Demystification of Bibliometrics, Scientometrics, Informetrics and Webometrics

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Abstract

Among the many statistical analyses of scientific publications, bibliometrics holds a privileged place for counting scientific papers. Bibliometrics is one of the sub-fields concerned with measuring the output of scientific publications. Bibliometrics ows its systematic development mainly to the works of its founders V V Naliv, D J D Price and Eugene Garfield in the 1950s. Since 1958 Bibliometrics has evolved as a field, taught in library and information science schools and it emerged as a tool for scientific evaluation for a number research groups around the world. This process was made possible by the work of Eugene Garfield and his Science Citation Index. Castell, an American psychologist was credited with the launching of Scientometrics, when he produced statistics on a number of scientists and their geographical distribution, and ranked the scientists according to their performance. He introduced two dimensions into the measurements of science, namely, quantity and quality. The term informertics was introduced by Blackert, Siegel and Nacke(1979) but gained popularity by the launch of the international informetrics conferences in 1987. A recent development in informetrics called the webometrics/cybermetrics, has become a part of the main stream library and information science research area. The term webometrics refers to the quantitative studies of the nature of scientific communication over the internet and its impact on diffusion of ideas and information. This paper reviews the evolution of bibliometrics and its fast growing offshoots, scientometrics, informaetrics and webometrics.

Keywords: Bibliometrics, Scientometrics, Informetrics, Webometrics,

1. Introduction

Biblimetrics, as a tool to measure scientific research output, has seen major changes over the last five decades and has emerged as an established filed of research in library and information schools. It has arisen as a recognised scientific specialism, taught in universities as part of information science courses both in Europe and America with a substantial body of techniques, some theories and an international group of specialist science evaluators (Thelwall, 2008). In 1906, Cattell launched the biographical directory of *American men of science,* published every

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five years and the directory collected information on thousands of American scientists active in research (Godin, 2007). Catell introduced two dimensions to the measurement of science, quality and quantity and these two dimensions still largely define the field of bibliometric strudies today. Quantity or productivity as he called it, was simple the counting of number of scientists a nation produces while quality or performance, was defined as contributions to the advancement of science and was measured by averaging the per rankings of colleagues (Godin, 2007). Although bibliometrics was used as a standard for measuring the publication output of scientists almost a century ago, it was largely the work of Eugene Garfield in the 1960s and his Science Citation Index through his newly developed Institute for Scientific Information (ISI) which made possible the quantitative analysis of scientific research output (Garfield, 1979). The two major changes in publishing are the computerization of the printing process, and the conversion of the entire publishing cycle that is, the submission of an article, refereeing and publication to the internet, allowing for faster and possibly cheaper communication thought.

This paper has a dual focus: general bibliometric and its development into scientometrics and informetrics and the applications of bibliometrics on the web called webometrics.

2. Bibliometrics

Bibliometrics is described essentially a quantitative analysis of publications for the purpose of ascertaining specific kinds of phenomena (Herubel, 1999). It encompasses the measurement of properties of documents, and document related processes.(Borgman and Ferner (2002)). It uses mathematical and statistical methods to analyse and measure the output of scientific publications. The vast majority of bibliometric studies have been devoted to scientific and technological disciplines. It is important to note that since E.W. Hulme wrote his famous study in 1923, the measurement of published scholarship and scientific research has developed its own momentum and evolved its own nomenclature. From statistical bibliography to bibliometrics to scientometrics and informetrics to webometrics, this type of publications has become instrumental for library and information science, as well as for scholarly communication (sengupta, 1992). Researchers can examine literatures and establish characteristics of disciplines, obsolence of scholarship, institutional affiliations and relationships, and types of materials constituting scholarly persuits. Bibliometrics is used as a methodology in many fields of science, first and foremost to map the publication pattern in different disciplines. For instance for the historian studying the intellectual heritage and evolution of a discipline bibliometrics is an indispensable tool.

2.1 The Origin of bibliometrics

Cattell, as pointed out above, is generally associated with the first systematic collection of statistics on science (Goddin, 2007). He laid the foundation for others who introduced the systematic use of bibliometrics. (Sengupta, 1992; Hood and Wilson, 2001). Catell used his bibliographical directory to study scientists and their activity in research in the United States and from the data, Catell produced statistics on the number of scientists and their geographical distribution and ranked scientists according to their performance. Catell can thus also be

credited for having launched scientometrics, or the systematic measurement of science.

Catell was followed by other psychologists like Buchner who started his series of reviews on psychology. In these reviews, he included discussion of recent papers, the number of psychologists, list of new journals, and statistics on publications, a percentage distribution of papers appearing in the Psychological Index and the interests of the psychologists (Godin,2006). But it was S W Fernberger of the University of Pennsylvania who developed the statistics on publication. He looked at the evolution of membership and placed increasing emphasis on publishing as a criterion for eligibility and discussed finances, journals of the Association, organisation and its meetings. He charted the number of papers presented at each meeting since 1892. He looked at the productivity of universities at these meetings and what he called the consistency of publication and fields of interest. He found that 19 universities produced 53% of all papers It was thus Fernberger who put forward the concepts of productivity and the Index for the measurement of science productivity.

Bibliometrics analysis predates the development of the Science Citation Index (*SCI*), but the advent of SCI and specifically the availability of electronic access (online, CD-ROM and web-based) to the Institute for Scientific Information's (ISI) massive datasets has had a catalytic effect on the popularity, scope and ambition of biliometric research, both within and beyond the information community. SCI was created as a database of references made by authors, to earlier publications which will lead the readers to other similar articles as well as encourage them to work on similar topics. The ISI also developed other databases such as the Social Sciences Citation Index *(* SSCI) and Arts and Humanities Citation Index (AHCI*)* and along with them new and varied statistics. These statistics reckons Thelwall (2008) include the number of citations to all articles in a journal or all articles by an author, research group, or country. Some are further developed in to named indicators with supporting theories and reasonably well accepted standard interpretations. The most well known is the journal impact factor (JIF).

Since the advent of SCI, three types of bibliometric applications have arisen , namely, descriptive, relational and evaluative (Borgman and Ferner, 2002). Descriptive bibliometrics places emphasis on the characteristic features of the document while relational bibliometrics seeks to illuminate relationships within research, such as cognitive structure of research fields, the emergence of new research fronts, or national or international co-authorship patterns . Evaluative bibliometrics seeks to assess the impact of scholarly work, and compares the relative contributions of two or more individuals or groups (Thelwall, 2008).

2.2 Descriptive Bibliometrics

Descriptive bibliometrics describes the characteristics or features of literature and is used to measure productivity of scientists and information scientists. The research is divided into geographic areas, time periods and departments and disciplines. The area of descriptive

bibliomerics includes the study of the number of publications in a given field or productivity of literature in the field for the purpose of comparing the research in different institutions/countries as well different periods.

2.3 Evaluative bibliometrics

Evaluative bibliometrics use citations as the source of its / their raw data (Thelwall, 2008). The theory for this stems from Robert Merton's (1973) sociology of science, which indicates that citations are the manner in which scholars acknowledge influential prior work. Based on this, citation counting is therefore used as an indicator of research of scientific value. Subsequent research has shown that Merton's perspective is a somewhat over simplification of reality. There are many and varied reasons to cite articles and

2.3 Relational Bibliometrics

Relational Bibliometrics are used to examine relations within scientific research through the use of ISI data. This was not possible in the early days due to lack of computing power and experience in technology. Even so these early relational analyses produced interesting insights into the structure of scienceresearch through simple means, such as network diagrams of the flow of citations between key sets of articles (Cawkell, 2000). This idea, says Telwall (2008), came from geneticist Allen in 1960, who sent his citation diagram to Garfield (Cawkell, 2000). Journal citation diagrams could illustrate the connections between journals within a field, both central and peripheral.

Garfield was credited with co–citation as a measure of similarity, i.e., if two documents often appear together in reference lists, (co-cited) they are likely to be similar in some way. This simply means that if collections of documents are arranged according to their co-citation counts it should produce a pattern reflecting cognitive scientific relationships.

3. The importance of Bibliometrics as a research tool

Modern bibliometrics as a research tool has been largely inspired by Derek de Solla Price and the seminal work carried out by him in the middle of the 2oth century. In his book "Little Science-Big Science" published in 1963, he analysed research communication and presented a number of quantitative evaluation techniques. He was the first to examine the growing trend of collaboration among chemistry researchers by using bibliometrics. Since bibliometrics has developed in to a research field in its own right, it has given rise to a community of specialised experts, called biliometricians. Bibliometrics, explains Mattison (2008), is used as a methodology in many other fields of science, mainly to map the publication pattern in different disciplines. In economics and sociology the main interest has been for cognitive purposes, that is studying researchers' publication behaviour.

Bibliometrics has gained increasing importance in science policy and management in the last

decade and it is specifically in the domain of research evaluation where it plays a prominent role. The development of performance indicators to respond to science policy questions has been the most common application. Indicators used for this purpose include: productivity analyses measuring the output and volume share of a specific actor, e.g. a country's world share of publications or citations; research impact analysis using citations, and relational indicators studying heterogeneity of collaboration patterns between different actors (Mattson, 2008).

One of the major focus area in bibliometrics is research collaboration which receives increasing attention from policy-makers and e general users. Modern research is regarded as increasingly complex and specialised, making it impossible for an individual researcher to master all the knowledge and technical skills needed. In collaboration, different skills compliment each other and so doing contribute to the stimulation of knowledge sharing and the generation of innovation and new ideas. As a result, collaborative research activities besides enabling the pooling and sharing of resources for enhanced efficiency also contribute to the quality of the research outcome (Mattson et.al, 2008).

Funding agencies and institutions therefore increasingly encourage collaborative research. Grants awarded by many different funding institutions and for many different disciplines often seek to encourage and at times require as a condition, collaborations between different countries, research fields or institutions. Research done by the National Science Foundation (where South Africa??) found that research done by multiple institutions has increased from 40% to 61% between 1988 and 2008. (NSF S&E indicators)

4. Scientometrics

It is a common misbelief that scientometrics is nothing else but the publication and citation based gauging of scientific performance or compiling of cleaned-up bibliographies on research domains extended by citation data.

Scientometrics is considered as the study of the quantitative aspects of science as a discipline or economic activity. It is part of the sociology of science and has application to science policy-making. It involves quantitative studies of scientific activities, including among others, publication, and so overlaps bibliometrics to some extent. The term scientometrics came to prominence as the name of a journal founded by T.Braun in 1977, originally published in Hungary and now in Amsterdam (Jean Tague-Sutcliffe, 1992). Main subjects of scientometrics are individual scientific documents, authors, scientific institutions, academic journals, and regional aspects of science. Van Raan (1994) reckons that there is a rapid addition of scientometrics but not bibliometric data, such as data on human resources, infrastructural facilities, and funding. In information science oriented scientometrics, in contrast to economy, sociology or psychology of science, aspects of information and communication are examined. These aspects may include productivity (documents per year), subjects of the documents (words or co-words), reception (readers of the documents) and formal communication, references and citations, and co-citations (Juchem, Schlogl and Stock, 2006).

Scientometrics is a multifaceted research strategy encompassing subareas such as structural, dynamic, evaluative and predictive scientometrics. Structural scientometrics came up with results like the re-mapping of the epistemological structure of science based, for instance, on co-citation, "bibliographic coupling" techniques or co-word techniques. Dynamic scientometrics on the other hand constructed sophisticated models of scientific growth, obsolescence, citation processes, etc. These **models** are not only of theoretical interest but can also be usefully applied in evaluation and prediction of what??? . Beyond policy relevant applications of scientometrics results, there are ~~recently~~ important applications in the context of studying the linkage between science and technology, or applications to related fields such as library and information science and more recently also Webometrics. Examples for the latter are the ongoing projects such as EICSTES (European Indicators, Cyberspace and the Science-Technology- Economy System) and WISER (Web indicators for scientific, technology and innovation research(Ganzel, 2003).

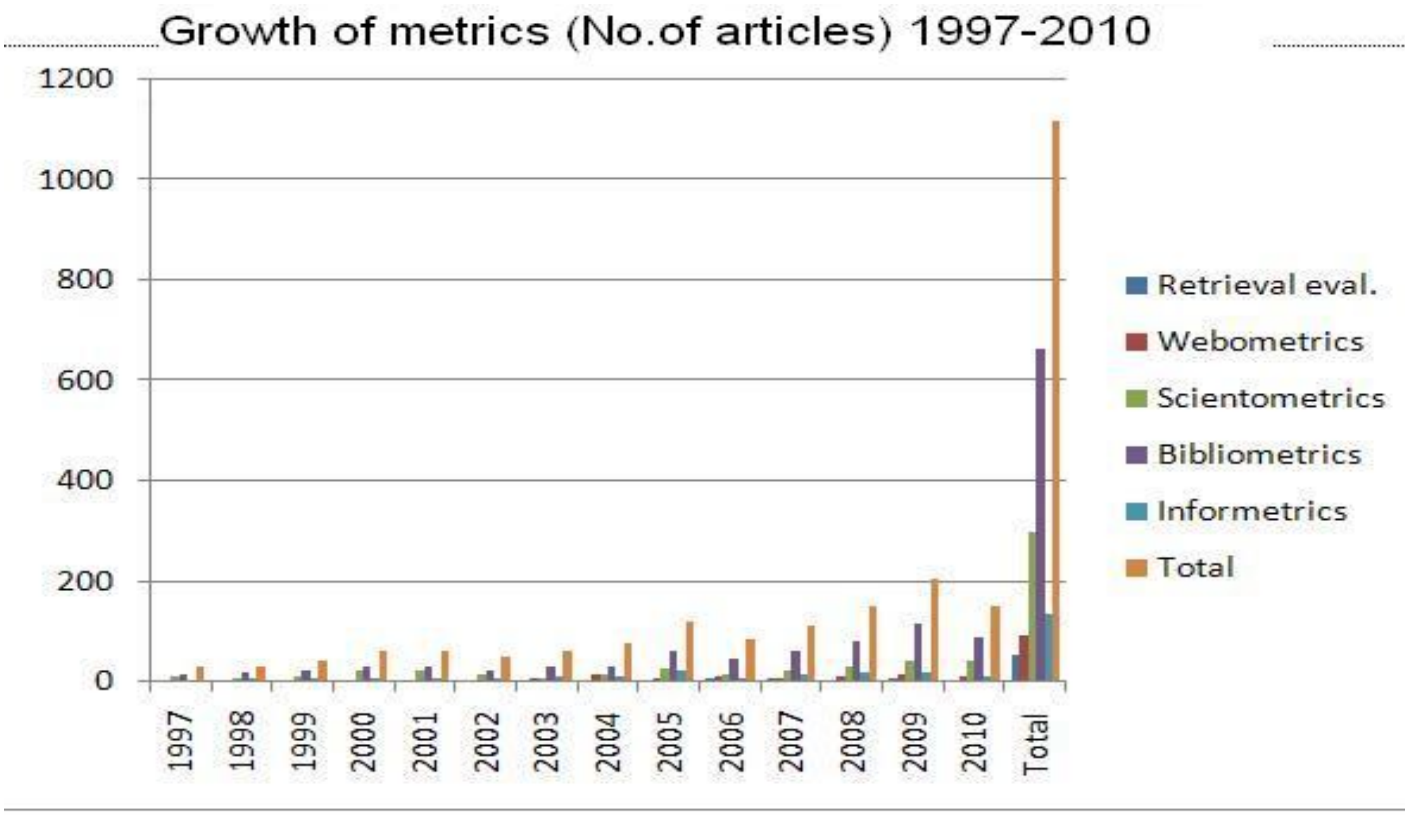
5. Informetrics

Informetrics is described as the study of the quantitative aspects of information in any form, not just records or bibliographies, and in any social group, not just scientists. It looks at both informal or spoken communication as well as recorded, and information needs (Tague –Sutcliffe, 1992). The quantitative study of recorded discourse may relate to any medium, although until recent decades print media have dominated informetric research. With the wider availability of documentary resources, the discourse electronic formats, particularly through machine-readable databases and more recently the internet, informetric research based on electronic data sets has become commonplace. It incorporates and utilizes many studies of measurements of information that lie outside the boundaries of both bibliometrics and scientometrics as such the term 'informetrics' is used as the broad term comprising of all-metrics and studies related to information science. Athough the field of informetrics can be trace back to the first half of the twentieth century through the works of Lotka (1926) Bradford (1934) and Zipf (1949). The term was popularised by Blackert and siegel (1979) and Nacke (1979) in the late nineteen nineties From here on the concept steadily gained popularity through the organisation of international informetrics conferences.

5.1 Growth and expansion of Informetrics.

According to Egghe there is a fast multidisciplinary expansion (growth) of the field of Informetrics, mainly due to the new topics that have been included in informetrics such as quantitative study of networks, including internet" (Stock and weber, 2006). (Egghe, 2006). This is confirmed by request on "Web of Science" and the use of its ANALYSE function. A searched for "TS= informetrics OR bibliometrics OR scientometrics OR webometrics OR retrieval evaluation" returned the results as shown in Table 1 below. From this it is clear that informetrics is a rapidly growing research field? / Or field of contemporary research.

Table 1 Relationship between growth metrics and publications



One of the main factors that contributed to the rapid growth of the field of informetrics over the last few decades (according to Lipetz(1999), is the advent and the exponential growth of the journal of the American Society for information Science and Technology which promulgated the publication of documents dealing with informetrics. The growth of the journal indirectly encouraged the publication of papers and in terms of number of authors and even in terms of average number of references per paper. The popularity and standard of the journal also encouraged the number of authors who wanted to have their papers published in JASIS. The popularity of the journal and its insistence on publishing informetrics papers of very good standard attracted authors from other scientific disciplines thereby encouraging the multidisciplinary growth of the field of informetrics.

Authors from different disciplines are responsible for a multidisciplinary growth of the field of informetrics. Summers, Oppenheim, Medows, McKnight and Kinnell (1999) indicate the influence of informetrics to other scientific disciplines. Multidisciplinarity is evident if one looks at the new topics which informetrics covers, such as: the metrics of the web, internet, intranets and other social networks and citation or collaboration networks. Informetrics thus owe much of its growth to the advent of the 'information society. LIpetz (1999) believes that the average

number of authors per paper is increasing as there seems to be a greater thrust on the need for collaboration. One can thus say that the field of informetrics today comprises the fast growing field of webometrics, (Hood and Wilson , 2001).

Journal of Documentation is a highly rated journal in Information studies and International authors have increased in numbers in their publications in this journal prove that their share in these journals become larger and larger indicating an increase of internationalization of the field of informetrics (Shubert and Spink, 2002). The same can be said of the authorship in the papers presented in the international conference of informetrics and the articles in the proceedings of the conferences. Egghe (2005) explained that the growth of the field of informetrics has lead some journals to increase their number of volumes or the number of issues per volume. The journal Information Processing and Management decided to devote two special issues from 2005 to the broad topic "informetrics"(bibliometrics, scientometrics, webometrics,…) where the scope of these special issues is to attract quality papers dealing with gathering important data sets and presenting original models and explanations. **

The recent expansion of information science to networks and the information society in general has resulted in more and more data being gathered in an automated way. Although data can be gathered in a much faster way than before the down side it is that the accuracy of the data collected is declining. . The main reasons for this, according to Egghe (2005), is that the data is collected from a documentary system such as OPAC, primary or secondary database or digital library and there is currently no clear definition of the topics due to a lack of standards. Glanzel (1996) and Rousseau (2002) concur with this view arguing that one is not completely sure of what one gets from these systems and besides, an electronic system may suffer from system breakdown in which case one is obliged to make interpolations that are not always accurate.

5.2 Informetric Distributions: From Social Principles to Laws

Informetric studies in Library and Information Sciences are based on the mathematical expression of three principles relating to social and economic life called the 80/20 rule also referred to as Pareto's rule. The Principle of Least Effort, the 80/20 rule and the Principle of Success Breeds Success are considered in the context of informetrics (Erar, 2003). The Principle of Least Effort means that a person will strive to solve his problems in such a way as to minimize the total work that he must expend in solving both his immediate problems and his probable future problems (Zipf, 1949). Zipf had used the term least effort to describe the least average rate of probable work. This principle emphasizes the importance of summarizing an article using "little words with substance", authors feeling free to repeat certain words instead of using new ones. To express with many words what can be expressed with a few is meaningless (Zilf, 1949).

The second principle, the 80.20 rule suggest that ….. it can be expected that 80% of the citations refer to a core of 20% of the titles in journals. Likewise, it can be stated that approximately 80% of the circulation are accounted for by about 20% of the collection or 80% of the articles in journals belong to about 20% of the authors.

Another general theory characterising processes of scientific communication is the principle of cumulative advantage. Price formulated this in 1976 as follows. The third principle …….. "success breeds success" (SBS) is also considered in the form "failure results in failure" from time to time. In the context of Informetrics, the rule means that a paper which has been cited many times is more likely to be cited again than one which has not been cited often. An author of many papers is more likely to publish again than one who has been less prolific. A journal that has been frequently consulted for some purpose is more likely to be turned to again than one of previously infrequent use (Potter,1981). So according to this rule, success in the past increases the chances of success in the future.

6. Inter-relations between the different metrics

The relationships between informetrics, bibliometrics and scientometrics are shown below from (Thelwall, Vaughan and Bjorneborn 2005) which shows the field of *informetrics* embracing the overlapping fields of *bibliometrics* and *scientometrics. Webometrics* on the other hand is seen as entirely emcompassed by bibliometrics, because web documents in their various forms such as text, multimedia are all recorded information stored on the web servers. In the diagram, webometrics is partially covered by scientometrics, because many scholarly activities today are web-based. Webometrics is depicted as contained within the field of cybermetrics which exceeds the boundaries of bibliometrics as some activities in the cyberspace are not normally recorded, but communicated synchronously as in chat rooms (tague-Sutcliffe, 1992).

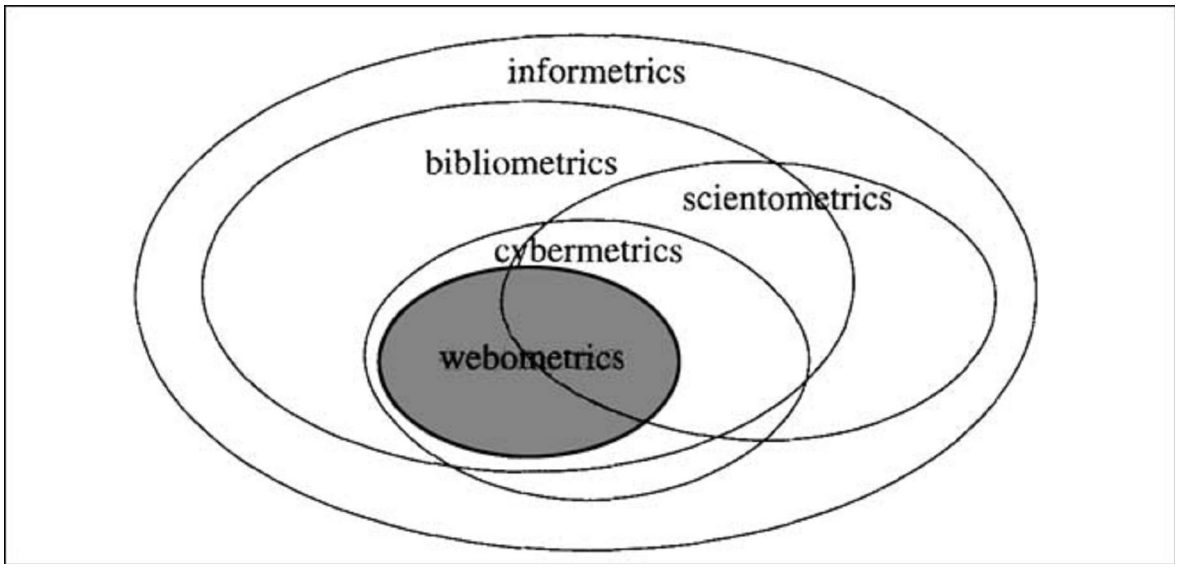


Figure 1 What does it describe??
Source: Thelwall, Vaughan and Bjorneborn 2005

The inclusion of webometrics expands the field of bibliometrics because webometrics will inevitably contribute further methodological developments. As ideas rooted in bibliometrics, scientometrics, and informetrics have contributed to the emergence of webometrics, insights from webometrics will likely contribute to the development of these more established fields (Thelwall, Vaughan and Bjorneborn, 2005).

7. Webometrics

Webometrics is the quantitative analysis of web-related phenomena, drawing upon informetric methods (Bojorneborn and Ingwersen, 2004), and typically addressing problems related to bibliometrics. Webometrics emerged when the realisation that the web is an enormous document depository with many of these documents being academic-related, (Almind and Inwersen, 1997).

Björneborn and Ingwersen have proposed a differentiated terminology. Distinguishing between studies of the web and studies of all internet applications. They used information science related definition of webometrics as "the study of the quantitative aspects of the construction and use of information sources, structures and terminologies on the world wide Web drawing on bibliometric and informetric approaches" (Björneborn and Ingwersen, 2001). This definition thus covers quantitative aspects of both the construction and usage sides of the web, embracing the four main areas of webometric research –(1)Web page content analysis, (2)Web link structure analysis, (3)Web usage analysis,(e.eg., exploiting log files of users' searching and browsing

behaviour), (4) Web terminology analysis (including search engine performance)"(Thelwall,Vaughan and Björneborn, 2004). Pirolli, Pitkov and Rao (1996) explored web analysis techniques for automatic categorization using link graph topology, text content, and metadata similarity as well as usage data. All four main research areas include longitudinal studies of changes on the dynamic web , for example, of page contents, link structures, and usage patterns.

Moreover, the web has its own citation indexes in the form of commercial search engines, and so it is ready for researchers to exploit (Egghe, 2005). One of the most visible outputs of webometrics is the ranking of world universities based on their web sites and online impact (Aguillo et al , 2006). Webometrics includes, explains Telwall (2008), 'link analysis, web citation analysis, search engine evaluation and purely descriptive studies of the web together with the recent addition of the web analysis of web 2.0 phenomena'.

7.1 Link analysis

Link analysis is the quantitative study of hyperlinks between web pages. The use of links in bibliometrics was caused by Ingwersen's (1998) web impact factor (WIF), created through analogy to journal impact factor. The hypothesis underlying early link analysis was that the number of links targeting an academic web site might be proportional to the research productivity of the owning organisation, at the level of universities (Thelwal, 2001), departments (Thomas and Willet, 2000), research groups (Barjak and Thelwal, 2008) or individual scientists (Barjak, Lee and Thelwal, 2007).

In essence says Thelwal and Harries (2004), the two are related because more productive researchers seem to produce more web content, on the average, although this content does not attract more links per page. Very often this pattern is likely to be obscured in most studies except in large-scale studies because of the indirect relationship between research productivity and web visibility, the reason being, some researchers produce highly visible web resources as the main output of their research, while others with equally high quality offline research attract less online attention.

Links are not used in an evaluative role, but they can be useful in describing the evolution or connectivity of research groups within a field, especially in comparison with other sources of similar information. But the main problem with link analysis is that the web is continually changing and seems to be constantly expanding so that the webometric findings might become obsolete (Thelwal, 2008). A series of longitudinal studies done to investigate the university websites in Australia, New Zealandand the UK have addressed this issue. These university websites seem to to have stabilised in size from 2001, after several years of rapid growth (Payne and Thelwal 2007).

7.2 Web citation analysis

A number of webometric investigations have focussed not on websites but on academic publications, using the web to count how often journal articles are cited. The rationale behind this is partly to see if the web can produce evidence of the wider use of research, including informal scholarly communication and for commercial applications. A number of studies have shown that the results of web-based citation counting correlates significantly with ISI citation counts across a range of disciplines, with web citations (Kousha and Thelwal, 2007).

Conclusions

Bibliometrics has changed out of all recognition since the late 1950s. Today it is taught widely in library and information science schools and is used as the core evaluatory tool by evaluation research groups around the world such as the centre for Science and Technology Studies in the Netherlands. Several coutries have taken journal impact factor (JIF) and bibliometrics when making important policy decisions about the future of the government funded research. Some of the studies done by experts on bibliometric indicators have shown that although most of the indicators are well known and easy to calculate , have significant flaws in which most of the users might overlook. Hence one important task for bibliometric practitioners is to convince policy makers of the importance of commissioning high quality robust indicators as well as ensuring that no indicator is taken at face value.

Scientometrics and Informetrics have also changed in the sense of expanding the number of data sources that can be used. Although Thomson Scientific has always been considered as the database for biblio, infor and scientometrics, it has been now challenged by two most important international databases, Google Scholar and Scopus. More importantly, large scale patent analysis is now much easier than before with digitisation and indexing of patent databases and this opens up an aspect of the commercial value of scientific research for informetric study. The metrics have changed and expanded the range of tasks investigated. This wide range of relational informetrics studies opens up new ways of understanding the scholarly communication process and the structure of science through citation.

Webometric studies have been conducted by both information scientists and computer scientists with different reasons. Within information science, webometrics has changed and expanded from its initial focus on bibliometric-style investigations to more descriptive and social science oriented research. Certainly, webometrics will continue to evolve in response to new web developments and to give valuable results. The web and hence the research on the web and webometrics is in contrast to the bibliometrics. The web can be timelier than ISI databases. While the time lag between the research project conducted and the results published in a journal is likely to take at least two years. Hence ISI-based bibliometrics is invariably always retrospective describing the research of years ago, where as a research project might start publishing a website and therefore be analysed with webometrics long before its research is

published. The web is free to access for all web users and so it potentially opens bibliometric-style analyses to those who could not access or afford ISI data.

Webometrics research also has shown some short comings… although web is available for all to access, it has no quality control unlike the ISI publication lists (Thelwall, 2008). As a result, the data tends to be of lower quality. The web data is also not standardised so that it is difficult to exact all except the simplest data like link counts. It is also difficult to separate out web citations in online journal articles from those in online course reading lists. Hence webometric results tend to be the total of a mix of sources with variable value (Harries, 2004; Wilkinson, 2003). Although the web data can be timely, it can be impossible to find publication date of a web page and so webometric results typically combine new and old web pages into one data set. In many cases, the web data is also incomplete in arbitrary ways.

Although some academic articles are freely available online, the majority of them are not. Similarly, some researchers and research groups maintain extensive and comprehensive web sites but others do not and hence the results reflect the web which is very partial with research activities.

Webometrics is very much advanced in many ways of manipulating the web for research advances, on comparing the advantages and disadvantages of it, we can find that it is unlikely to replace traditional bibliometrics. But it can be used for fast pilot studies to identify areas for follow-up systematic bibliometric analysis (Robinson et al., 2006).

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