Extracting Structural Holes in Iran Medical Genetics Scientists’ Co-authorship Network: A Case Study of Faculty Members in Five Selected Centers

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Abstract

Background: Structural holes as a considerable issue in network approach can be tracked in central indices. Objectives: This research aims to survey indices that can measure structural holes. We are looking for the most important scientific authors and their connections in the field of medical genetics to facilitate information flow in the network of medical genetics relations. Methods: First, co-authorship network of Iranian medical genetics scientists (faculty members) was extracted via searching Scopus, Web of Science, and PubMed databases, as a result of which 7451 articles were retrieved. With co-authorship techniques, the most central nodes in the network were picked as highlighted scientists. In the next phase, two other indices (i.e., hypertext induced topics search [HITS] and PageRank) were calculated with the help of Sci2 and compared to redundancy, efficiency and effective size as structural hole indices. Results: There was a significant relationship between the two groups of indices. There were few structural holes in our network because redundancy and constraint were low. Constraint index and centrality indices can be used for extracting structural holes. Conclusions: In confirmation of previous studies, the constraint index can be used as a method for extracting structural holes. Compared to the HITS algorithm, the constraint index works best in this regard. At the same time, the study of HITS and PageRank indicators showed a significant association between the figures derived from the calculation of these two indicators, and each one can be employed to find structural holes.

Keywords: Structural Holes, Co-authorship, Social Network Analysis, Centrality Measures, HITS Algorithm, PageRank Algorithm, Genetics, Medical

1. Background

Structural holes point to important seats in network, and based on Burt, they are the relationship between two non-duplicate persons (1). The major advantage of this theory is its ease of understanding and implementation (2). Standing among dissimilar people provides an added value and facilitates coming up with new ideas, having access to alternative thoughts, and having the opportunity to choose and combine ideas (3). The abilities of the structural hole concept are the reason for choosing it to extract key people in the field of medical genetics. Promoting scientific collaboration with key people can be effective in promoting the scientific level of this field. Therefore, the objective of the present study was to identify opinion leaders in scientific communication and improve the transfer of qualified information in the scientific communication network of medical genetics.

The review of social network literature shows that these nodes are known as boundary spanners, broker organization, bridging organizations (4, 5), critical blocks (6), coordinators, gatekeepers, consultants, representatives, liaisons (5, 7, 8), mediators/conflict resolvers, go-between, peripheral specialist, Tertius gaudens (the third who enjoys), and Tertius iungens (the third who joins) (4). The concept of structural holes is one of the most frequent titles in names. In the communications network, it is not clear to anyone who plays a bigger role in the transfer of information. The present analysis seeks to introduce the indexes that can bring these nodes the confidence to invest in them.

For example, giving key posts to these people in institutions can improve academic communication and, as a re-
Algorithms for extracting structural holes from network data are centrality measures, PageRank, hypertext induced topics search (HITS), and redundancy. Centrality measures (specially betweenness and closeness) (1). Opinion leaders are the very central nodes in a network. If a person connects these leaders he/she will be in the position of a structural hole. Initiated by Google, PageRank is used to estimate the importance of a node and to consider the highest score as structural holes (9) Shortcomings concerning citation analysis such as ignoring the importance of the citing papers, are compensated by the PageRank algorithm (10) Developed by Jon Kleinberg, HITS is applicable in rating important nodes in a subgraph. Basically, HITS is similar to PageRank and sometimes they are surveyed simultaneously. In HITS, algorithm hubs and authority scores are calculated. An authority is a page that many hubs link to. A hub is a page that links to many authorities (11), that is, a node with a high authority value is pointed to by many other nodes with high hub values, and a node with a high hub value points to many nodes with high authority values (12).

Burt’s proposed algorithm for measuring structural holes is based on the two concepts of redundancy and constraint (2). In Burt’s view, non-redundant information sources are known as structural holes. He introduced effective size and efficiency for measuring redundancy. A connection is considered as redundant when no valuable information is exchanged. Burt defined the effective size of a node’s neighborhood as the non-redundant portion of it (13). Efficiency is 0 when all connections are redundant and is 1 when all connections are non-redundant. The efficiency of a node’s local neighborhood refers to the proportion of that node’s neighborhood that is non-repetitive. This can be derived from the ratio of effective size to the degree of the node (13).

Constraint index is designed to measure the amount of surrounding a node in the network (14). This index refers to the degree of limitation of a node in a network and the node’s functionality in obtaining information from structural holes. None of the network measures is sufficient to extract structural holes. However, some measures and algorithms have so far been used in research for this purpose. Degree, betweenness, and closeness are suggested by different researchers to extract structural holes (1, 2, 15, 16).

Structural holes span different fields; thus, a variety of techniques have been used in this area (17). Long et al.’s review showed that there are many roles for this concept in the literature, including brokers and brokerage opportunities.

Ding used the PageRank algorithm to rank authors and compared the results with other traditional bibliometrics and social network measures. He found citation rank highly correlated with PageRank, while it was not significantly correlated with centrality measures (10). Lee and Kim in 2011 focused on nonlinear relationships between many network dimensions including network centrality, tie strength, and structural holes. Results of a study performed in local governments in South Korea showed that employees’ network centrality had an inverse relationship with affective commitment and that structural holes had a U-shaped association with affective commitment (18). In a review of 24 articles, Long determined non-redundant contacts, network constraint, betweenness, centrality, effective size, efficiency, hierarchy and other measures as structural holes (19-22), but in none of those articles all these indices were compared. Long believed that PageRank, degree centrality, and betweenness were the most suitable measures for structural holes (23). There are other researchers who also point to centrality measures as the most frequently used measures for structural holes (24, 25).

Network analysis provides promising methods for discovering unofficial and invisible forms of communication in the social structure. Social communication structure theoretically integrates social relations and social cognition in order to link the study of human relationships between different branches of science (26). One of the methods of network analysis is to study how information can be exchanged and shared through the creation of co-authored networks, and the presumption of this approach is that the authors who collaborate in science know each other and share their experiences through co-authorship (27).

Medical genetics groups of Iran medical universities were chosen as the background of this research as universities and research institutes are the most important institutions for distributing credible information. The health care sector is a context that is rich in isolated clusters in need of connectivity. It is a key challenge in health service management to understand, analyze, and exploit the role of key agents who have the competency to connect disparate groupings in systems (4).

2. Objectives

In the network of scientific communications, there are nodes that are more important and effective. The main objective of this study was to extract opinion leaders in the field of medical genetics in Iran using the network indices. The present study seeks to discover these nodes as opinion leaders and influential people in scientific communication networks. This general goal will be followed by analyzing the network structure and discovering nodes that play the
role of structural holes. The main research questions are as follows:

1. Are the opinion leaders in the field of medical genetics in Iran based on the structural holes indicators the same as leaders based on HITS?
2. Are the opinion leaders in the field of medical genetics in Iran based on the structural holes indicators the same as leaders based on PageRank?
3. Are the opinion leaders in the field of medical genetics in Iran based on the structural holes indicators the same as leaders based on centrality measures?

And our hypotheses are:
1. There is a significant relationship between HITS and structural holes.
2. There is a significant relationship between PageRank and structural holes indices.
3. There is a significant relationship between all centrality measures and structural holes.

3. Methods

This is an applied original article that surveys a community of the most influential faculty members of the field of medical genetics. In this study, co-authorship is chosen as a network methodology. Centrality measures (28), HITS, and PageRank are used for co-authorship and co-citation network (12, 29). In this study, after consultation with medical geneticists, five research centers active in this field in Iran were selected as research fields. The researchers’ data were searched and extracted from Scopus, PubMed, and Web of Science databases as the most used databases in medical fields. Table 1 shows the search strategy. In order to analyze the extracted records from these databases, UCINET and SCI2 software programs were used. Prior to entering the data for analyzing the indices, PRIMAP was used to smooth the data structure. The scientific productions (articles) of faculty members in the studied centers was the population of the present study. Totally, 7451 articles were chosen as sample for the first stage of the research.

4. Results and Discussion

After the information was extracted based on the above strategy, the UCINET software was used to draw up a co-authorship network. For preparing data for co-authorship survey, the entries for authors need to be standardized. The objective is to consolidate name of a particular author or organization in order to ensure the correct acknowledgement of their scientific production. This step can be performed manually or using a specific software (30). We manually reviewed all the names, with the help of Ravar Preamp. Data clearing consists of smoothing out the authors’ names. Of the 19,000 records extracted from the three databases, about 6,000 records were duplicate or false and were deleted. From over 13,000 authors, we chose 606 authors as the most productive ones (Table 2). A matrix form of data was extracted to be readable by the software. In the next step, we calculated structural holes using UCINET commands.

Based on the information obtained from 606 nodes, 434 nodes had hub and authority scores. In this scheme, a node with a high authority score was cited by a number of other nodes that had a high hub score, and a node with a high hub score pointed to nodes with a high authority score. Accepting this description, these two scales in the unweighted network were very close to each other (12). In addition, since the current network was non-directional, both scores were consistent. According to Table 3, authority and hub score varied from 0.001 to 0.916. As the table presents, less than 20% of the community had high hub scores. In sum, most of the authors scored low on this index.

Redundancy indicates the degree of overlap between contacts. Maximizing the non-redundancy of contacts maximizes the structural holes obtained per contact (12). Table 4 depicts the scores. The efficiency value was calculated from 0.293 to 1. The effective size varied from 1 to 158, and degree value ranged from 1 to 168. Constraint index was between 0.06 and 1.06. Hierarchy varied between 0.039 and 1, and density was between 0.04 and 1.

Structural constraints use the concept of proximity between nodes as the goal of scale and dependence between nodes as a criterion for evaluation. The higher the value of constraint the denser the network, and the more redundant data flow in the network the less structural holes (14). Since network constraint showed a moderate amount, it was not possible to predict structural holes from this value. The low degree of structural holes indicates a high dependence between the nodes. The higher the degree centrality the lower the network constraint, and the more structural holes the weaker the dependency around the node (1). Accordingly, since the degree of most nodes was less than 30, we had a finite network with few structural holes.

In the current network, the average size was 22. This value indicates that each person’s communications in this network are limited to 22 nodes. In other words, since node communications are limited, the constraint index rises. This is while in larger networks, constraint is lower, because the amount of time and energy the manager uses for each member decreases with increasing the number of members.

As opposed to Long et al.’s review which showed that densely linked networks are more efficient at diffusing
information to all their members (compared to sparsely linked groups) (4). Zhongtai et al. stated that dense networks are more restrictive because they have more connections. These communications increase the amount of redundant information and reduce the chances of information flow between connections (2). Long et al. argued that it is not the most efficient way to transfer information (4).

The average density in the network was estimated at 0.265, which reduces the amount of redundancy in the network, and subsequently, diminishes the supply of information between connections. As Burt et al. stated, as network size increases, the density decreases. In this way, the connections that each player supports is reduced. Therefore, when the density decreases, structural holes in the social context are reduced (3). The low density in this network indicates that there are few structural holes. Hierarchy is an-
other kind of closure, which is the minority of communications that are at the forefront of others and are a source of energy. While network constraints show the level of communication redundancy, the network hierarchy measures how far this redundancy can be derived from one or two nodes. Network constraints increase with density and hierarchy (2). The average hierarchy in this network was similar to density (0.27). These figures prove the high network constraint.

In order to investigate the correlation between the variables, the normality of the variables was first tested by a histogram, and all the variables were diagnosed normal. Thus, we used a parametric test in order to compare the variables. According to Pearson’s correlation coefficient, there was a significant correlation between all the variables, except for hubs and authorities with efficiency, effective size, density, and hierarchy. In addition, we found no significant relationship between hierarchy and effective size, betweenness, and degree (Table 5).

For answering the first research question, we have to consider the statistical relationship between the structural hole and HITS indicators. Increasing effective size reduces the values of constraint, hierarchy, density, and hub variables. In contrast, there was a positive correlation between the value of this variable and efficiency, betweenness, degree, PageRank, closeness, and eigenvector. The statistical significance of these variables indicates a significant relationship between effective size, constraint, betweenness, degree, PageRank, closeness, and eigenvector. The efficiency index had a significant relationship with all the indicators, except the effective size and hub. The constraint index had a significant association with all the indicators, except hub. Further, the hierarchy index only had a significant relationship with efficiency, constraint, density, PageRank, and eigenvector. Therefore, in response to the first question, it can be stated that the structural hole indices have a negative correlation with the HITS algorithm, but there is no significant relationship between them. Therefore, opinion leaders are not the same according to these two indicators (Table 5).
Considering the second research question, there was a significant relationship between the structural hole index and PageRank score; therefore, PageRank can be used as an alternative to the structural hole index (Table 5). In response to the last question, a significant relationship was also found between all the centrality indices and structural holes, except hierarchy. Therefore, we can use the centrality indices to determine structural holes.

4.1. Conclusions

In recent years, a number of empirical studies have shown that individuals or organizations who bridge "structural holes" in networks gain significant payoff advantages (31).

The analysis of the data shows that the relationship between degree and structural hole indices (i.e., constraint and redundancy) is significant. Therefore, in line with Cai's theory, there are few structural holes in the current network. Depending on the average degree in the current network, one can vote for high constraint. Another point is that since there is a significant relationship between density and structural hole indices, we can conclude that according to Zhongtai et al. there are few structural holes. Zhongtai's other theory is also proven in this study, that is, there is good coordination between hierarchy and constraints and congestion, this is to say, hierarchy and density increase constraint.

As can be noted in the literature, we can strongly use the constraint index as a determinant of structural holes. One point that can be added to this hypothesis is that hierarchy, hubs, and authorities cannot be identified with certainty as structural holes, which rejects the first research hypothesis. The second research hypothesis is confirmed based on the a significant relationship between PageRank and structural holes.

### Table 5. Associations Between Variables

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<tr>
<th>Variables</th>
<th>Effective size</th>
<th>Efficiency</th>
<th>Constraint</th>
<th>Hierarchy</th>
<th>Betweenness</th>
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<td>0.548**</td>
<td>0.560**</td>
<td>0.560**</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>0.018</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
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</tr>
</tbody>
</table>
and structural holes as shown on Table 5. On the whole, all the centrality indicators can be used as reliable indicators for structural holes.

In our network, there are few structural holes because of low amount of redundancy and constraint. As a general result, disregarding centrality indices, PageRank and HITS are more in line with the concept of structural holes. Of course, the field study of these two indices among medical geneticists in the five main centers of this area in the country showed no significant convergence between the calculated figures for these two indicators. In contrast to the centrality indices, a more coordinated role for the two indices can be used along with other network analysis indicators, such as centrality, to explore structural holes.

The results of this research can be used to discover the important nodes in the scientific communication network of the medical genetics field. These nodes, which so far were determined based on one or two indicators, could make this calculation vulnerable because no indicators are comprehensive and each index is affected by certain parameters. Therefore, defining structural holes with the help of several indicators in parallel can reduce the damage to these calculations and add to its strength and reliability.

The most important limitation of research is the inaccessibility of the network analysis in Iran and the limited access to the existing software programs.

Supplementary Material

Supplementary material(s) is available here [To read supplementary materials, please refer to the journal website and open PDF/HTML].

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Footnotes

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References


