Sixth International Conference on Webometrics, Informetrics and Scientometrics & Eleventh COLLNET Meeting, October 19 – 22, 2010, University of Mysore,

Author Co-Citation Analysis (ACA): a powerful tool for representing implicit knowledge of scholar knowledge workers

Rasool Zavaraqi
zavaraqi@ut.ac.ir, rasoolzavaraqi@gmail.com
Library and Information Science PhD Student, University of Tehran

Abstract
In the last decade, knowledge has emerged as one of the most important and valuable organizational assets. Gradually this importance caused to emergence of new discipline entitled "knowledge management". However one of the major challenges of knowledge management is conversion implicit or tacit knowledge to explicit knowledge. Thus Making knowledge visible so that it can be better accessed, discussed, valued or generally managed is a long-standing objective in knowledge management. Accordingly in this paper author co-citation analysis (ACA) will be proposed as an efficient technique of knowledge visualization in academia (Scholar knowledge workers).

Introduction
In the last decade, knowledge has emerged as one of the most important and valuable organizational assets. The term 'knowledge worker', coined by Peter Drucker (1959), gained acceptance and became associated with the users of information systems and information technology (IS/IT) (Drucker, 1993). Gradually this importance caused to emergence of new discipline entitled "knowledge management". The interest in Knowledge Management started in 1993 with Drucker's book The Post-Capitalist Society. Drucker described how our society is being transformed into one whose primary resource will be knowledge. He claimed that the true investment in the future of our society is not in machines and tools but in the knowledge of the knowledge worker.
Knowledge management is the process of creating value from an organization's intangible assets. Intangible assets, also referred to as intellectual capital, include human capital, structural capital, and customer or relationship capital. Human capital is the brain power — the people knowledge — in the organization. Structural capital refers to intellectual assets that cannot be easily taken home with the employees, such as patents, trademarks, certain databases, and other related items. Customer or relationship capital is what can be learned from the organization's customers or stakeholders.(Liebowitz, 2001, p.2).
In other hand, one of the major challenges of knowledge management is conversion implicit or tacit knowledge to explicit knowledge. Thus Making knowledge visible so that it can be better accessed, discussed, valued or generally managed is a long-standing objective in knowledge management (Sparrow, 1998). However experts use Knowledge maps, knowledge cartographies, knowledge landscapes or generally knowledge visualization techniques for this but nevertheless these terms rarely defined, described or demonstrated (Eppler and Burkhard 2007).
In this paper we suggest author co-citation analysis (ACA) for extracting implicit knowledge produced in universities and colleges or in other words visualizing scientific knowledge of scholar knowledge workers by emphasizing on visualization in two disciplines of knowledge management and scientometrics.

Implicit (tacit) Knowledge versus Explicit Knowledge

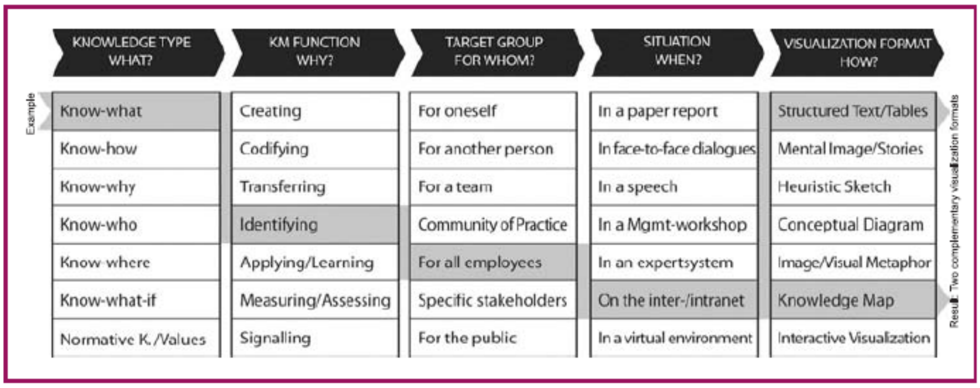
For years, organizations paid lip service to the management of knowledge, being concerned with more tangible and physical assets. The knowledge component of the value-chain had been obscured by the tendency to think of work as fundamentally a physical activity (Zuboff, 1988). Nevertheless the potential advantages that intellectual capital brings in the form of greater earnings through licensing technology have revised this trend. Polanyi (1958, 1966) and, later, others (Bateson, 1973; Nonaka, 1990; Naisbitt, 1994; Nonaka and Takeuchi, 1995 and etc.) made distinctions between tacit and explicit knowledge. Polanyi (1966) defines tacit knowledge as personal, context-specific and, thus, not easily visible and expressible — nor easy to formalize and communicate to others. He added that Individuals may know more than they are able to articulate. He also has illustrated how the knowledge involved in riding a bicycle has not been made explicit, involves an embodied skill and cannot easily be articulated. Polanyi (1958: 20) argues that a 'sharp distinction between tacit and explicit knowledge does not exist and that ''tacit thought'' forms an indispensable part of all knowledge'. Even if knowledge has been articulated into words or mathematical formulas, this explicit knowledge must rely on being tacitly understood and applied. Therefore, 'all knowledge is either tacit or rooted in tacit knowledge' (Polanyi, 1966: 7). Tacit knowledge is deeply embedded personal beliefs, attitudes, values and experiences that give tacit knowledge its meaning (Popper, 1972). As such it is at best difficult and at worst impossible to articulate as it is highly situated in the context and to abstract it from its context of application is to lose much of its intrinsic meaning and value. Thus it is this tacitness precisely that makes tacit knowledge difficult to imitate or import from organization to organization and therefore makes it an important organizational resource for securing competitive advantage (Grant, 1996). Necessarily, this tacit knowledge is subjective and personal, but it can be shared to some extent, and passing on the knowledge is a process that can be helpful to others and ultimately valuable to the organization so that it can carry on and complete its work successfully. By "fixing" the knowledge or attempting to represent it in a format such as a manual, a step-by-step video guide, or a graphic schematic (as a result of visualization techniques), a knowledge artifact for instance as a paper and other scientific formats in academia, is created.

Therefore we can say that visualizing implicit knowledge is most important aspect of knowledge work. When tacit knowledge has not been represented and made explicit in an organization, there could be lost opportunities in performance, opportunities that other organizations may exploit for their own purposes (McInerney, 2002). Accordingly Polany emphasized that the main challenge of knowledge management is conversion of tacit or implicit knowledge to explicit knowledge. Therefore Making knowledge visible so that it can be better accessed, discussed, valued or generally managed is a long-standing objective in knowledge management (Sparrow, 1998).

On the other hand in recent years, with the increasing cooperation among academia, industries and governments, researchers and scholars have come to see the importance of knowledge management in academia. As mentioned by Kidwell et al. (2000), 'colleges and universities have significant opportunities to apply knowledge management practices to support every part of their mission—from education to public service to research. Hence they want to do visible their scholar intellectual capital or intellectual structure to be more productive. For this reason, researchers constantly are following tools or techniques to do visible their intellectual capital which in academia in named intellectual structure. One of recent tools and techniques is knowledge visualization.

The knowledge type perspective can be used to identify the type of knowledge that has to be transferred. The framework distinguishes among six types of knowledge: declarative knowledge (know-what), procedural knowledge (know-how), experiential knowledge or experience (know-why), people-related knowledge (know-who), orientation or location-based knowledge (know-where), scenario-based knowledge (know-what-if) or normative, value-based knowledge. For a similar distinction, see for example, Alavi and Leidner (2001).

Figure 1 A Framework for the use of visualization in knowledge management



Thus we can use visualizing techniques for extracting all type of knowledge in academia. Knowledge visualization offers great potential for the creation of new knowledge in groups, thus enabling innovation. Knowledge visualization offers methods to use the creative power of imagery and the possibility of fluid re-arrangements and changes. It inspires and enables groups to create new knowledge, for instance by use of heuristic sketches. Unlike text, these ad-hoc graphic formats can be quickly and collectively changed and thus propagate the rapid and joint improvement of ideas. They also capture more implicit aspects of personal knowledge (Polanyi, 1958) that cannot be expressed easily through verbal means, but rather shown through graphic analogies or symbols.

Yet another application area for visualization in knowledge management is knowledge identification. Knowledge maps (Eppler, 2002) have been used for a while to map the expertise located within a particular company and link it to personal homepages of specific experts. Such maps can provide an overview on various forms of knowledge sources, such as experts, documents, project teams, organizations or even patents.

Knowledge visualization can also help to evaluate, rate and measure knowledge. Next to identifying relevant knowledge, visualization can be employed to facilitate the process of evaluating knowledge assets. By providing conceptual diagrams as interactive graphic frameworks and multi-dimensional scales as communication support, knowledge can be jointly assessed and evaluated and weak spots or core competencies can be detected.

A further area where visualization can add value to knowledge management is knowledge application. In this context it is vital that individuals can use the documented explicit knowledge of others and are not overloaded by it. Visualization can be used as an effective strategy against information overload: Information overload is a major problem in knowledge-intensive organizations. Knowledge visualizations help to compress large amounts of reasoned information with the help of interactive visualization, i.e. graphic models and simulations that absorb complexity and render it accessible through easy-to-use manipulation. This can be a vital prerequisite for the three application domains mentioned previously (transfer, creation, and communication).

A final, often neglected area of knowledge management, where visualization can play a pivotal role is knowledge marketing. Through the help of appealing visuals abstract competence can be converted into tangible value propositions. In order to market their skills and experiences, companies rely not only on symbols, such as knowledge brands, but also use visual representations of their knowledge to signal competence. Knowledge maps and visual metaphors seem particularly apt for this purpose as they make new material accessible through familiar structures (Eppler and Burkhard 2007).

In other hand, a majority of our brain's activity deals with processing and analyzing visual images. To understand perception, it is important to remember that our brain does not differ greatly from our ancestors, the troglodytes. At that time, perception helped for basic functions, for example for hunting (motion detection), seeking food (color detection), or applying tools (object-shape perception). To comprehend visual perception, the Gestalt Principles (Koffka, 1935) are helpful to understand how we perceive groups of objects or parts of objects, by identifying various perceptual phenomena. The Gestalt Principles provide descriptive insights into form and pattern perception. But unfortunately they do not offer explanations of these phenomena. To understand how or why we perceive forms and patterns, we need to consider explanatory theories of perception. But before we come to these theories it is introduced how visual information is being processed (Farah, 2000; Goldstein, 2001; Gregory, 1998; Ware, 2000). Visual information processing can be divided into two stages: In the first stage, information is parallel processed in the eye and the primary visual cortex, where individual neurons in specific areas (called V1, V2, V3, V4, MT) are specialized to identify particular features (e.g., orientation, color, texture, contour, or motion). At this early stage information processing proceeds pre-attentively and very rapidly. In the second stage, information processing is divided into two functionally independent complementary subsystems, "two cortical visual systems" in the terminology of Ungerleider and Mishkin (1982): One visual subsystem is more important for object identification (~what) and the other for spatial localization (~where). But these findings from visual information processing do not explain yet how we visually perceive form.

Accordingly Visualization can be classified as scientific visualization, software visualization, or information visualization. Although the data differ, the underlying techniques have much in common. They use the same elements (visual cues) and follow the same rules of combining visual cues to deliver patterns. They all involve understanding human perception (Encarnacao, Foley, Bryson, & Feiner, 1994) and require domain knowledge (Tufte, 1990). Although (computer-based) visualization is a relatively new research area, visualization has a long history. For instance, the first known map was created in the 12th century (Tegarden, 1999), and multidimensional representations appeared in the 19th century (Tufte, 1983). Bertin (1967) identified basic elements of diagrams in 1967, and Tufte (1983) published his theory regarding maximizing the density of useful information in 1983. Both Bertin's and Tufte's theories have had substantial impact on subsequent information visualization. Nevertheless the term "information visualization" was first used in Robertson, Card, and Mackinlay (1989) to denote the presentation of abstract information through a visual interface. Early information visualization systems emphasized interactivity and animation (Robertson, Card, & Mackinlay, 1993), interfaces to support dynamic queries (Shneiderman, 1994), and various layout algorithms on a computer screen (Lamping, Rao, & F'irolli, 1995). Later visualization systems presenting the subject hierarchy of the Internet (H. Chen, Houston, Sewell, & Schatz, 1998), summarizing the contents of a document (Hearst, 1995), describing online behaviors (Donath, 2002; Zhu & Chen, 2001), displaying Web site usage patterns (Eick, 2001), and visualizing the structures of a knowledge domain (knowledge visualization) (C. Chen & Paul, 2001) have been stimulated by the networked and virtual nature of human society resulting from the adoption of advanced technologies (Zhu and Chen 2005).

In Burkhard and Meier (2004) the first definition of knowledge visualization was introduced, which allowed to discuss the difference between knowledge visualization and information visualization. This first definition also helped to differentiate knowledge visualization and knowledge domain visualization (Börner & Chen, 2002). Today the following definition of knowledge visualization is being accepted by information visualization, knowledge visualization, and knowledge domain visualization experts: "Knowledge Visualization examines the use of visual representations to improve the transfer and creation of knowledge between at least two persons".(Burkhard, 2004a; Burkhard & Meier, 2004; Eppler & Burkhard, 2004).

As a result The task of knowledge comprehension could be facilitated by an emerging field of study - Knowledge Domain Visualization (KDV), which tries to depict the structure and evolution of scientific fields (Borner, Chen and Boyack, 2002). A knowledge domain is represented collectively by research papers and their inter-relationships in this research area and its domain's intellectual structure can be discerned by studying the citation relationships and analyzing seminal literatures of that knowledge domain (Lee and Chen 2007). Using these knowledge visualization techniques, Beyond the mere transport of information or facts, people who employ knowledge visualization aim to create, assess, reference or transfer insights, experiences, attitudes, values, expectations, perspectives, opinions and predictions, and this in a way that enables someone else to re-construct, remember, find or apply these insights correctly (Eppler and Burkhard, 2007).

Author Co-Citation Analysis (ACA) as a representation tool of implicit knowledge in academia

Different disciplines suggest special method for conversion of implicit knowledge to explicit one. As follow knowledge visualization is an information scientist's solution for academia and scholar knowledge workers. The visualization of information is by no means a new practice in the field of Documentation: suggested over 60 years ago by Bush (1945), and put into practice just over 40 years ago by Garfield, Sher and Torpie (1964), the visualization of scientific information has long been used to "uncover" and divulge the essence and structure of science.

As Vannevar Bush envisaged in his Memex (Bush, 1945), the value of a knowledge structure is how we make various intellectual connections, or trails, and how we may be inspired by such intellectual connections made by others. Although hypertext, notably via the revolution of the World-Wide Web, has made it possible to accomplish a great deal of what Bush envisaged, problems such as lost in cyberspace and cognitive overload have been identified (Conklin, 1987). Users of digital libraries are facing similar challenges (Bollen, Luce, Vemulapalli, & Xu, 2003). Furthermore, users need tools that enable them to keep track the evolution and impact of scientific knowledge over time. In other words It is important nowadays for both intellectual and policy reasons to be able to know the relationship between concepts, ideas and problems in science and social sciences. There are several ways in which such, is to seek the views of relatively small number of experts (peer review) (Law and Whittaker, 1992). Bibliometric research is another way to achieve this task from quantitative perspective (Ding, Chowdhury and Foo, 2001). Bibliometric research is devoted to quantitative studies of literature. It encompasses a number of empirical methods such as citation and co-citation analysis. Co-citation analysis is an important subset of bibliometrics. Since small (1973) introduced and concept and defined it as "the frequency with which two items of earlier literature are cited together by the later literature", co-citation analysis have been successfully applied to examine the intellectual structure of many disciplines. the criteria generally involve counting the number of items certain markers occur or co-occur, giving rise to information on such author co-citation, journal co-citation, keyword co-citation, and so on. In particular they can be applied to the formal record of scholarly communication from different points, such as authors, journals and textual content. The pioneering Atlas of Science (ISI, 1981) of the Institute of Scientific Information (ISI) and their latest work in visualizing science (Garfield, 1998; Small, 1999) has mapped the macrostructure of science. In contrast, instead of the entire science as a whole, domain visualization tends to focus on a specific domain or discipline such that one can explore the dynamics of a scientific discipline as an organic system, for example (White & McCain, 1998) on information science, and (Chen, 1999) on hypertext. Most of these works derive high-level structures from document co-citation, author co-citation, and classification code co-occurrences.

As a result, until fairly recently, sociologists believed that bibliographic citations were some sort of system for the control of intellectual property safe-guarded in scientific publications. The importance that they wielded, additionally, in reflecting cognitive and social connections among researchers went unacknowledged (Merton, 2000). But in the field of Documentation, authors soon began to appreciate this alternative facet of citation. Networks borne through the citation of scientific documents can clearly signal the emergence of new research fronts (Price, 1965) just as they can be used to obtain ethnographic information referring to the presence and nature of social relations – for example, to discover through citation a close colleague whom one has never met in person (White, 2001). The use of this technique can be extended beyond bibliometrics or sociology to become a general notion in which different sub disciplines flow together, including: scientometrics, infometrics, and bibliometrics in the strict sense.

Indeed nowadays Astrophysicists have the Hubble Telescope to study remote stars and galaxies –they are the unit of their analysis. Biologists have the microscope to examine the microcosms – the unit of their analysis. Why do scientists not have a viewfinder to their own fields? In his Little Science, Big Science Derek Price (Price, 1963) suggested that the science of science should learn from thermodynamics. The behavior of gas is influenced by various conditions of temperature and pressure. Thermodynamics is not particularly concerned with the trajectory of a specific molecule; rather, it concentrates on the phenomenon as a whole. Price suggested that one should study science in a similar way in terms of the volume of science, the trajectory of "molecules" in science, the way in which these "molecules" interact with each other, and the political and social properties of this "gas". The seminal work Networks of Scientific Papers (Price, 1965) studies the intellectual structure interwoven between scientific papers. In 1974, Small and Griffith examined issues concerned with identifying and mapping specialties from the structure of scientific literature, especially based on co-citation patterns (Small and Griffith, 1974). In 1977, Small conducted a longitudinal study of collagen research and found that rapid changes of focus took place in this research (Small, 1977). He computed co-citation strengths between pairs of documents and grouped documents into clusters to represent leading specialties, or paradigms. Rapid shift in research focus is evident when a number of key documents abruptly disappear from the leading cluster in one year and they are replaced by a set of new documents in the following year. This is an important type of specialty change, which is an informative indicator of "revolutionary" changes. More recent studies in related areas include Braam et al. (1991a, b), Garfield (1994) and Small (1997, 1999).

Literature review shows that various efforts to map the structure of science have been undertaken over the years. Science mapping studies are typically focused at either the macro or micro level. At a macro-level such studies seek to determine the basic structural units of science and their interrelationships (Bassecoulard & Zitt, 1999; Nederhof & van Wijk, 1997). Some macro level studies also allow exploration of the fine scale structure underlying the global networks (Small, 1999). However, the majorities of science mapping studies are performed at the discipline or domain level (Leydesdorff, 1994; Spasser, 1997; Noyons &

van Raan, 1998; McCain, 1998; White & McCain, 1998), and seek to inform science policy and technical decision makers. Studies at both levels probe the dynamic nature of science and the implications of the changes. Alternate approaches with more applied goals (such as S&T management) include textual data mining (Losiewicz, Oard & Kostoff, 2000) and database tomography methods (Kostoff, Eberhart & Toothman 1999), and are usually applied at the discipline level. A variety of databases and methods have been used for these studies. Primary among databases are the Science Citation Indexes (SCI and Social SCI) from the Institute for Scientific Information (ISI), which have gained widespread acceptance for bibliometric studies. Science and technology maps are most often based on computed similarities between journal articles using citation analysis (Small, 1999), or co-occurrence or co-classification using keywords, topics, or classification schemes (Nederhof &van Wijk, 1997; Noyons & van Raan, 1998; Spasser, 1997). Studies to identify intellectual or social networks are performed using author co-citation analysis (White & McCain, 1998; Chen, Paul & O'Keefe, 2001) or on the basis of co-authorship (Newman, 2001). Macro-level maps can be based on journal inter-citation patterns (Bassecoulard & Zitt, 1999; Leydesdorff, 1994; McCain, 1998). Citation and classification based techniques have been used recently to map technology domains based on US patents (Boyack et al., 2000). Latent semantic analysis (Landauer, Foltz & Laham, 1998; Borner, 2000), a memory-intensive text-based process, has also become more prominent as computing resources have increased. Once relationships between objects (articles, terms, authors, etc.) have been defined and a similarity matrix (based on co-citation or co-occurrence, etc.) has been computed, algorithms are used to cluster the data. Common clustering methods for producing maps include hierarchical clustering, k-means algorithms, multidimensional scaling, principal components analysis, and self-organizing maps. Historically, the standard mapping output has been a circle plot where each cluster is represented by a circle sized to represent the number of documents. Links between circles provide relationship information including the strength of the link. Traditionally, map outputs have been paper-based and only resolve structure at a few discrete levels. However, in recent years, several systems have been reported that use a computer display and allow some navigation of the map space. (Boyack, Wylie, and Davidson 2001)

But generally Co-citation is a widely used to measure similarities and to derive intellectual structures, to name a few examples (White & Griffith, 1981; White & McCain, 1998 and etc). In co-citation analysis, a set of items (authors, documents, journals, etc.) is selected to represent a research area, and relationships between these items are then analyzed using co-citation counts - the number of articles that have cited two items together in the same articles - as similarity measures and multivariate analysis techniques as analysis tools, in order to study the intellectual structure of this research field and to infer some of the characteristics of the corresponding scientific community.

However out of all the methods for co-assignment or co-occurrence, that of authors is the most widely used, Author co-citation takes place when one author cites, in a new document, any work by another author, together with the work of a third, fourth, or fifth author. This is based on the understanding that works cited in conjunction (co-cited) reveal the existence of an intellectual relationship between the co-cited authors.

As a result, Information scientists for extracting scholar implicit knowledge (intellectual structure), use Author co-citation analysis (ACA). One of the pioneering studies, Author Co-citation Analysis (ACA), is used to present the intellectual structure of knowledge domain. Recent studies in knowledge visualization adopt this ACA approach as its underlying methodology and outfitted the intellectual structure with visual cues and effects (Chen, 2004) and focuses on interrelationships among influential authors in the literature, instead of on individual publications. ACA aims to identify underlying specialties in a field in terms of groups of authors who were cited together in relevant literature. An ACA study typically focuses on a network of cited authors connected by co-citation links. The unit of analysis in ACA is authors and their intellectual relationships as reflected through scientific literatures. Author co-citation is a more rigorous grouping principle than typical subject indexing, because the connectivity is based on repeated and collective views of subject experts expressed in their publications. Typically, the process of an ACA starts with sampling representative publications from a literature of a given field of study. Science Citation Index (SCI) and Social Science Citation Index (SSCI) are among the most widely used sources of citation data - both from Institute for Scientific Information (ISI). An intellectual structure of prominent authors in the field provides a good candidate for knowledge visualization. Normally the predominance of an author is determined by citations he or she has received or by other criteria, such as the membership of a scholarly institution. Author co-citation frequencies among these selected authors are then calculated. If a pair of authors X and Y is cited by the same scientific publication, the author co-citation counts of the pair will increment by one.

This approach as a special type of co-citation analysis was introduced by WHITE & GRIFFITH, 1981. ACA has mostly been used to analyze the intellectual structure of a given scientific field (McCain, 1990). McCain states that there are four main steps in an ACA. First we compile the author co-citation matrix; next make similarity matrix from the author co-citation matrix; next perform a multivariate analysis; finally interpretation and validation of the results. McCain used the Pearson's correlation coefficient. But there is a research that this coefficient is probably not an optimal choice of a similarity measure in ACA. In ACA, instead of articles or journals, individual authors are used as data points in the literature. Authors are the unit of analysis. ACA provides invaluable information about how authors, as domain experts, perceive the interconnectivity between Published works. An in-depth author co-citation analysis was reported by White and McCain (1998) in 1998. They analyzed the domain of information science based on author co-citation data drawn from 12 key journals in the field over a 23-year period (1972–1995). The top 120 authors were selected for the study according to citation counts. Several maps were generated for the top 100 authors in the field, using multi- dimensional scaling (MDS), and a factor analysis was conducted to identify major specialties in information science, which revealed that information science consists of two major specialties with little overlap in their memberships: experimental retrieval and citation analysis. Their work clearly demonstrates the strength and potential of ACA. Their work represents the state of the art in ACA, which typically uses factor analysis and clustering techniques to determine intellectual groupings, and then depicts the results as MDS solutions. As White and McCain have pointed out in 1998, citation analysis must not only identify the value of particular works, but also explain why some are more valued than others. Noyon, Mode and Luwel (1999) combined domain mapping and citation analysis in a bibliometric study to emphasize the evaluation aspect of bibliometrics.

Traditionally, ACA studies are limited to the first author of a cited reference only, primarily because of the lack of required data to perform all-author analysis. More recent studies have confirmed that all-author co-citation patterns reveal stronger groupings than first-author only patterns (Schneider, Larsen, & Ingwersen, 2009). Also, ACA traditionally relies on a range of data analysis methods in order to identify emergent patterns in the co-citation data. Commonly used methods include cluster analysis, factor analysis, and multidimensional scaling (MDS).

Also Because of time-consuming approach of White and McCain (1998), Chen and Paul (2001) have developed a generic approach that extends traditional ACA analysis by integrating structural modeling and information visualization techniques to provide a 3D knowledge landscape based on citation patterns. In particular, they introduce the following steps to extend conventional ACA to visualize intellectual structures:

• replace MDS with the Pathfinder network scaling technique to display interrelationships and local structures explicitly and more accurately,
• visualize the intellectual groupings determined by factor analysis in traditional ACA, and
• evaluate the citation impact in the context of a co-citation network (Chen and Paul, 2001).

The past 20 years have witnessed the application of several techniques for the construction of ACA-based visualizations. In data entry, co-citation values in a pure state have been used, as well as the recount of the number of pairs of authors standardized through some type of similarity measure such as the Pearson correlation coefficient, or that of Salton, or the cosine. For the spatial distribution of the information displayed, techniques have been sought in Multidimensional Scaling (MDS), clustering, FA, Self- Organizing Maps (SOM), geographic maps, and PFNET. Of these, the two-dimensional representations obtained with PFNET and effected with pure co-citation values, then visualized through spring-embedder-type programs, are the ones that appear to offer the best results (Lin; White; and Buzydlowski, 2003) as we will see later on.

Conclusion

The main objective of this study was proposing author co-citation analysis (ACA) as an efficient approach for scientific knowledge visualization. As argued in this paper Companies and institutes need to monitor the activities of their competitors, identify information on the market, technologies, or government actions. These monitoring activities are necessary for them to define alliance strategies, innovation and customer oriented strategies. Organizations need methods and tools to lead such activities, that gather information, mine them and display the results in a friendly and efficient way. Large-scale analysis becomes possible thanks to the availability of large sources of publication, patent, scientific literature (Buter & Noyons, 2002), and other data available in electronic form in academia. Thus according to these data we can visualize implicit knowledge of scholar knowledge workers.

More generally speaking, Visualization as an implicit knowledge extraction tool can be justified by the fact that the world is multifaceted, multidimensional, multi- phenomenal, and is presented as a continuum (Vargas-Quesada & Moya-Anegón, 2007, 4). It is true that ACA is a tool with great potential for the display of the intellectual structure of the different disciplines within science, as it shows and validates the intellectual structure or intellectual capital of the domain it represents, by means of the consensus of the main authors involved therein. Finally we can say that Research into ACA has demonstrated its potential as a powerful tool for visualizing the intellectual structures or intellectual capital of scholar knowledge workers and policy makers or administrators of academia can use it as an indicator of state of the art of science and technology of a university, a region, a discipline, a country and ….

References

Alavi M, Leidner D. (2001). Knowledge management and knowledge management systems: conceptual founda- tions and research issues. MIS Quarterly 25(1): 107–136

Bassecoulard, E. & Zitt, M. (1999). Indicators in a research institute: A multi-level classification of scientific journals. Scientometrics, 44, 323- 245.

Bateson G. (1973). *Steps to an Ecology of Mind*. Paladin: London.

Bertin, J. (1967). Semiology of graphics: Diagrams, networks, maps. Madison: University of Wisconsin Press.

Bollen, J., Luce, R., Vemulapalli, S. S., & Xu, W. (2003). Usage analysis for the identification of research trends in digital libraries. D-Lib Magazine, 9(5).

Börner, K. (2000). Visible threads: A smart VR interface to digital libraries. Proceedings of the IST/SPIE 12th Annual Symposium: Electronic Imaging 2000, Visual Data Exploration & Analysis, San Jose, CA, Jan. 2000.

Börner, K., Chen, C., Boyack, K.: Visualizing Knowledge Domains (2002). In: Cronin, B. (ed.) *Annual Review of Information Science and Technology*. *American Society for Information Science and Technology*, Medford, New Jersey, vol. 37, pp. 179–255.

Börner, K., & Chen, C. (Eds.). (2002). Visual Interfaces to Digital Libraries. LNCS 2539. Heidelberg: Springer-Verlag.

Boyack, K. W., Wylie, B. N., Davidson, G. S. & Johnson, D. K. (2000). Analysis of patent databases using VxInsight. Proceedings of New Paradigms in Information Visualization and Manipulation 2000, McLean, VA, November 10, 2000, to be published by ACM

Boyack, K. W., Wylie, B. N., & Davidson, G. S. (2002). Domain Visualization Using VxInsight™ for Science and Technology Management. *Journal of the American Society for Information Science*, *53*(9), 764 -774. doi: 10.1002/asi.10066.

Braam RR,Moed HF, and Raan AFJv (1991a).Mapping of science by combined co-citation and word analysis. II:Dynamical aspects. Journal of the American Society for Information Science,42(4),252–266.

Braam RR,Moed HF, and Vanraan AFJ (1991b).Mapping of science by combined cocitation and word analysis. 1. Structural Aspects. Journal of the American Society for Information Science,42(4), 233–251.

Burkhard, R., & Meier, M. (2004). Tube map: Evaluation of a visual metaphor for interfunc- tional communication of complex projects. In K. Tochtermann, & H. Maurer (Eds.), Pro- ceedings of I-KNOW ’04 (pp. 449-456). Graz, Austria: Know-Center Austria.

Bush, W. (1945). as we may think. *Atalantic monthly*, July 1945, Retrieved from http://www.theatlantic.com/doc/194507/bush

Chen, C. (1999). Visualising semantic spaces and author co-citation networks in digital libraries. *Information Processing and Management*, 35(2), 401–420.

Chen, H., Houston, A. L., Sewell, R. R., & Schatz, B. R. (1998). Internet browsing and searching: User evaluation of category map and concept space techniques. Journal of the American Society for Information Science, 49(7), 582-603

Chen, C., & Paul, R. J.(2001) Visualizing a Knowledge Domain’s Intellectual Structure. *Computer*, 34, 65–71 .

Chen, C., Paul, R. J. & O’Keefe, B. (2001). Fitting the jigsaw of citation: Information visualization in domain analysis. Journal of the American Society for Information Science and Technology, 52(4), 315-330.

Chen, C.(2004) Searching for Intellectual Turning Points: Progressive Knowledge Domain Visualization. *PNAS*, 101, 5303–5310.

Conklin, J. (1987, September). Hypertext: An introduction andsurvey. IEEE Computer, 17-4 1.

Ding, Y., Chowdhury, G. & Foo, S. (2001). Bibliometric cartography of information retrieval research by using co-word analysis. *Information Processing & Management*, *37*(6), 817-842.

Donath, J. (2002). Supporting community and building social capital: A semantic approach to visualizing online conversations. Communications of the ACM, 45(4), 45-49.

Drucker P. (1959). *Challenge to management science*. Long Range Planning 5, No. 2, 238–242.

Drucker P. (1993). *Post-Capitalist Society*. Butterworth/Heinemann: Oxford.

Eick, S. G. (2001). Visualizing online activity. Communications of the ACM, 44(8), 45-50

Eppler, M., & Burkhard, R. (2004). Knowledge Visualization: Towards a New Discipline and its Fields of Applications. Working Paper, Wirtschaftsinformatik. Retrieved from http://www.wirtschaftsinformatik.de/wi_arbeitsberichte.php?op=anzeigearbeitsbericht&abid=142.

Eppler, M. J., & Burkhard, R. A. (2007). Visual representations in knowledge management: framework and cases. *Journal of Knowledge Management*, *11*(4), 112-122.

Encarnacao, J., Foley, J. D., Bryson, S., & Feiner, S. K. (1994). Research issues in percep- tion and user interfaces. IEEE Computer Graphics and Applications, 14(2), 67-6

Farah, M.J. (2000). The cognitive neuroscience of vision. Malden, MA: Blackwell Publishers.

Garfield E (1994). Scientography: Mapping the tracks of science. Current Contents. Social & Behavioural Sciences, 7(45), 5–10.

Garfield, E. (February, 1998*). Mapping the world of science*. Paper presented at the the 150 Anniversary Meeting of the AAAS, Philadelphia, PA.

Garfield, E., Sher, I.H., & Torpie, R.J. (1964). *The use of citation data in writing the history of science*. Philadelphia: Institute for Scientific Information

Goldstein, B.E. (2001). Sensation and Perception (6th edition). Pacific Grove: Cole Publishing.

Grant R. (1996). Towards a knowledge based theory of the firm. *Strategic Management Journal*, 17, No. 1, 109–122.

Gregory, R.L. (1998). Eye and Brain. The Psychology of Seeing (5th edition). Princeton, NJ: Princeton University Press.

Hearst, M. (1995). TileBars: Visualization of term distribution information in full text infor- mation access. Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems, 59-66.

ISI. (1981). *ISI atlas of science: Biochemistry and molecular biology, 1978/80*. Philadelphia, PA: Institute for Scientific Information.

Kofka, K. (1935). Principles of Gestalt psychology. New York: Harcourt-Brace.

Kohonen, T. (1995). Self-organizing maps. Berlin: Springer-Verlag

Kostoff, R. N., Eberhart, H. J. & Toothman, D. R. (1999). Hypersonic and supersonic flow roadmaps using bibliometrics and database tomography. Journal of the American Society for Information Science, 50(5), 427-447.

Lamping, J., Rao, R., & Pirolli, P. (1995). A focus + context technique based on hyperbolic geometry for visualizing large hierarchies. Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems, 401-408.

Landauer, T. K., Foltz, P. W., & Laham, D. (1998) Introduction to latent semantic analysis. Discourse Processes, 25, 259-284.

Law, J. & Whittaker, J. (1992). Mapping acidification research: atest of the co-word method. *Scientometrics*, 23 (3), 417-461.

Lin, X., White, H. D. & Buzydlowski, J. (2003). Real-time author co-citation mapping for online searching. *Information Processing and Management*, 39(5), 689-706.

Lee, M. R., & Chen, T. T. (2007). Visualizing Trends in Knowledge Management. *Knowledge Management*, 362-371.

Leydesdorff, L. (1994). The generation of aggregated journal-journal citation maps on the basis of the CD-ROM version of the Science Citation Index. Scientometrics, 31, 59-84.

Liebowitz, J. (2001). *Knowledge Management: Learning from Knowledge Engineering*. *America*. Florida: CRC Press LLC.

Losiewicz, P., Oard, D.W. & Kostoff, R.N. (2000), Textual data mining to support science and technology management. Journal of Intelligent Information Systems, 15(2), 99-119, 2000.

MCCAIN, K.W. (1990), Mapping authors in intellectual space – A technical overview, *Journal of the American Society for Information Science*, 41 (6) : 433–443.

McInerney, C. (2002). Knowledge management and the dynamic nature of knowledge. *Journal of the American Society for Information Science and Technology*, *53*(12), 1009-1018. doi: 10.1002/asi.10109.

Merton, R. K. (2000). On the Garfield input to the sociology of science: A retrospective collage. In B. Cronin & H. B. Atkins (Eds.), The web of knowledge: A festschrift in honor of Eugene Garfield (pp. 435-448). Medford, NJ: Information Today.

Nederhof, A. J. & Van Wijk, E. (1997). Mapping the social and behavioral sciences world-wide: Use of maps in portfolio analysis of national research efforts. Scientometrics, 40, 273-276. Newman, 2001

Nonaka I, Takeuchi H. (1995). *The Knowledge-Creating Company*. Oxford University Press: Oxford

Nonaka I. (1990). Redundant, overlapping organizations: a japanese approach to managing the innovation processes. *Californian Management Review*, 32, No. 3, 27–38.

Noyons, E.C.M., Moed, H.F., & Luwel, M. (1999). Combining mapping and citation analysis for evaluative bibliometric purposes: A bibliometric study. *Journal of the American Society for Information Science* , 50(2), 115-131

Noyons, E. C. M. & Van Raan, A. F. J. (1998). Advanced mapping of science and technology. Scientometrics, 41, 61-67.

Polanyi M. (1966). *The Tacit Dimension*. Routledge and Kegan Paul: London.

Polanyi M. (1958). *Personal Knowledge: Towards a Post-Critical Philosophy*. University of Chicago Press: Chicago, IL.

Popper K. (1972). *Objective Knowledge: An Evolutionary Approach*. Clarendon Press: Oxford.

Price, Derek J. de Sola (1963). Little science, big science. Columbia university press.

Price, D. J. d. S. (1965). Networks of Scientific Papers. Science, 149(3683), 510- 515.

Robertson, G. G., Card, S. K., & Mackinlay, J. D. (1989). The cognitive co-processor for inter-active user interfaces. Proceedings of UIST89, ACM Symposium on User Interface Software and Technology, 10-18.

Robertson, G. G., Card, S. K., & Mackinlay, J. D. (1993). Information visualization using 3D interactive animation. Communications of the ACM, 36(4), 56-71.

Shneiderman, B. (1994). Dynamic queries for visual information seeking. IEEE Software, 11(6), 70-77.

Schneider, J.W., Larsen, B., & Ingwersen, P. (2009). A comparative study of first and all-author cocitation counting, and two different matrix gener- ation approaches applied for author cocitation analyses. Scientometrics, 80(1), 103–130.

Small, H. (1973). Co-citation in the scientific literature: a new measure of the relationship between two documents. *Journal of the American Society for Information Science*, 24, 265-269.

Small, H.G. (1977). Co-citation model of a scientific specialty: – a longitudinal study of collagen research. Social Studies of Science, 7 (2), 139–166.

Small, H. (1999). Visualizing science by citation mapping. *Journal of the American Society for Information Science*, 50(9), 799–813.

Small, H., & Griffith, B. C. (1974). The Structure of Scientific Literatures: Identify- ing and Graphing Specialties. Science Studies, 4, 17-40.

Sparrow, J. (1998). *Knowledge in Organizations: Access to Thinking at Work*, Sage Publications, Thousand Oaks, CA.

Spasser, M. A. (1997). Mapping the terrain of pharmacy: Co-classification analysis of
the International Pharmaceutical Abstracts Scientometrics, 39, 77-97.

Tegarden, D. P. (1999). Business information visualization. Communications of the Association for Information Systems, 1, Article 4. Retrieved January 29, 2004, from http://cais.isworld.org/articles/default.asp?vol=l&art=4

Tufte, E, R. (1983). The visual display of quantitative information. Cheshire, CT Graphics press

Tufte, E. R. (1990). Envisioning information. Cheshire, CT Graphics Press.

Ungerleider and Mishkin (1982):

Vargas-Quesada, B., & Moya-Anegón, F. D. (2007). *Visualizing the Structure of Science*. *Analysis*. New York: Springer.

Ware, C. (2000). Information visualization perception for design. San Francisco: Morgan Kaufmann.
White, H.D., & McCain, K.W. (1998). Visualizing a discipline: An author co-citation analysis of information science, 1972–1995. *JOURNAL OF THE AMERICAN SOCIETY FOR INFORMATION SCIENCE*, 49(4):327–355
White, H.D. & Griffith, B.C. (1981). Author Co-citation: A Literature Measure of Intellectual Structure. Journal of the American Society for Information Science 32, 163–171.
White, H. D. (2001). Authors as citers over time. Journal of the American Society for Information Science and Technology, 52(2), 87-108.
Zhu, B., & Chen, H. (2001). Social visualization for computer-mediated communication: A knowledge management perspective. Proceedings of the Eleventh Workshop on Information Technologies and Systems (WITS '011, 23-28.
Zhu, B., & Chen, H. (2005). Information Visualization. *Annual Review of Information Science and Technology*.
Zuboff S. (1988). In *The Age of the New Machine*. Basic Books: New York.