Measuring Social Capital and its influence on Individual Performance

Alireza Abbasi
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Measuring Social Capital through Network Analysis and Its Influence on Individual Performance

Alireza Abbasi 1, 2, Rolf T. Wigand 2, Liaquat Hossain 3

1 School of Engineering and IT, University of New South Wales Canberra, ACT 2600, Australia;
2 Departments of Information Science & Management, University of Arkansas at Little Rock, AR 72204-1099, USA;
3 Centre for Complex Systems Research, Faculty of Engineering and IT, University of Sydney, Sydney, NSW 2006, Australia;

Abstract
Studies on social networks highlight the importance of network structure or structural properties of a given network and its impact on performance outcome. One of the important properties of this network structure is referred as “social capital” which is the “network of contacts” and the associated values attached to these networks of contacts. In this study, the aim is to provide empirical evidence of the influence of social capital and performance within the context of academic collaboration (co-authorship). This study suggests that the collaborative process involves social capital embedded within relationships and network structures among direct co-authors. Thus, association between scholars’ social capital and their citation-based performance measures is examined. To overcome the limitations of traditional social network metrics for measuring the influence of scholars’ social capital within their co-authorship network, the traditional social network metrics are extended by proposing two new measures of which one is non-weighted (Power-Diversity Index: “h-index of co-authors’ h-indices”) and the other is weighted (Power-Tie-Diversity Index) by the number of collaboration instances. The Spearman correlation rank test is used to examine the association between scholars’ social capital measures and their citation-based performance. Results suggest that research performance of authors is positively correlated with their social capital measures. This study highlights that the Power-Diversity Index and Power-Tie-Diversity Index serve indeed as indicators of power and influence of an individual’s ability to control and influence communication and information in this setting.

Keywords
Social capital, social network analysis, co-authorship analysis, individual performance, tie strength, power-diversity.

1. Introduction

Notable sociologists such as Burt (1992), Coleman (1988) and Granovetter (1973) claim that individuals’ personal characteristics are not their only success factors, but it is the extent of social capital accrued in their respective personal networks which is more influential (Oh, Choi, & Kim, 2006). The core idea of social capital is that a person’s (or a group of people’s) associates (e.g., family members, friends, colleagues) form an important asset that can be used to gain optimal performance (Woolcock & Narayan, 2000). Social capital produces benefits or outcomes for individuals and collective actors drive from their social structure (Burt, 1992).

The concept of social capital provides a useful and comprehensive conceptual perspective (Sawyer, Crowston, & Wigand, 1999; Tsai & Ghoshal, 1998) for understanding the benefits and outcomes of individual and collective action as well as value creation within a networking context. Accordingly, social capital means “the set of social resources embedded in relationships” (Tsai & Ghoshal, 1998) p. 464).

Social capital has three components: structural, relational, and cognitive (Tsai & Ghoshal, 1998; Wellman, 1988). The structural dimension involves social interaction that the actor uses to gain access, information, or resources. The relational dimension encompasses aspects that arise from the interactions (including trust and
loyalty). The cognitive dimension includes attributes such as shared norms, codes of action, and convergence of views. In this line of research, there have been studies which anticipated “the creation of value” owing to the existence of social relationships (Arregle et al., 2007).

This research suggests that conceptualizing social capital in terms of network structures, such as articulated by the strength of weak ties theory (Granovetter, 1973, 1983), provides valuable insight into scholars’ co-authorship activities. In most large organizations, performance of individuals and teams are measured through a set of metrics that pertain to task and contextual performance. Similarly in academia, scholars and scientists are evaluated based on their academic performance (e.g., research productivity, teaching evaluations, governance capabilities, funded research grants). Such evaluation of scholars is not only needed for faculty recruitment and promotion schemes, but also for industry and government funding allocation and for achieving a high reputation within the research community (Abbasi & Jaafari, 2013).

Collaboration is needed for graduate students’ and post-docs’ knowledge and experience enhancement (Bozeman & Corley, 2004) and leads to improved productivity of scholars (Melin, 2000). Therefore, this encourages most governments to enhance the level of international collaborations through policies (Katz & Martin, 1997). The implication of such evaluation and ranking provides the basis for governmental funding thus encouraging high research standards and goals. Therefore, on a global level, with respect to governmental funding (i.e., the allocation of funding for a specific project to a scientific research group) and university strategy, it is important to identify key scholars, collaboration areas and research strengths within universities with the aim of maximizing research output, cost optimization, and resource utilization.

A researcher’s time, abilities, skills and resources are restricted. Therefore, collaborative work is required to conduct most large research projects. This, in turn, leads to large scale scientific collaboration. However, having scholars with different skills, expertise and knowledge as human capital, in-group work is needed (McFadyen, Semadeni, & Cannella, 2009). Diversity of actors involved in group work facilitates the integration of expertise, contributes to successful projects’ implementation and accelerates cycle time for new product development (Cummings, 2004; Eisenhardt & Tabrizi, 1995; Griffin & Hauser, 1992; Pinto, Pinto, & Prescott, 1993), but having a basic shared understanding of each other’s knowledge and expertise is necessary to have a shared understanding about the entire project or research.

A co-authorship network is a form of collaboration network among scholars that represents their scientific interactions and collective action to conduct research and produce the results in the form of a publication. Therefore, social norms and trust build among scholars, through their collaborations over time, and they constitute a form of social capital for academia. In other words, when researchers collaborate on projects, they do share substantial amounts of knowledge. This flow of knowledge, during research collaboration, becomes a stock of knowledge, which mutually benefits the researchers not only in their respective future projects (Dierickx & Cool, 1989), but also in the current research by gaining new knowledge and reputation. Therefore, social capital resulting in collaboration networks can be used to explain the concept of knowledge capital (Oh et al., 2006).

The motivating questions for this study are: (i) How does one measure the concept of social capital of scholars? (ii) Do scholars’ social capital metrics associate with their performance? For the analysis at an exploratory level, a real co-authorship network is used. To shape the co-authorship network of active scholars in the field of “information science”, publication records having “information science” in their title or keywords or abstracts, published during the time period of 2001 and 2010, are extracted from the Scopus bibliometric database.

The number of collaborations is the simplest proxy for quantifying the collaborative activities of scholars. Other studies used concepts such as proximity (e.g., Frenken, Hardeman & Hoekman 2009; Ponds, van Oort & Frenken, 2007; Havermann, Heinz & Kretschmer, 2006) and diversity (e.g., Abbasi & Jaafari, 2013) to conceptualize the frequency of relationships among authors and institutions. This approach reflects only the local position of the scholars in their respective collaboration network considering only the direct partners. In order to overcome this simplicity, considering only the number of partners, Rc-Index (Abbasi, Altmann, & Hwang, 2010) is proposed as a bibliometric measure of scholars’ collaborative activity which takes into account the performance of collaborators in combination with their frequency.

Furthermore to quantify and highlight the importance of global position and role of the scholars in their collaboration network, studies used traditional centrality measures (Abbasi, Altmann, & Hossain, 2011; Yan & Ding, 2009; Zhuge & Zhang, 2010) and also proposed new hybrid centrality measures (Abbasi, 2013; Abbasi
These studies have shown the applicability of social network measures for co-authorship networks to indicate how centrality measures (as a proxy for scholars’ collaboration activity) are useful to reflect scholars’ performance based on their position and influence within their collaboration network. But most of those studies are lacking a proper theoretical justification for the network measures used to evaluate scholars’ collaborative activity. To fill this gap, this study considers the social capital theory to conceptualize the scholars’ collaborative activity, emphasizing the importance of co-authors’ role and position in their collaboration network, and new collaborative measures are proposed. High correlation between the new measures and citation-based performance metrics of scholars show the applicability of the new proposed social capital-based collaborative measures.

2. Literature Review

2.1. Social Capital and Network Theories

The concept of social capital has become increasingly popular in a wide range of social science disciplines (e.g., political science, economics, and organization science). Social capital has been used as an important factor to explain actors’ success in a number of areas (e.g., educational performance, career success, product innovation, inter-firm learning, and real-estate sales) by social scientists. Hanifan’s (1916) work on evaluating effects of community participation in enhancing school performance can be considered as the first study on social capital. But Bourdieu’s (1986; 1992) and Coleman’s (1987, 1988, 1990) work on education as well as Putnam’s (1993, 1995, 2001) work on civic engagement and institutional performance are the main studies inspiring most of the current researches in social capital (Woolcock & Narayan, 2000).

Bourdieu (1986) identified several forms of capital: *Economic capital*: “which is immediately and directly convertible into money and may be institutionalized in the forms of property rights” (p. 47); *cultural capital*: which could be embodied (in persons), objectified (e.g., in art), institutionalized (e.g., university degrees); *Social capital*: resources grounded in durable exchange-based networks of persons; *Symbolic capital*: manifestation of each of the other forms of capital when they are naturalized on their own terms. Bourdieu and Wacquant (1992) defined social capital in detail as “the sum of the resources, actual or virtual, that received by an individual (or a group) due to having a lasting network of more or less institutionalized relationships of mutual acquaintance and recognition” (p. 119).

Coleman (1988), the late eminent sociologist interested in the role of social capital in human capital creation and educational outcome (Narayan & Cassidy, 2001), defines social capital as a function of social structure producing advantage: “It is not a single entity but a variety of different entities, with two elements in common: they all consist of some aspect of social structures, and they facilitate certain actions of actors—whether persons or corporate actors—within the structure.” (p. 598). Putnam (1993) also defined social capital as “those features of social organization, such as trust, norms and networks that can improve the efficiency of society by facilitating coordinated actions” (p. 167) or as “features of social life - networks, norms and trust - that enable participants to act together more effectively to pursue shared objectives” (Putnam, 1995) (pp. 664-665).

Coleman’s (1988) definition regards social capital as one of the potential resources, which an actor can use besides other resources such as human or cultural capital (their own skills and expertise), physical capital (tools) and economic capital (money) (Gauntlett, 2011). He also highlighted the importance of social capital effecting the creation of human capital. But social capital differs fundamentally from other types of capital as it resides not in the objects themselves (e.g., people) but in their relations with other objects. For instance, human capital represents individual attributes and characteristics (e.g., attractiveness, intelligence, and skills). These assets are possessed by individuals yet social capital is additionally embedded in the relationships among individuals (Shen, 2010).

Emphasizing social capital’s function in different contexts, Portes (1998) defines social capital as “the ability of actors to secure benefits by virtue of memberships in social networks or other social structures” (p. 3). Furthermore, Adler and Kwon (2002) defined social capital as “the resources available to actors as a function of their location in the structure of their social relations” (p. 18). They focus on social capital as a resource that exists essentially (permanently) in the social network binding a central actor to other actors.
In another approach, Lin’s (1982) social resource theory claims power, status and wealth as determinants of valued resources in most societies. Accessing and using social resources can lead to better socioeconomic status and are determined by structural positions and use of ties. In addition, some researchers defined social capital considering capital (attributes) individuals possess in a network. For instance, Boxman et al. (1991) defined social capital as “the number of people who can be expected to provide support and the resources those people have at their disposal” (p. 52) while Burt (1992) defined this concept as “friends, colleagues, and more general contacts through whom you receive opportunities to use your financial and human capital” (p. 9) and also “the advantage created by a person’s location in a structure of relationships” (p. 5). Therefore, from this point of view, social capital can be evaluated by the amount or variety of such characteristics of other actors to whom an actor has ties directly or indirectly (Lin, 1999). The core idea is that the actions of individuals (and groups) can be greatly facilitated by their direct and indirect links to other actors in their respective social networks (Adler & Kwon, 2002).

In the above definitions, the focus is on the sources (e.g., networks, norms and trust) rather than the consequences of social capital. They considered different dimensions for social capital, namely bonding and bridging (Woolcock & Narayan, 2000) taking into account valued social resources. On the bonding views of social capital, the focus here is on collective actors’ internal characteristics and ties structure (Adler & Kwon, 2002). Therefore, the bonding view of social capital undergirds reciprocity and solidarity, builds trust within the group and provides substantive and emotional support (Shen, 2010). Bonding social capital is viewed as a property of a network (group of individuals), which, however, is not the focus of this study.

2.2. Individual’s Social Capital-Related Theories of Network

2.2.1. Tie Strength Theories

Granovetter (1973)’s theory of the ‘strength of weak ties’ argues that an individual obtains new and novel information from weak ties rather than from strong ties within that individual’s group structure. Examining people looking for a job, Granovetter (1973), contrary to popular belief, found that the most successful job seekers were not those with the strongest ties as weak ties with acquaintances provide a broader set of information and opportunities than strong ties with family and friends.

The strength of a link between actors (interpersonal tie) in a network could be indicated and measured by the amount of time the link has been established, the degree of emotional intensity, the degree of intimacy, and reciprocal services (Granovetter, 1973). The interaction among the individuals creates opportunity for knowledge sharing and information exchange and is considered crucial in the building of trust among individuals.

On the other hand, Krackhardt (1992) showed that strong ties are important in the generation of trust. He introduced the theory of ‘strength of strong ties’ in contrast to Granovetter’s (1973) theory. Levin and Cross (2004) found that strong ties, more so than weak ties, lead to the receipt of useful knowledge for improving performance in knowledge-intensive work areas. However, controlled for the dimension of trust, the structural benefit of weak ties emerged in their research model. It suggests that the weak ties provide access to non-redundant information. Weak ties thus facilitate faster project completion times, if the project is simple. It enables faster search for useful knowledge among other organizational subunits. Strong ties foster complex knowledge transfer, if knowledge is highly complex (Hansen, 1999; Reagans & Zuckerman, 2001).

2.2.2. Structural Holes Theory

Burt (1992) argues that the structural configuration of an individual’s social network, which provides optimized “bridging” or “brokerage” position is what dictates structural advantages such as information novelty and control. The basis for this argument rests on the fact that maximizing the number of ties (ego-network size), regardless of being weak or strong, in an individual’s network does not necessarily provide benefits. Furthermore, as an individual’s personal network grows over time, the extent of information coming from closely knit clusters tends to become redundant.

This is consistent with Freeman’s (1979) approach to betweenness which is built around the concept of ‘local dependency’. Therefore, it could be seen that Burt’s (1992) notion of structural holes built further upon
the assumption of betweenness centrality that advocated the idea of a brokerage position as providing information and control benefits.

Burt (1992) claimed that increasing the number of direct contacts (ego-network size) without considering the diversity reached by the contacts makes the network inefficient in many ways. Therefore, the number of non-redundant contacts is important to the extent that redundant contacts would lead to the same people and, hence, provide the same information and control benefits. He defined ego-network effectiveness as the number of clusters which the ego is connected to and can obtain novel information and benefits (Burt, 1992).

A structural hole (hole in the network structure) is defined as lack of tie between any pair of actors in the network. Network brokerage refers to the social structure where an actor builds connections across structural holes (Burt, 2005) linking otherwise disconnected actors. Brokerage brings novel information and opportunities, but the connections are too weak to provide emotional and substantive support. For instance, in economic networks, producers brokering more structural holes were found to make better profits from negotiating more favorable transactions with suppliers and customers (Burt, 1992). Within organizations, individuals’ mobility is enhanced by having an informational network rich in structural holes (Podolny & Baron, 1997).

Thus, Burt (1992) capitalizes on his theory of structural holes by focusing on the importance of structural position (e.g., brokerage) rather than structural properties (e.g., ego’s network size). Therefore, on this view of social capital as bridging, social capital can help explain the differential success of actors (e.g., individuals and firms). Therefore, bridging social capital leads to a broad worldview, diversity in opinions and resources, and information diffusion (Shen, 2010). This bridging view of social capital focuses on a property of individuals (ego-network and not whole-network).

These views highlight the social network engagement as a prerequisite for social capital. Walker et al. (1997) highlighted that “a social network structure is a vehicle for inducing cooperation through the development of social capital” (p. 110). Therefore, in brief, social capital could be regarded as the value of social networks, bonding similar people and bridging between diverse people, with norms of reciprocity (Uslaner, 2001).

### 2.3. Measuring Individuals’ Social Capital

Measuring social capital is required in order to use it as a development tool. Although multi-dimensionality (i.e., different levels and units of study) and dynamicity of social capital over time (due to change of the social interaction over time) makes obtaining a single, true measure almost impossible (Woolcock & Narayan, 2000) but several researchers proposed different metrics to measure social capital.

Bourdieu’s (1986) tool to quantify social capital is network size: “The volume of the social capital possessed by a given agent thus depends on the size of the network of connections he/she can effectively mobilize and on the volume of the capital (economic, cultural or symbolic) possessed in his/her own right by each of those to whom he/she is connected” (p. 249). It should be considered that while greater network size is desirable but the quality of the individuals is crucial for social capital.

As explained earlier, the fact that social capital is rooted in social networks and social relations could interfere in its measurement in that it must be also measured relative to them (Lin, 1999). Therefore, network science and social network analysis metrics could be used for measuring social capital. In this regard, several researchers asserted the location of actors in a network: tie strengths (Granovetter, 1973; Portes, 1998), structural holes and constraints (Burt, 1992), as the key elements of identifying social capital.

As social network’s engagement is the principal for social capital, social network analysis metrics are also used (supporting the dimensions discussed in the literature) to measure social capital of scholars in their co-authorship network. Social network analysis (SNA) is the mapping and measuring of relationships and flows between nodes of a social network. It provides both a visual and a mathematical analysis of human-influenced relationships. The social environment can be expressed as patterns or regularities in relationships among interacting units (Wasserman & Faust, 1994).

The main indicators of social capital are summarized followed by their focus as discussed in the literature in Table 1. To measure social capital, indicators covering the focus of related studies are used. Diversity of contacts (ego’s network size) (Bourdieu, 1986), representing the available resources for an individual, has been considered in the literature as one of important factors on information diffusion and novelty. Another important factor emphasized in the literature is tie strengths (Granovetter, 1973; Krackhardt, 1992). In
addition, ego-betweenness centrality (Freeman, 1979) and effectiveness (Burt, 1992) are used in order to measure the structural position and brokerage characteristics of an individual in the network, respectively.

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Focus</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ego network size</td>
<td>Diversity of contacts</td>
<td>(Bourdieu, 1986) &amp; (Boxman et al., 1991)</td>
</tr>
<tr>
<td>Ego Average Tie Strengths</td>
<td>Tie strengths</td>
<td>(Granovetter, 1973) &amp; (Krackhardt, 1992)</td>
</tr>
<tr>
<td>Ego Betweenness Centrality</td>
<td>Structural position</td>
<td>(Burt, 1992)</td>
</tr>
<tr>
<td>Ego Effectiveness</td>
<td>Brokerage &amp; diversity</td>
<td>(Burt, 1992)</td>
</tr>
<tr>
<td>Contact Status (Power)</td>
<td>Embeddedness resources</td>
<td>(Lin, 1982) &amp; (Burt, 2005)</td>
</tr>
</tbody>
</table>

In order to provide synthesis of two different approaches of social capital, diversity and power (as determinants of valued resources) (Lin, 1982), social capital is defined as the frequency and diversity of contacts (directly connected actors) to the powerful (high performance) contacts. Therefore, having the power (value) of actors in a social network, social capital is measured for an individual. A new measure, the Power-Diversity Index (PDI), is proposed here to take into consideration the added value of direct contacts in addition to their quantity. Furthermore, proposing another measure, the Power-Tie-Diversity Index (PTDI), the tie strength factor is also added to the previous measure (i.e., PDI). These measures are explained in detail in Section 2.2. These two new proposed measures (i.e., PDI and PTDI) reflect the thinking that connecting to more powerful individuals will, in turn, give individuals also more power. Accordingly then, this reflects individuals’ power and influence on transmitting and controlling information as well as the popularity of an individual based on popularity of its direct contacts.

3. Data and Measures

3.1. Data

Scopus is one of the main sources presenting bibliometric data. To construct a database for this study, publications are extracted using the phrase “information science” in their titles or keywords or abstracts and restricting the search to publications in English published between 2001 and 2010. Indeed, the publications extracted cannot be considered as representing the world production in the “information science” field but it illustrates a good portion of publications in this field that do not have limitation to a specific sub-field, conference, journal, institutes and country.

After extracting the publications’ meta-data from Scopus and importing the information (i.e., title, publication date, author names, affiliations, publisher, number of citations, etc.), an application program is used for extracting relationships (e.g., co-authorships) between and among researchers, and stored the data in tables in a local relational database. Four different types of information were extracted from each publication metadata: Publications information (i.e. title, publication date, journal name, etc.); authors’ names; affiliations of authors (including country, institute and department name, etc.); and keywords.

Exploring the original extracted data affiliation information is found inconsistent, where there were several fields missing for some of the publications and also different written names for the country of origin and institutions. So in the second step manual checks were undertaken (using Google) to fill the missing fields using other existing fields (e.g., institute names are used to find country). Also manually the universities and departments which had different names (e.g., misspellings or using abbreviations) in the original extractions were merged. Finally, after the cleansing of the publication data, the resulting database contained 4,579 publications published in 1,392 journals and conference proceedings (indexed by Scopus) reflecting the contributions of 10,255 authors from 99 countries.

3.2. Measures

3.2.1. Measuring Scholars Performance

To assess the performance of scholars, many studies suggest quantifying scholars’ publication activities as a useful measure for the performance of scholars. But there are also many researchers pointing to the limits
and bias of such quantification focusing on publication, mainly on the most visible articles from international databases. Further research shows the number of citations a publication receives qualifies the quantity of publications (Lehmann, Jackson, & Lautrup, 2006). Progressively, new citation-based metrics are being proposed, following Hirsch’s (2005) h-index as the core metric for measuring the combination of quantity and quality of researchers and academic communities. Although there is considerable debate on the reliability of the h-index (Haque & Ginsparg, 2009), the h-index is still widely used world-wide among academicians. While the reliability of the measure is not the subject of this paper per se, it does provide at least an empirical and very widely used metric so as to gauge a researcher’s prolificacy. Thus, the h-index is considered and operationalized as a citation-based surrogate measure and as a proxy for the performance of scholars.

3.2.2. Measuring Scholars’ Social Capital

In Table I and the following paragraphs, the proper indicators recommended in the literature to measure social capital are demonstrated. Each indicator definition and their respective equations are explained more precisely in this section. To answer precisely the first research question: “how does one measure the social capital of scholars?”, the following metrics are proposed to measure individuals’ social capital. Although some of them have been used previously, here two new measures (Power-Diversity Index and Power-Tie-Diversity Index) are presented which combine two and three different properties of individuals in their respective social network in order to quantify their social capital.

3.2.2.1. Existing measures:

- **Individual Network Size (Degree Centrality)**

In order to measure diversity of contacts representing the available resources for an individual, as one of important factors of information diffusion and innovation, individual degree centrality which is defined as the number of direct contacts it has is used. In a co-authorship network, network size of an author is the number of her co-authors. The degree centrality of a node i (i.e., pi) is given by:

\[ D(p_i) = \sum_{j=1}^{n} l(p_i, p_j) \]

Where \( n \) is the number of nodes in the network and \( l(p_i, p_j) \) is a distance function: \( l(p_i, p_j) = 1 \), if and only if node \( p_i \) and node \( p_j \) are connected, \( l(p_i, p_j) = 0 \) otherwise.

- **Individual Tie Strengths (Average Tie Strengths & Weighted Degree Centrality)**

To evaluate an individual’s tie strengths, the sum of tie strengths and also average tie strengths are used as proxy for social capital in order to represent the average strength of each tie of an actor. The sum of tie strengths of an author is the total number of collaborations she has (including redundant collaborations with any co-author). The sum of tie strength (weighted degree centrality) of a node i (i.e., pi) is given by:

\[ WD(p_i) = \sum_{j=1}^{n} w_l(p_i, p_j) \]

Where \( n \) is the number of nodes in the network and \( w_l(p_i, p_j) \) shows the frequency of connections (in our analysis co-authorships).

Average tie strengths is simply the average of the weights of her collaborations. This means dividing the sum of tie strengths (i.e., the number of collaborations) by the network size of the author (i.e., the number of different co-authors). Thus, simply the equation is as follows:

\[ ATS(p_i) = \frac{WD(p_i)}{D(p_i)} \]

- **Individual Effectiveness**

In order to optimize an individual’s network by capitalizing on structural holes, Burt (1992) claims that increasing the number of direct contacts (network size) without considering the diversity reached by the contacts makes the network inefficient in many ways. Therefore, the number of non-redundant contacts is
important to the extent that redundant contacts would lead to the same people and hence provide the same information benefits. The term **effectiveness** is used to denote the average number of people reached per primary contact in networks. Burt (1992) uses ‘effective size’ as a term to denote the same.

In conclusion, effectiveness of an individual is defined as the number of non-redundant (not connected) contacts. Precisely, it is the number of contacts that an individual has, minus the average number of ties that each contact has to other contacts of individuals. Assume that node A has links to three other nodes, and all of them are linked to each other. The links are “redundant” because node A can reach all three neighbors by reaching any one of them. So, the effectiveness of node A is \(1:3\) (the number of contacts) – \(2\) (the average degree of the neighbors).

- **Ego-Betweenness Centrality**

Considering bridging dimension, actors’ ego-betweenness centrality is used to measure social capital. Betweenness centrality is an indicator of an individual’s potential control of communication within the network and highlights bridging (brokerage) behavior of an actor (Freeman, 1979). Ego-betweenness centrality is defined as the sum of an individual’s proportion of times this individual lies on the shortest path between each part of alters (direct contacts to ego) (Hanneman & Riddle, 2005). For alters connected to each other, the contribution to the ego-betweenness of that pair is 0, and for contacts connected to each other only through ego (individual), the contribution is 1, for alters connected through ego and one or more other alters, the contribution is \(1/k\), where \(k\) is the number of nodes that connect that pair of alters.

### 3.2.2.2. Proposed measures:

- **Individual Power-Diversity Index (PDI)**

  In order to synthesize the two different approaches of social capital, diversity and power, the individual **Power-Diversity Index (PDI)** is defined to measure social capital based on both the frequency of connections and also considering the power of contacts (directly connected individuals). Having captured the power (value) of individuals in a social network, an individual’s sum or average of the power of direct contacts could be simply calculated to synthesize quantity (frequency of contacts) and quality (their value) of embedded resources (contacts) of an individual as a proxy for his/her social capital. But in order to have a more advanced and accurate metric (rather than merely the sum or average), the h-index (Hirsch, 2005) base formula is used to quantify the quality of contacts of an individual by counting top \(h\) powerful (valued) contacts whose power value is at least \(h\).

  Therefore, the **PDI** of an individual is the largest number such that her top \(h\) co-authors have each at least a power value (e.g., h-index, citation count) of \(h\). In other words, **PDI** is the “h-index of co-authors’ h-indices” or “h-index of co-authors’ citation count”. Here, the h-index of authors is considered as the ongoing indicator of their power or value as is still widely used world-wide among academicians despite the debate on its reliability (Haque & Ginsparg, 2009). But as shown other power measures (e.g., citation count) can be substituted. For instance, looking at Table II the author has 17 co-authors who have h-indices of 6, 3, 2, ..., 1, ..., 0 her **PDI** is 2 as only two of her co-authors have an h-index of equal to or higher than 2 and one cannot find three co-authors who have an h-index of equal to or higher than 3.

- **Individual Power-Tie-Diversity Index (PTDI)**

  In another effort, individuals’ tie strengths are taken into consideration as another important property of individuals’ social capital discussed in the literature. This measure can be applied in weighted networks. It is similar to the individual **Power-Diversity Index** but taking the weight (strength) of ties into account. To define this new measure for an individual (in a weighted network), first one defines co-authors’ power-strength which is the h-index of each co-author multiplied by the strength of the tie between that co-author and the author. So, the individual **Power-Tie-Diversity Index (PTDI)** is the largest number such that her top \(h\) co-authors have each at least the power-strength of \(h\).

  In a co-authorship weighted network to calculate the individual **PTDI**, first one needs to calculate the power-strength (co-ps) of each of her co-authors as her h-index times the number of collaborations (tie strength) they have had. Then, **PTDI** of an individual is the largest number such that her top \(h\) co-authors have each at least co-ps of \(h\). For instance, Table 2 shows the co-authors’ power-strength of an author which are 9,
8, 6, 4, 4, ... in descending order. Thus, the author’s PTDI is 4 as for 4 of her co-authors’ power-strengths (co-ps) are equal to or higher than 4. The PDTI value is always higher or equal to PDI since in the calculation of PTDI the tie strengths value (which is at least 1) times co-authors’ power are used.

Table 2. An Individual (M. Thelwall)’s co-authors and their h-index and frequency of collaborations

<table>
<thead>
<tr>
<th>Co-authors</th>
<th>h-index</th>
<th>Freq. of Collaborations</th>
<th>power-strength (co-ps)</th>
</tr>
</thead>
<tbody>
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4. Analysis and Results

4.1. Scholars Performance and Social Capital Measures

Based on the available publication meta-data of scholars, every pair of authors is retrieved who are listed as authors of a publication. Repeated co-authorships are merged by increasing more weight (tie strength) to their link (tie) for each relation. Therefore, the co-authorship network of scholars are formed and a weighted network. This relational data (i.e., who is connected to whom with which frequency) is the basis for social network analysis. These data are imported to UCINET to calculate the social network measures. In addition, using (Abbasi & Altmann, 2011) application, the number of publications and their respective citations count for each scholar have been extracted. This enabled the calculation of the citation-based performance measures (e.g., h-index, and citation count) of all scholars in the information science collaboration dataset.

To answer the second research question, “Do scholars’ social capital metrics associate with their performance?”, we calculated both the citation-based performance measures (i.e., h-index and citation count) and the social capital measures (i.e., network size, weighted size, average tie strength, effectiveness, ego-betweenness, Power-Diversity Index, and Power-Tie-Diversity Index), discussed the previous section, of each scholars. To illustrate, the results for the top ten productive scholars are shown in Table 3.

Then, the Spearman correlation rank test is applied between the social capital measures and scholars’ performance measures. As Table 4 shows the results of the correlation test, there are high significant correlation coefficients between social capital measures and scholars’ citation-based performance. Results suggest that individuals’ Power-Diversity Index (PDI) has the highest coefficient with their respective performance either considering citation count or h-index. This highlights the importance of the power and role of co-authors to generate social capital for an author in her co-authorship network which may also lead to enhance her performance.
Table 3. Top 10 high performance scholars and their social capital measures

<table>
<thead>
<tr>
<th>Name</th>
<th>h-index</th>
<th>Citation Count</th>
<th>Network Size (Degree)</th>
<th>Weighted Degree</th>
<th>Avg. Tie Strengths</th>
<th>Effectiveness</th>
<th>Ego-Betweenness</th>
<th>Power-Diversity</th>
<th>Power-Tie-Diversity</th>
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<tr>
<td>M. Thelwall</td>
<td>9</td>
<td>460</td>
<td>17</td>
<td>26</td>
<td>1.53</td>
<td>16.45</td>
<td>245</td>
<td>2</td>
<td>4</td>
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<tr>
<td>H.J. Kimble</td>
<td>8</td>
<td>1125</td>
<td>28</td>
<td>40</td>
<td>1.43</td>
<td>23.68</td>
<td>557.3</td>
<td>3</td>
<td>4</td>
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<tr>
<td>Y. Wang</td>
<td>8</td>
<td>328</td>
<td>30</td>
<td>35</td>
<td>1.17</td>
<td>19.56</td>
<td>376</td>
<td>2</td>
<td>3</td>
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<tr>
<td>E.R. Dougherty</td>
<td>7</td>
<td>606</td>
<td>16</td>
<td>21</td>
<td>1.31</td>
<td>13.88</td>
<td>186</td>
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<td>B. Cronin</td>
<td>6</td>
<td>164</td>
<td>4</td>
<td>6</td>
<td>1.50</td>
<td>4.33</td>
<td>12</td>
<td>1</td>
<td>2</td>
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<tr>
<td>C. Oppenheim</td>
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<td>153</td>
<td>20</td>
<td>26</td>
<td>1.30</td>
<td>19.19</td>
<td>352</td>
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<td>L.J. Meho</td>
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<td>6</td>
<td>8</td>
<td>1.33</td>
<td>5.67</td>
<td>24</td>
<td>1</td>
<td>1</td>
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<tr>
<td>H.D. White</td>
<td>5</td>
<td>169</td>
<td>2</td>
<td>2</td>
<td>1.00</td>
<td>1.00</td>
<td>0</td>
<td>1</td>
<td>1</td>
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<tr>
<td>J.C. Principe</td>
<td>5</td>
<td>120</td>
<td>13</td>
<td>14</td>
<td>1.08</td>
<td>10.79</td>
<td>114</td>
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<td>1</td>
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<tr>
<td>Y.B. Jun</td>
<td>5</td>
<td>89</td>
<td>6</td>
<td>6</td>
<td>1.00</td>
<td>5.33</td>
<td>26</td>
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Table 4. Spearman correlation rank test between scholars’ centrality measures and their performance

<table>
<thead>
<tr>
<th>Scholars’ Social Capital Measures (N=10,254)</th>
<th>Scholars’ Performance Measure</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Citation Count</td>
</tr>
<tr>
<td>Individual Network Size [Degree Centrality] (DC)</td>
<td>.219 *</td>
</tr>
<tr>
<td>Weighted Degree Centrality [Sum of Tie Strengths] (WDC)</td>
<td>.226 *</td>
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<tr>
<td>Average Tie Strengths (ATS)</td>
<td>.135 *</td>
</tr>
<tr>
<td>Individual Effectiveness (IE)</td>
<td>.192 *</td>
</tr>
<tr>
<td>Ego Betweenness Centrality (EBC)</td>
<td>.172 *</td>
</tr>
<tr>
<td>Individual Power-Diversity Index (PDI)</td>
<td>.446 *</td>
</tr>
<tr>
<td>Individual Power-Tie-Diversity Index (PTDI)</td>
<td>.444 *</td>
</tr>
</tbody>
</table>

*. Correlation is significant at the .01 level (2-tailed).

It is noteworthy that while these correlations are formally statistically significant, most of these coefficients (10 out of 14) are rather low (between 0.1 and 0.3) but the PDI’s and PTDI’s coefficient values are approximately two times higher than the second highest measure (i.e. ego-betweenness centrality for the h-index and weighted degree centrality for citation count). This could be explained in that PDI and PTDI may not be independent from the two performance measures (i.e. citation count and the h-index). One possibility is that an h-index of an individual is highly correlated to h-indices of her collaborators (if they belong to a highly dense cluster having very similar co-authors which is based on similar publications) simply because they are based on “exactly the same” papers on which both the author and his/her collaborators were coauthors. But this is not always the case, especially when authors have sole-publications or young scholars have few collaborations with prominent authors.

As shown and expected, the coefficients for PTDI and PDI are almost equal. PTDI’s slightly higher coefficient indicates that repeated collaborations with the same co-authors (even if they are prominent) do not create good social capital for them rather than having collaborations with many powerful (prominent) co-authors. The ego-betweenness centrality (EBC) coefficient is higher than tie strengths and diversity measures (i.e., degree centrality (DC), weighted degree centrality (WDC) and average tie strengths (ATS)). This shows bridging characteristics of scholars in their co-authorship network seems more important than the diversity of their co-authors and their ties’ strengths in regard to their performance.
5. Discussion

This study highlights the importance of the co-authorship network as a tool for evaluating scholars’ performance which is necessary in academia. Social capital theory is used to explain how scholars’ co-authorship networks affect each individual scholar’s performance. Although there are several definitions for social capital, most definitions’ emphases are on the social relations that have productive benefits. Social capital is rooted in social networks and social relations and must be measured relative to them (Lin, 1999). Reviewing the literature, scholars’ structural position (e.g., network size, degree, betweenness) in their co-authorship network is highlighted and so are scholars’ contacts characteristics (power and performance) as proper indicators of their respective social capital.

Reviewing the literature on social scientists’ and particularly network scientists’ studies on social capital, different approaches and dimensions for social capital and focus on these approaches are highlighted which evaluate individuals’ property in the network. Although multi-dimensionality and dynamicity of social capital makes having a single, true measure almost impossible (Woolcock & Narayan, 2000) but as measuring social capital is required in order to use it as a development tool, several researchers proposed different metrics.

Several measures (i.e. individual network size, tie strengths, ego-betweenness centrality, Power-Diversity Index and Power-Tie-Diversity Index) use network analysis metrics. This assists to quantify social capital resulting from the co-authorship through the social network, which is considered important for research management, academic institute as well as government policy makers over recent years. While several measures have been used by other researchers earlier, the last two measures (i.e. Power-Diversity Index and Power-Tie-Diversity Index) are new which combine two and three properties of authors in their co-authorship network, respectively, to quantify the extent of social capital they gain.

The correlation of the proposed measures of authors with their research performance is examined which all show a positive significant association, although most of them (all except the new measures) had a low coefficient between 0.1 and 0.3. The results highlighted the importance of scholars’ social capital characteristics on their performance. Significant association between scholars’ Power-Diversity Index and performance follows that connecting to more powerful contacts will lead to have better performance which is due to contacts’ relative power and influence on transmitting and controlling information as well as the popularity of an individual based on popularity of its direct contacts. The Power-Diversity Index indicates individuals being diversely connected to prominent contacts. These kinds of actors have special strategic positions that can control the flow of information in the network.

This research conceptualized social capital in terms of network structures, such as articulated by the strength of weak ties theory (Granovetter, 1973, 1982) and provided valuable insight into co-authors’ activities. The strength of weak ties theory suggests that the social network of any network member is the co-author’s primary resource. Moreover, this network can be viewed as being comprised of participants who vary by the relative strength of their relationship with one another. Strongly tied-together members in a network tend to be more similar to each other than different, more likely to be available for each other, share more common interests, and interact more frequently. Conversely, weakly tied members in a social network tend to communicate less frequently, are more different than similar, and provide both newer information into the network and more access to other social networks (Sawyer, Crowston & Wigand, 1999). When applied to the co-author network, this suggests that co-authors with large social networks populated with more weak ties will have more social capital. The more resource-rich co-authors will get influential linkages and connections (via acquaintances) and be able to point to more influential co-authors who might be able to provide value-adding services.

6. Conclusion

Using publication data and extracting co-authorship relations, an overview of collaboration efforts and collaborative networks in the “information science” research area has been presented. The collaboration networks of scientists in “information science” have been analyzed by using author affiliations from publications having ‘information science’ in their ‘title’ or ‘keywords’ or ‘abstract’ between 2001 to 2010 as extracted from Scopus. The extracted publication dataset does neither support nor represent the complete
world production of research on “information science” (due to the possibility of significant biases: ignoring the relevant publications which are not using the exact phrase ‘information science’; publications in other languages). Hence, the database does not pretend to represent the complete universal field.

In brief, two social capital newly created measures (i.e. the power-diversity index and power-tie-diversity index) are proposed. They can be described as an h-index of collaborators’ h-indices. One is non-weighted (PDI) and the other is weighted (PDTI) by the number of collaboration instances. In addition, the findings show that the Power-Diversity Index (PDI) is a useful surrogate of the importance of a scholar in her co-authorship network by considering the diversity of contacts and also their value and power (performance). The PDI identifies individuals having direct connections to diverse powerful individuals. The PDTI identifies individuals having direct strong connections to diverse powerful individuals. So, these measures are indicators of the power and influence of an individual’s ability to control communication and information.

Applying these new measures for other social networks to test their association with individuals’ performance could be a useful extension of standard centrality measures and a suitable proxy for the performance of individuals in a network. In order to accomplish this, validation of these new measures are needed by testing it in other social networks.

Collecting network data has its own limitations and unfortunately this study is not an exception as well. Using keywords to search for scholars in a particular domain is not necessarily reflective of all people and all of the publications of the authors but this method was used to cover more scholars active in information science. Name disambiguation (different names of authors or institutes in the affiliations) and apparent repetitive names (authors with similar names) of the scholars are, unfortunately, inevitable in this kind of data collection.

REFERENCES


