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Scientometrics: Tools, Techniques and Software for Analysis

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Abstract - **This paper aims to discuss the significance of e-resources on scientometrics study. Tools for scientometric analysis are listed out. Data collected from literature search and website of softwares. Citation tracking tools like Web of science, Scopus and Google Scholar citations, CiteseerX etc., are discussed. Various software tools for bibliometric analysis like Bibexcel, CiteSpace, Histcite, Pajek, Publish or Perish, Scholarometer, VOS viewer-tool for constructing and visualizing bibliometric networks, CitNet explorer - tool for visualizing and analysing citation networks of publications etc are discussed, The study concludes that combination of different software tools can be used for complete scientometric analysis and the familiarization of bibliometric software among students and researchers will help to promote research in scientometrics in a more productive method.**
Keywords: **Scientometrics, Scientometric Analysis, Citation Tracking Tools, Bibliometric Software**

I. INTRODUCTION

"Few would dispute the claim that a nation's science and technology base is a critical element for its economic strength, political structure and cultural validity",

Eugene Garfield

The importance of scientific knowledge is recognized like never before in this knowledge millennium age. There are many ways of looking at Science. According to Concise Oxford English Dictionary, science is the pursuit of systematic and ordered knowledge. It is a very complicated system of knowledge production and knowledge exchange. It can be viewed as a means of constructing models of reality. Science is a major human activity having far reaching applications and implications in every aspect of human life. But measuring such an activity, knowledge or its impact in human life is a challenge and therefore the next best thing to do is to measure all that is measureable about them like measuring the volume of research, i.e., scientific output of a country by the number of research papers published by scientists in that country, extent of collaboration, citation rate for measuring the impact of articles etc.,

Quantification is imperative in all aspects of life. The academic and research activities need to be measured even in the scholarly world. Scientometrics has become a leading tool for measuring the value of research activities. The term "Scientometrics" has been first used as a translation of the Russian term "naukometriya" (measurement of science) coined by Nalimov and Mulchenko (1969). Scientometrics is a branch of science which can also be termed as "Science of Science". It involves quantitative studies of scientific activities, especially publications, which overlap with bibliometrics to some extent. The terms bibliometrics and scientometrics were almost simultaneously introduced by Pritchard and by Nalimov and Mulchenko in 1969. Pritchard explained the term bibliometrics as "the application of mathematical and statistical methods to books and other media of communication, Nalimov and Mulchenko (1989) define scientometrics, "as the application of those quantitative methods which are dealing with the analysis of science viewed as an information process. According to these interpretations, scientometrics is restricted to the measurement of science communication whereas bibliometrics is designed to deal with more general information processes. Scientometrics is related to and has overlapping interests with bibliometrics. The term bibliometrics and scientometrics refer to component fields related to the study of the dynamics of disciplines as reflected in the production of their literature. Now a day's both terms are used as synonyms and the borderlines between the two specialties almost vanished. The work that gave rise to the laws of bibliometrics was perhaps the earliest research with in the scientometric field. The first law, which came to be known as Lotka's Law, after Alfred Lotka, in 1926 suggested that within a defined area over a specific period a low number of authors accounted for a large percentage of publications in the area. In 1935, George Kingsley Zipf, described the frequency of words in a text and became known as Zipf's Law. In 1948 Samuel Clement Bradford's analysis indicated that within a given area over a specific time a few journals publish a high percent of articles and there are many journals that publish only a few articles each which came to be known as Bradford's Law. These laws form the foundation of the development of the modern-day scientometric literature. The development of the Impact Factor and the work of Eugene Garfield is one of the most renowned accomplishments in the field of scientometrics. Garfield first described the Impact Factor in 1955 as a method of selecting journals for inclusion in a genetics citation index he had been developing. This eventually resulted in the publication of the Science Citation Index in 1961 as a means of linking articles together via their references. Since then, journal Impact Factor has developed into a widely used bibliometric indicator. In the meantime, Derek De Solla Price was studying the exponential growth of science and the citation activity of scientific literature. Several papers were published by him who described the key elements of scientometric analysis, including work on patterns of communication between scientists and the overall history and study of science itself.

II. APPLICATIONS OF SCIENTOMETRIC TECHNIQUES

Scientometrics as a technique has extensive applications in understanding the structure of a discipline, identifying the research trends and research networks, growth of knowledge, calculating the research impact of a published work, , trends in authorship and collaboration in research, identify suitable research partners in one's own specialized research field, potential for cross disciplinary work, and potential for national and international collaboration. In the area of information dissemination, it helps in the decision making of - where to publish for maximum visibility, analyze and compare journal information and track how research is received by others. Institutions can use scientometrics tools to make informed decisions like allocation of funds, policy decisions, track emerging trends and find niche research areas, compare and benchmark impact of research with other institutions, find collaborating partner/institutions national, internationally, with in an institution/track corporate/academic collaboration. It also helps to find an institutions disciplinary focus/to see how institutions collaborate geographically/institutions research strength/most productive author and institutions in a particular discipline. It helps to identify the core periodicals, journal impact factor, citation studies/productivity metrics, author metrics, scholarly output, h- indices and so on. The most common units of analysis in science mapping are journals, documents, cited references, authors and descriptive terms or words.

III. SCIENTOMETRIC INDICATORS

Indicators for science and technology may be defined as "statistics which measure quantifiable aspects of the creation, dissemination and application of science and technology. Scientometric indicators guide the decision of science and technology policy makers. Systematic and appropriate scientometric indicators would provide the policy makers with an indication of the national science and technology system and the relationship between scientific and technological efforts and economic growth .They can serve as instruments of planning, evaluation and resource allocation. The scientific information is measured in two ways both in practical and strategic domain. Search of information by users is included in the practical way and monitoring of science developments and the analysis of the changing structure of science is included in the strategic way. Growth rate, average relative impact factor, collaboration rate, international collaboration rate, national collaboration rate, number of papers, specialisation index, visualisation of collaboration network are some of the scientometric indicators.

IV. WEB BASED TOOLS

The Impact Factor continued to grow as a significant factor and in the late 1990s Thomson Scientific launched a web-based version of the citation indices, allowing users to search across citation databases on the Internet. Internet and e-resources has become an essential tool for research and analysis. Several new citation measures were developed that were formerly impractical. These include article download counts and Google's Page Rank, a numerical value that represents the importance of a page on the Web. New areas such as webometrics have also developed to look at the quality of Web pages and links within them. Web usage and weblog analysis are sophisticated new techniques that allow researchers to understand how the Web is used for analysis. In 2004 Scopus was released as a new tool to search and navigate through the literature and link between references and citations. This abstracts and provide citation database of peer-reviewed literature& patents. Web sources has also introduced additional tools that increase the speed and accuracy of research evaluation. One of these is the Author Identifier that automatically matches and de-duplicates author names, with a 99% accuracy rate. Attention is increasingly turning from rating the performance of journals to also rating individual authors. The h-index, a simple metric developed in 2005 by Professor J. Hirsch and adopted by Scopus and Web of Science is one way to do this, while the Scopus Citation Tracker allows users to track who is being cited, how often and by whom. This can also help identify research trends. Other key indicators that have been developed include the Eigen factor, the Y factor and the g-index.

V. SCIENTOMETRIC STUDY: SOURCES FOR DATA

Journals are traditionally the most valued data source for scientometric study. However most of recent studies use digital data sources. Data collection from publications will be cumbersome task for researchers. Many digital data sources are now available and output of the study depends on the knowledgeable selection of data source. Multiple databases are also used for studies. The bibliographic and citation data for analysis are collected through bibliographic databases, citation databases, journal indices, library catalogs and information systems, institutional information systems, national databases and so on. Scientometric analysis has different steps: data retrieval, preprocessing, network extraction, normalization, mapping, analysis, visualization and conclusions.

VI. KINDS OF DATA SOURCES

Nowadays, there are several online bibliographic and bibliometric databases where scientific works and documents and their citations are stored. These sources of bibliographic information allow us to search and retrieve information about the majority of scientific fields.

A. Bibliographic Databases: Bibliographic databases or Indexes are fine for finding further resources written about a particular subject. They contain bibliographic information (title of article, journal name, author, date of publication, volume #, issue, page #, etc.) about various types of publications and formats (print, video, audio, software, etc.). - CAS, Compendex, ERIC, LISA, Inspec, MathScinet,and Pubmed are basically bibliographic databases. These databases can't be used for studies related to citation analyses as they do not contain citation data. The difference between bibliographic databases and citation databases is in the fact that bibliographic databases contain only the bibliographic details whereas the citation databases contain both bibiliographic details and citation data.

B. Citation Databases: Citation databases somewhat vary in their content with that of bibliographic databases. To acknowledge the ideas taken from prior works, citation is the top practice among scholarly society. The acknowledgement will be in the form of references at the end of the article. Citation databases are specific for presenting each article incorporated in the base also by the respective list of references in addition to bibliographic record. These lists of references are called cited references or citations. The search according to cited references is more complete because it enables follow up of a particular topic through all articles on the topic which are included in the database. Specifically citations are assumed to be linked to the topic of the current paper by their contents, irrespective of the reasons for their citing. Citation databases provide data on the number of citations received by a particular journal, author, or paper as well as allowing the literature searching according to topic Citation databases includes Web of Science, Google Scholar, Scopus, CiteseerX etc. Each source has its own merits and demerits and therefore selection of data source is a critical question.

VII. DATABASES AS DATA SOURCES

Databases developed by commercial establishments or by public or private institutions form the sources of data for web based scientometric studies. One or more databases for every established academic discipline is also there. Subject oriented fields (e.g. classification codes, descriptors, identifiers, keywords, words in the title, words in the abstract, words in the full text), type of publication (e.g. journal paper, conference paper, book, patent, report, etc.),

source (e.g. journal title, CODEN, ISSN number, ISBN number, patent number, year of publication, volume, number of issue, pages, name of publisher, place of publication), responsibility (e.g. name of authors, editors, translators), geographical and institutional information (e.g., country of its editor, name and corporate affiliation of the authors - name of organization, city, country , language(s) of publication , secondary source (eg. year, volume and number of the abstract), citations or references are some among the data elements in the databases used for scientometric studies.

Some of the widely used data sources for scientometric studies are:

A. Chemical Abstracts Service (CAS): CAS is a division of American Chemical Society. It is a source of chemical information. It includes CAplus and Registry. CAplus consists of bibliographic information and abstracts for all articles in chemical journals worldwide and chemistry related articles from all scientific journals, patents and other scientific publications. Its coverage is from 1907 onwards an is located in Columbus, Ohio, United States

B. CiteseerX: Citeeser was the first digital library and search engine to provide automated citation indexing and citation linking by autonomous citation indexing. Citeseer was developed in 1997at the NEC Research Institute, Princeton, New Jersey by Steve Lawrence, Lee Giles and Kurt Bollacker. It is an evolving scientific literature digital library and search engine that has focused primarily on the literature in computer and information science. CiteSeerX aims to improve the dissemination of scientific literature and to provide improvements in functionality, usability, availability, cost, comprehensiveness, efficiency, and timeliness in the access of scientific and scholarly knowledge.

CiteSeerX has developed new methods and algorithms to index PostScript and PDF research articles on the Web. Autonomous citation indexing, automatic metadata extraction, citation statistics, reference linking, author disambiguation, citation context, related documents, full-text indexing, query-sensitive summaries, metadata of articles are some of the features.

C. Ei Compendex: It is a product of Elsevier. Ei Compendex is the broadest and most complete engineering literature database available in the world. It provides a truly holistic and global view of peer reviewed and indexed publications with over 20 million records from 77 countries across 190 engineering disciplines. Every record is carefully selected and indexed using the Engineering Index Thesaurus. Founded in 1884, Engineering Index has recorded virtually every major engineering innovation from around the world. The Engineering Index back file provides a comprehensive, historical view of engineering innovations from 1884-1969 with over 1.7 million records digitized from the original print indexes. It is available on Engineering Village.

D. ERIC: The Education Resources Information Center (ERIC) - is an online digital library of education research and information. ERIC is sponsored by the Institute of Education Sciences (IES) of the U.S. Department of Education. ERIC provides ready access to education literature to support the use of educational research and information to improve practice in learning, teaching, educational decision-making, and research. ERIC provides unlimited access to more than 1.4 million bibliographic records of journal articles and other education-related materials, with hundreds of new records added multiple times per week. If possible, links to full text in Adobe PDF format are included. Within the ERIC Collection, you will find records for: journal articles, books, research syntheses, conference papers, technical reports, policy papers, and other education-related materials.

E. Google Scholar: Google Scholar a freely available citation database for searching scholarly literature was introduced by Google Inc in 2004. Google Scholar has become a major data source for citation analysis and scholarly information for researchers, librarians and others because of free availability and indexing of different forms of scholarly information (book chapters, conference proceedings, books, pre-print servers and other forms) other than journals.

F. Inspec: The Inspec database contains 13 million abstracts and specialized indexing to the world's quality research literature in the fields of electronics, computer science, physics, electrical, control, production and mechanical engineering since late 1960's. It contains index and abstracts of articles selected from nearly 5000 scientific and technical journals (1600 of which are indexed from cover to cover), some 2500 conference proceedings, as well as numerous books, reports, dissertations and scientific videos. It is published by The Institution of Engineering and Technology, Stevenage, Herts., U.K.

G. Library and Information Science Abstracts (LISA): LISA (maintained by ProQuest) is an international abstracting and indexing tool designed for library professionals and other information specialists. LISA currently abstracts over 440 periodicals from more than 68 countries and in more than 20 different languages. The temporal coverage is from 1969 onwards.

H. MathSciNet: It is an electronic database of reviews, abstracts and bibliographic information for mathematical sciences literature. Over 100,000 new items are added each year, most of them classified according to the Mathematics Subject Classification. MathSciNet contains over 2.8 million items and over 1.6 million direct links to original articles. Bibliographic data from retro digitized articles dates back to the early 1800's. This web of citations allows users to track the history and influence of research publications in the mathematical sciences.

I. Pub Med: National Library of Medicine (NLM), United States has been indexing the biomedical literature since 1879, to help provide health professionals access to information necessary for research, health care, and education. MEDLINE contains journal citations and abstracts for biomedical literature from around the world. Since 1996, free access to MEDLINE has been available to the public online via PubMed. It comprises more than 22 million citations for biomedical literature from MEDLINE, life science journals, and online books. Citations may include links to full-text content from PubMed Central and publisher web sites.

J. Scopus: Scopus is multidisciplinary and diversified literature database produced and upheld by Elsevier launched in 2004. It is an abstract and citation database of peer-reviewed literature with smart tools that track, analyze and visualize research. Scopus covers nearly 36,377 titles (22,794 active titles and 13,583 inactive titles) from approximately 11,678 publishers, of which 34,346 are peer-reviewed journals in top-level subject fields: life sciences, social sciences, physical sciences and health sciences. It covers three types of sources: book series, journals, and trade journals. All journals covered in the Scopus database, regardless of who they are published under, are reviewed each year to ensure that high quality standards are maintained. The complete list is on the SCImago Journal Rank website. Its strength is standardising and reliably identifying author names and institution names. Searches in Scopus also incorporate searches of patent databases. Scopus gives four types of quality measure for each title; those are *h*-Index, CiteScore, SJR (SCImago Journal Rank) and SNIP (Source Normalized Impact per Paper).

K. Web of Science: Originally produced and upheld by Institute of Scientific Information, afterwards by Thomson Reuters and today by Clarivate Analytics, Web of Science is a platform consisting of several literature search databases designed to support scientific and scholarly research. Web of Science is a premier research platform for information in the sciences, social sciences, arts, and humanities. It is a collection of databases, most important among them being Science Citation Index, Social Science Citation Index, and Arts & Humanities Citation Index. It contains nearly the same journal publications as Scopus, over 18,000 high impact journals, over 180,000 conference proceedings, and over 80,000 books from around the world. Its coverage is from the year 1900 to present day and provides the possibility to search for publications, citations and h-indexes. Search results can also be analyzed in the same way as within the Scopus database. The use of Web of Science is significantly slowed down by the fact that the author names have not been standardised.

VIII. SOFTWARE FOR SCIENTOMETRIC ANALYSIS

In the technology era, qualitative and reliable databases are there for collecting and analyzing huge amount of data for scientometric studies. There are a number of analyzing tools which can be used for scientometric analysis. The databases provide fast, inexpensive, advanced, domain dependent, reliable and reproducible analytical tools. Article counting on different attributes, removal of duplicate items (when multiple sources are used), frequency analysis, defining of subset, ranking on specific criterion, h-index calculation, link analysis, mapping, visual representation, integration with external programs, etc., are all possible with modern databases. The popular bibliometric software/tools are: BibExcel, CiteSpace, HistCite, Pajek, Publish or Perish, Scholarometer, Scholar h-index Caculator and so on.

A. BibExcel: It is a free-software designed by Olle Persson of Sweden for academic and non-profit use. It can be used for analyzing Frequency distribution (Authors, Titles, Citations, or any field specified), and Co-occurrence analysis (includes Co-citation analysis, Bibliographic coupling, Co-author analysis, Coword analysis). A useful feature in Bibexcel is the one that enables us to produce data matrices for export to statistical software. It allows easy interaction with other software, e.g. Pajek, Excel, SPSS, etc. The program offers the user high degree of flexibility in both data management and analysis and this flexibility is one of the program's real strengths.

B. BiblioTool: It is a set of python scripts (open source) written by Sebastian Grauwin. They can read ISI data in csv format and do some analyses including cooccurence map and bibliographic coupling.

C. Cite Space: A free Java based software created by Chaomei Chen is a tool to visualize and analyze trends and patterns in scientific literature. It is a free Java application that can be downloded by the users. The input data sources for CiteSpace are Web of Knowledge, PubMed, arXiv, ADS, and NSF Award Abstracts. A unique feature of CiteSpace is that records from Derwent World Patents Index can also be visualized. CiteSpace provides various functions to facilitate the understanding and interpretation of network patterns and historical patterns, including identifying the fast-growth topical areas, finding citation hotspots in the land of publications, decomposing a network into clusters, automatic labeling clusters with terms from citing articles, geospatial patterns of collaboration, and unique areas of international collaboration. CiteSpace supports structural and temporal analyses of a variety of networks derived from scientific publications, including collaboration networks, author co-citation networks, and document cocitation networks. It also supports networks of hybrid node types such as terms, institutions, and countries, and hybrid link types such as co-citation, co-occurrence, and directed citing links.

D. Copal Red: A free program written by Xavier Polanco for the analysis of scholarly publications and scientometric purposes like analyzing and visualizing the network structure of a scientific field.

E. HistCite: A free software developed by Eugene Garfield, popularly known as the father of Citation Analysis. HistCite is a system designed to help selectively identify the significant (most cited) papers retrieved in topical searches of the Web of Science (SCI, SSCI and/or AHCI). Once a marked list of papers has been created, the resulting Export file is processed by HistCite to create tables ordered by author, year, or citation frequency as well as historiographs which include a small percentage of the most-cited papers and their citation links.

F. Interdisciplinary Research (IDR): A free tool to measure and map interdisciplinary research. It creates overlay maps of science, as a method to explore the degree of interdisciplinarity of a set of publications.

G. Loet Leydesdorff: Leydesdorff's software is a set of command-line programs that enable a science mapping with different analysis functions to be performed. It was developed at the UniversityofAmsterdam (TheNetherlands). The set of programs is freely accessible to the academic community. It is a software to transform and analyse bibliometrics data obtained from sources such as Scopus, Web of Science and Google Scholar for co authorship, international, institutional collaboration networks, co-word, co-citation and bibliographic analysis. The results can be visualized using external software such as Pajek,

H. Pajek: It is a free python based software for analyses and visualization of huge networks with a large to very large number of vertices. Pajek, an unusual name in English, means a spider Slovenian language. It was started in the year 1996 and developed into one of the most popular software in the field of visualization and largely used by experts in scientometrics. Pajek is very useful tool in areas like organic chemistry, genealogy, data mining, diffusion networks etc. It can also be used in bibliometrics for visualize the collaboration and citation networks. Pajek is developed by Vladimir Batagelj and Andrej Mrvar. Some procedures were contributed also by Matjaz Zaversnik.

I. Publish or Perish: It is a popular software program among scholars that retrieves and analyzes academic citations. It is developed and maintained by A.W. Harzing. It interprets Google Scholar outputs and allows academics to easily check their own or others performance. It computes excellent citation statistics about each author's work, including an overall 'times cited' score and times cited per year since publication. Total number of papers Total number of citations ,Average number of citations per paper, Average number of citations per author , Average number of papers per author , Average number of citations per year , Hirsch's h-index and related parameters , Egghe's g-index and some more metrics can be calculated using this.

J. Scholarometer: Scholarometer (previously Tenurometer) is called so as it provides service to scholars by computing citation-based impact measures. It is a social tool to facilitate citation analysis and help evaluate the impact of an author's publications. Scholarometer helps authors and academic administrators evaluate the impact of someone's research publications, citation-based impact measures. Using Scholarometer, one can compute Hirsch's h-index, Egghe's g-index, and Schreiber's hm index. The latest version of Scholarometer can also calculate the new universal h-index (developed by Radicchi, Fortunato and Castellano).

K. VOSviewer: A free Java based program, intended to be used for analyzing and visualizing bibliometric networks. It can create maps of publications, authors or journals based on a co-citation network or to construct maps of keywords based on a co-occurence network. Apart from these, SciMAT, Sci2 Tool, Scientometric Project, VOS viewer and SAINT, Network Workbench etc are some other software tools used for scientometric analysis.

IX. CONCLUSION

The merits and drawbacks of each software tools vary as each of has different characteristics and implements different techniques that are carried out with different algorithms. Therefore combination of different software tools can be used for complete scientometric analysis and will help in measuring knowledge in different perspectives. The scientometric researchers need to know about the various popular data analysis, mapping and visualisation softwares. Some software are able to do scientometric analysis, some are able to create maps and networks, while some are specialised in information visualisation. Most of these softwares are designed and developed in a way to capture the input data from the various popular data sources such as: Scopus, Web of Science, Google Scholar, PubMed and many others, and with the help of these softwares analysis of large scale data can be done in a lesser time. Data convergence and compatibility feature are there in many softwares which supports interoperability and crosswalk of input and output data. These scientometric analysis, mapping and visualization softwares are now widely used by the researchers. The study gives interesting information about scientometric study and its tools available online which will be helpful to researchers who want to identify primary sources of scientometric study. The familiarization of different bibliometric softwares among students and researchers will help to promote research in scientometrics in a more productive method. New web based alternatives called altmetrics, cybermetrics or webometrics have emerged which negotiates the landscape of traditional impact metrics as interest in online venues for scholarly communication are getting higher giving rise to the new art and science of impact measurement.

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