distinction between "service library" and "dormitory library"; Design of library building, fittings, and furniture; 6. Book selection;

Absolute syntax and facet syntax in relation to classification; Length of class number; and Variation in style in writing catalogue entries. Thelibrametrics studies if developed properly as suggested by Ranganathan could become a good indicator for measuring various activities of librarianship both quantitatively and qualitatively.

Bibliometrics

The term bibliometrics was first coined by Prichard (1989) in 1969 in preference to existing terminology 'statistical bibliography'. The word "Bibliometrics" has two roots: 'biblio' and 'metrics. The term 'biblio' is derived from the combination of Latin and Greek word 'biblion' equivalent to Bylos, meaning book, paper which in turn was derived from the word Bylos, a city of Phenonicia, a noted city for export trade in paper. The word 'metrics', on the other hand, indicates the science of meter, i.e., measurement and is derived either from Latin or Greek word 'metricus' or 'metricos' respectively, each managing measurement. This term was coined for the first time by Alan Pritchard. He used the term to describe all 'studies which seek to quantify the process of written communication'. Fairthorne (1969) also defined it as 'the quantitative treatment of the properties of recorded discourse and behaviour pertaining to it.

Bibliometric studies include studies of the growth of the literature in some subject, how much literature is contributed by various individuals, groups, or organisations or countries; how much exists in various languages; how the literature on some subject is scattered (e.g., over documentary types, language journals); and how quickly the literature on some subject becomes out-of-date (Studies of obsolescence). Another important group of bibliometric studies relates to what sources author cite. Day-byday this study is attaining sophistication and complexity, having national, international and inter disciplinary character. The backbone of Bibliometrics lies in its sound theoretical foundation most effectively laid by some pioneers like Lotka (1926), Bradford (1934), Zipf (1949), Duck J de Sola Price (1963), Bookstein (1976), Mandelbrot (1952), Brookes (1968,1969a,1969b,19905), Garifield (1976a, 1976b), Egghe (1990) and many others, and their techniques are capable of throwing light on various complicated problems faced by information scientists to

quantify the process of written communication. The bibliometric tools can be applied to:

1. Studies related to scattering of articles 2. Geographical distribution, language-wise distribution, institution-wise distribution of articles 3. Age distribution of documents 4. Use of information storage and retrieval 5. Application, in the library use studies. 6. To study the trends in research and identifying the growth of literature. 7. To identify authorship trends in documents on various subjects. 8. To measure the utility of library services 9. To evaluate the library collection, etc.

These definitions of librametrics and bibliometrics show that librametrics primarily aims at the quantitative analysis of the management of libraries and bibliometrics is limited to recorded knowledge. The publication in both the fields suggests that in librametrics and bibliometrics, one examines the statistical distributions of the processes relating to the utilization of documents, Library staff, and Library users, to establish a theory for the structural aspects of library. Bibliometrics and librametrics may therefore be commonly defined as areas in which one studies 'information processes and information handling in libraries and information centres by quantitatively analysing the characteristics and behaviour of documents, library staff, and library users.'

Scientometrics

Derek John de Solla Price (1963) was treated as the father of scientometrics. He was a physicist, a historian of science, an information scientist and worked as a teacher of applied mathematics at Raffles College (which was to become part of the University of Singapore in 1948). It was there that he formulated his theory on the exponential growth of science, an idea that occurred to him when he noticed the growth in the Philosophical Transactions of the Royal Society between 1665 and 1850. He had the complete set in his home while Raffles College had its library built. Further, Garfield's contribution (1976a, 1976b) to scientometrics is quite significant; his contributions are evolved through his Science Citation Index. Merton (1952) also had his view on scientometrics.

In the 1960s, particularly in Eastern Europe, the term "scientometrics" was used to denote "measurement of informatics process." The term informatics was then widely used to mean "documentation / information handling activities;" obviously, there is not much difference between bibliometrics of the West and the scientometrics of the East Europe. The term Scientometrics originated as a Russian term for the application of quantitative methods to the history of science, which studies the quantitative aspects of science. It was suggested by Dolrov and Kormoni (1969), often used with same meaning as the bibliometrics to mean 'the application of quantitative methods to history of science'. This term came into prominence with the founding of the journal named 'Scientometrics' by T. Braun in 1977, originally published in Hungary and currently from Amsterdam, The Netherlands. Scientometrics used to mean communication process in science including socio-cultural aspects, and appears to be almost synonymous with science of science with more stress on its quantitative aspects.

It is also used as a generic term for a system of knowledge, which endeavours to study the scientific (and technological) system by using a variety of approaches within the area of science and technology studies. Scientometrics is concerned with the quantitative features and characteristics of science and scientific research. Emphasis is placed on investigations in which the development and mechanism of science are studied by statistical mathematical methods. Scientometrics is now considered as a part of the sociology of science and is applied to science policy making. Thus Scientometrics involves studies in:1. Sociology of Science, 2. History of science, 3. Growth of literature 4. Behaviour of scientists, 5. Science indicators.

Informetrics

Information, in its most restricted technical sense, is a sequence of symbols that can be interpreted as a message. Information can be recorded as signs, or transmitted as signals. Information is any kind of event that affects the state of a dynamic system. Conceptually, information is the message being conveyed. Informetrics is the study of quantitative aspects of information. This includes the production, dissemination and use of all forms of information, regardless of its form or origin.

According to Brookes (1990) the word 'Informetrics' was first proposed by Otto Nacke of West Germany in 1979. FID constituted a committee with this name and Nacke was its first Chairman. Rajan (Rajan&Sen 1985), the next Chairman of the Committee, reformulated the objectives of informetrics as to (Almi&Ing 1997) provide reliable data for research and development, policy-making, planning; to evaluate institutions, projects, articles, products, and other academic activities, and (toidentify or to develop the techniques to trace the origins and development of concepts. Ravichandra Rao (1985, 1993, 1996) in a short communication on "Informetricsvisà-vis Bibliometrics: Scope and its Development", mentioned that it is a field wherein the flow of information and behavior of information are analysed, measured and quantitative relationships are established. It is a scientific field wherein the developments of measurement of impact of information are assessed continuously. Bibliometrics may therefore be treated as synonymous to informetrics having a scope to analyse quantitative characteristics of information. An FID Committee constituted with broadly defined objectives in the provision of research and technical data subsequently gave this name.

Third International conference on Informetrics was held in Bangalore,India in 1991. 'Informetrics' was used as a generic term to mean "The use and development of a variety of measures to study and analyse several properties of information in general and documents in particular the study of the quantitative aspects of information in any form, not just records or bibliographies. Informetrics is the study of quantitative aspects of information. This includes the production, dissemination and use of all forms of information, regardless of its form or origin. As such, informetrics encompasses the fields of which studies quantitative aspects of science. It is mostly concerned with development of models to explain and identify the various characteristics of the literature. It also discusses scientific productivity, collaborative research, etc.

Webometrics

The term webometrics was first coined by Almind and Ingwersen (1997) "the study of web-based content with primarily quantitative methods for social science research goals using techniques that are not specific to one field of

study" (Thelwall, 2009), which emphasizes the development of applied methods for use in the wider social sciences. The purpose of this definition was to help publicize appropriate methods outside of the information science discipline rather than to replace the original definition within information science. The science of webometrics (also cybermetrics) tries to measure the World Wide Web to get knowledge about the number and types of hyperlinks, structure of the World Wide Web and usage patterns. According to Björneborn and Ingwersen (2004), the definition of webometrics is "the study of the quantitative aspects of the construction and use of information resources, structures and technologies on the Web drawing on bibliometric and informatics approaches

Cybermetrics is one of the recently emerged fields in the line of metric studies. It has gained much popularity since the mid-1990 with the advent of Information Technology. As it is mainly concerned with the computer-science-based approaches, it has superseded all other metric studies in this Internet Era. Cybermetrics is proposed as a generic term for "The study of the quantitative aspects of the construction and use of information resources, structures and technologies on the whole Internet drawing on bibliometric and informetric approaches." Cybermetrics thus encompasses statistical studies of discussion groups, mailing lists, and other computer – mediated communication on the internet, including the www. Besides covering all computer-mediated communication by using internet applications, this definition of cybermetrics also covers quantitative measures of the internet backbone technology, topology and traffic. The breadth of coverage of cybermetrics implies large overlaps with proliferating computer-science-based approaches in analyses of web contents, link structures, and web usage and web technologies. The Webometrics which studies are the quantitative aspects of the World Wide Web. The Cybermetrics which is similar to webometrics, but broadens its scope which include namely the electronic resources. Research of all network-based communications by using informetrics or other quantitative measures is called webometrics.

There has been a revolutionising symbiosis between computer and communication technologies in the west over the past ten years. The invention of World Wide Web (www) a part of the 'INTERNET', which is the

mother of networks, has practically webbed the information globally under less than one roof. There has been a shift in navigational approaches from syntactical to semantic (i.e., from sentences to words), as an ever increasing number of research institutes, universities and business organisations are currently providing information about themselves in the form their articles, publications, reports, catalogues and other information resources on the INTERNET in general and the www in particular. This is now becoming the accepted method of disseminating and sharing information resources in hypermedia. Information science research has also changed, with much research to find out, how the new technologies are being used, particularly e-mail and the web. In addition to user studies there have been attempts to extract new kinds of information from the web. Being a global document network initially developed for scholarly use, it is now inhabited by a diversity of users, and the web constitutes an obvious research area for bibliometrics, scientometrics and informetrics.

Altmetrics

Altmetrics or alternative metrics for measuring research impact emerged as a subfield of webometrics (Priem, 2011). It is largely depending on social web has expand the scope of webometrics. Application designers should continue to build systems to display altmetrics, develop methods to detect and repair gaming, and create metrics for use and reuse of data ultimately. With the setting up of a metric to be used for performance assessment; researchers will modify their behaviour to optimize their performance. By promoting their work through publishing, giving talks at meetings, doing interviews, things like that, it helps raise awareness of their work and apparently increases its impact. The focus of Altmetrics is the attention received by their work in social media namely Facebook, Twitter, blogs, forums, micro blogs, social networks, products/services reviews, virtual world and others. No one can claim that Altmetrics is perfect but it is one way forward in the quest for perfection (Sangam, 2015).

Knowledgometrics

Knowledge metrology is an interdisciplinary integrated research topic."Knowledge Metrology is the scientific evaluation of Wuhan University,

China Research centre in bibliometrics, information metrology, scientific metrology, network metrology etc. It is having its own theory, method and application (1-4-2017).It further studies the whole human knowledge system as research object, and study the social ability of knowledge, and the social relationship of knowledge through the quantitative analysis and computing technology. In addition to the important research of Wuhan University. Early in 1998, the discipline planning of the "knowledge metrology" was put forward in the International Symposium on Research Evaluation and Scientometrics held in Beijing, the idea oriented from the concept of "element of knowledge" created by Hongzhou Zhao (1999).Another notable study was The "element of knowledge" theory put forward by Hongzhou Zhao was published in Chinese Journal in 1990, and which has been re-visited in detail in Chapter 2 of Turning Points-The Nature of Creativity written by Chaomei Chen (2011) The emerging of "Knowledge domain mapping", "Knowledge discovery" "text mining" used in knowledge management are all the important development in knowledgometrics. Apart from this, China has big contribution from WISE Lab and other Research Institutes and Universities.

Theoretical Principles and Science Concepts

Bibliometrics is concerned with theoretical and philosophical foundations. Some of the important studies on theoretical and philosophical foundations are in the area of: Law of Scattering (Bradford's law); Author productivity (Lotka's law) ; Word productivity (law of Least Efforts); Impact Factor of Journal; H-index , Success-breeds success phenomenon ; Circulation theory ; Information Product and Processes (IPP) and Duality in IPPs. There are other theoretical studies, especially in the area of circulation theory, citation analysis, sources-items relation, etc. Some of these are discussed in: Quantitative Method for Library and Information Science. By I K Ravichandra Rao. Wiley-Eastern. New Delhi. 1983. Proceedings of the ISSI Conferences in Scientometrics and Informetrics (held bi-annually since 1987); Introduction to Informetrics: Quantitative Methods in Library, Documentation and Information Science. By Leo Egghe and Ronald Rousseau. Elsevier. Amsterdam. 1990 Power Laws in the Information Production Process: Lotkai an Informetrics. By Leo Egghe. Elsevier. Amsterdam. 2005. Scientometrics: Quantitative Methods for Library and Information Science. By S.L.Sangam, Bangalore,

ContentCrafts, 2015.Informetrics: Thoery,methods and applications by QiuJunping was published by Wuhan University Press in January 2007.

The early development stage has five main fields. The arrangement reflects the principal components variance contribution as follows: (1) scientific literature structure, citation analysis theory; (2) bibliometric laws of quantitative and statistical; (3) application of citation analysis, scientific cooperation; (4) discipline analysis; (5) evaluation of scientific research. During the gradual maturing stage also contains five main themes: viz. (1) citation theory, basic scientific research evaluation; (2) scientific collaboration; (3) co-citation, science mapping; (4) scientometric indicators, application of bibliometrics; (5) scientific elite. Seven focusing topics arises during the golden development stage: (1) application of citation indexes, patent analysis; (2) assessment of research performance; (3) scientometrics classic probability distribution and its application; (4) social network analysis and scientific research collaboration, the university ranking; (5) hirsch-type index; (6) research collaboration and national research performance; (7) application and visualization of scientometric indicators (Zhao, & Zhao,2014).

Studies based on citation data have several limitations

Citation studies are mostly dependent on data from databases such as Web of Science, SCOPUS, etc. which cover only a limited number of journals and its coverage does not remain constant since new journals are added regularly and some are dropped, Solutions to problems of eliminating self-citation are cumbersome.

A primary objective of bibliometric research is the development of a general and systematic set of theories from which hypotheses can be generated and tested. Scientometric studies vary from each other from several points of view. They adopt different methods of data collection as well as different techniques. Even there are no universally accepted terminologies. In addition, use of algebraic symbols varies from one study to another. Under these circumstances, it would be difficult to think of “bibliometric or scientometric standards” let alone formulating them.Most of the scientometric studies are empirical in nature. In such circumstances, to reproduce the research, one has to repeat the survey and analyse the data right from the

beginning. Even then, we may not get the same result. In natural sciences, it is possible and quite common that research may be repeated in laboratories. But in social sciences this is not only difficult, but is not possible. Further, an important cause of the overall unreliability and therefore a cause of invalidity in any basic research in the social sciences are due to space and time factors. It is therefore difficult to reproduce the results of research.

The fact, whether we call our research area as bibliometrics or scientometrics or informetrics or Knowldgemetrics most of the topics we deal with are: Quantitative aspects of library and information studies, especially use and user studies, growth of collection, age distribution of documents, circulation statistics, etc. Journal productivity (by coverage, by use, by citation, cost-effectiveness measures, impact factor, h-index, sources of citations, immediacy of citations, age of sources cited, coverage in databases, etc.) Measures of productivity or author productivity, including studies related to multiple authorship (number of publications. cost-effectiveness measures, impact factor, h-index, reprints request, photo copies made, sources of citations, immediacy of citations, number of reviews, adoption rates (text books) etc.) Obsolescence and growth of literature, Co-citation, bibliographic coupling, co-word analysis, rank distribution of words, etc. Quantitative analyses of science (science indicators — country-wise, language wise, subject-wise, etc.) Identifying relationships among various disciplines, structure of subjects, etc. Evaluation of scientific research (by institutions, by individuals, by countries, etc.)

Acceptance of a single term to define a subject and acceptance of its scope are necessary for any scientist. Otherwise, it is difficult to include it in a course syllabus. It is also difficult to get research grant from different agencies. It helps us in identifying the research groups especially at national and international levels. At present, the term ‘scientometrics’ is used as synonym to both ‘bibliometrics’ and ‘informetrics’.

In order to encourage communication and exchange of professional information in the field of scientometrics and informetrics, a Society, called ‘the International Society for Informetrics and Scientometrics’ (ISSI) was founded in 1993. It is an association of professionals active in the emerging

interdisciplinary fields of informetrics, bibliometrics / scientometrics, technometrics and webometrics. Among its membership are scientists from over 30 countries representing all five continents. The Articles of Association state that the aim of ISSI is the advancement of the theory, methods and explanations through the following two main streams:

1. Quantitative Studies related to Scientific, technological and other scholarly substantive information. Science of science and technology, social sciences, arts and humanities. Generation, diffusion and use of information. Information systems, including libraries, archives and databases
2. Mathematical, Statistical, and Computational Modelling and Analysis of Information Processes.

Associations/ Institutions/Organizations

Garfield founded the Institute for Scientific Information (ISI) in 1955. In addition to the ISI's Science Citation Index, a system used to chart connections between pieces of scientific literature that later became accessible electronically via the Web of Science, Garfield launched Current Contents, an early effort that sought to compile important information on the scientific literature. He founded The Scientist in 1986, as a news magazine for researchers.

International Society for Scientometrics and Informetrics (ISSI) was founded at the International Conference on Bibliometrics, Informetrics and Scientometrics held in Berlin, 11-15 September in 1993. This conference was the fourth of a series of prominent biennial conference that subsequently have been held under the auspices of the Society. The first three earlier conferences were held in Diepenbeek, Belgium (1987, Chairman: Dr. Leo Egghe), London, Ontario, Canada (1989, Chairman: Dr J M Tague) and in Bangalore, India (1991, Chairman: Dr I K Ravichandra Rao). The Society was incorporated with formal Articles of Association in 1994 in the Netherlands (Utrecht.) Dr.HildrunKretschmer was elected its first President.

With Berlin as its virtual center COLLNET was set up on January 1st, 2000, under the leadership of HildrunKretschmer, in her capacity as coordinator. The

network is to comprise the prominent scientists, who work at present mostly in the field of quantitative science studies, coming from 15 countries of America, Asia, Australia and Europe. The intention is to work together in co-operation both on theoretical and applied aspects. COLLNET conducts every year International Conference in scientometrics.

There are four important journals in scientometrics - Journal of Scientometrics, Journal of Informetrics and COLLNET Journal of scientometrics and Information Management, Journal of Scientometrics Research (edited by S. Bhattacharya, CSIR NISTADS India). These journals are publishing original studies, short communications, and preliminary reports, and review papers, letters to the editor and book reviews on scientometrics. Due to its fully interdisciplinary character, the journal is indispensable to research workers and research administrators. It provides valuable assistance to librarians and documentalists in central scientific agencies, ministries, research institutes and laboratories. Apart from the above journals several Science &Technology journals, Library and Information Science journals are also publishing articles on scientometrics.

On 27th March 2011 at Tumkur in India, “Institute of Scientometrics “ was founded by Prof.S. LSangam; along with his research students, with an objective to promote research in Scientometrics. It is a virtual and non-profit organization. Much of the research works in this area were carried out in National Institute of Science Communication and Information Resources (NISCAIR, a wing of CSIR) (formerly known as INSDOC), National Institute of Science Technology and Development Studies (NISTADS, a wing of CSIR) and Documentation Research and Training Centre of the Indian Statistical Institute. In recent times, a number of research works were published from Departments of Library and Information Science of many Universities in India. In 2009, UGC recognized Department of Library and Information Studied of the Karnataka University, Dharwad a Special Assistant Program (SAP) in scientometrics.

Challenges of future research in the field of Scientometrics

Scientometrics has strong connections with economics and sociology of science as well as science policy. It has many challenges for future research:

1) Delineation and mapping of scientific areas; 2) Measuring multi-disciplinarily; 3) Positioning indicators have challenged the traditional input-output measures, prioritizing volumes, market shares and productivity; 4) Capturing creativity and innovation; 5) Growth-diversity models; and 6) Data de-mining, knowledge, flow measurements, infometrics and diversity issues.

Conclusion

The field of cybermetrics exceeds the boundaries of bibliometrics, because some activities in cyberspace normally are not recorded, but communicated synchronously as in chat rooms. Cybermetric studies of such activities still fit in the generic field of Informetrics as the study of the quantitative aspects of information "in any form" and 'in any social group" as stated by Tague-Sutcliffe (1992 The main research areas of each stage concentrated on the major topic like citation analysis has been a core research area during every stage; research interest has shifted from theoretical research to applied aspect; visualization methods and scientific mapping have attracted more and more attention and will become a main research area of scientometrics. The inclusion of webometrics expands the field of bibliometrics, as webometrics inevitably will contribute to further methodological developments of web-specific approaches. As ideas rooted in bibliometrics, scientometrics and Informetrics contributed to the emergence of webometrics, ideas in webometrics might also contribute to the development of these all-embracing fields. Certainly knowledgometrics open new vistas in quantitative methods. The two main aspects of the reliability of measurement outcomes are accuracy and precision.

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