Social Network Analysis on LiDAR Research Through Relationship of Institutions and Authors

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***Abstract*—Social network analysis systematically connotes relationships and associated patterns between various groups. It unravels the groups in finding ties structures and their impact on individuals and their relationships. This article explores the structural patterns of collaboration in the area of LIDAR usage in vehicles by utilizing 709 Science Citation Index and Science Citation Index Expanded research articles. Social network analysis measures of degree, betweenness, and eigenvector centrality are used to probe into the impact of social networks. Empirical analysis reveals that the USA is the most influential country when international co-authorship is considered. The following countries in this category are the UK, China, Germany and Australia respectively. On the other hand, the California Institute of Technology, the University of Los Angeles, NASA, and the University of Maryland USA are ranked as 1st, 3rd, 4th, and 5th respectively when the top 5 co-institutions are considered. Wuhan University of China, Yonsei University, and Seoul National University of South Korea are placed at 2nd, 6th, and 7th place respectively in this category.**

***Keywords*—social network analysis; LiDAR; co-authorship; co-institution; pattern analysis**

I. Introduction

Social network analysis (SNA) has risen as a pivotal technique in the study of modern sociology. Not only that, it has also emerged as a significant tool of study in the fields of communication studies, economics, geography, social psychology, and more recently information science. SNA uses the idea of a social network (SN) to connote relationships between entities or people serving as nodes in a setup. J. A. Barnes was the first to use this term systematically to represent traditional concepts of social scientists in 1954. SNA is the science of analyzing the relationships and flows between various entities, individuals, and groups of SN. SNA helps to explore the shape of a SN which determines its suitability and benefit to its individuals. Open networks with more connections, for example, represent the probability of more ideas and increased collaboration than closed networks.

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The modern global world has seen very rapid and wide collaboration of research especially in novel and innovative technologies. International collaboration is contemplated as an index of quality to investigate and disseminate the knowledge on latest research trends to developing countries [1]. Collaboration gives rise to the use of common platforms to work on generating and developing new tools and technologies without countries' boundary limits [2]. Recent international collaborations have inspired and accelerated the co-authorship trend, especially in the research field. Such co-authorship gains prosperity in standardization as well as the enhanced visibility of scientific research [3]. Analyzing the co-authorship network helps to find the direction of leading research areas and assists in directing improvements to future work. Another important contribution of co-authorship network analysis is the identification of potential research areas where new policies and funding are needed by the government or other similar autonomous bodies. The second unit of collaboration is the joining of various institutions residing both inside and outside a country to work on similar areas of interest in research and development. Such co-institution collaboration essentially leads to expanded scientific contribution [4]. Analysis of co-institutions draws the global picture of institutions working in a specific research field. It not only provides country-to-country relationship and their position in respective domains but also may unravel the emerging research discipline and its trend of evolution over time with respect to specific countries.

Various research efforts have been made to make use of SNA in different research fields to view the impact of co-institutional and co-authorship work on development in the specified fields. Mehmood et al. [5] use SNA in the research area of the Internet of Things (IoT) to analyze the patterns of affiliation between authors and institutions. SNA measures of degree, betweenness, flow betweenness, and eigenvector centrality are used to find the effects of social networks. Using SNA, influential countries and their affiliation as well as the effectiveness of individual institutions and their corresponding ranks are identified successfully. Research identifies China and the USA as the most central countries in both co-author and co-institution networks.

Several works can be found in the literature analyzing collaborative networks using SNA. Hu et al. [6] use SNA to analyze spatiotemporal evolution in the world concerning innovations in the world and discuss the position of China. Trends of stakeholder engagement are analyzed in [7] with respect to urban village renovation plans in Tianjin. Similarly, Ramirez et al. [8] opted for SNA to study central institutions' participation in the Ecuadorian input-output network. Similarly, studies have been carried out using SNA in different fields such as digital library research [9], management and organizational studies [10], information systems [11], etc.

Although the research works described above, investigate many areas of research, the LiDAR research area is yet to be explored. So, this paper aims to find the impact of co-authorship and co-institution on development and current trends in the given domain..

II. Methodology

A. Data Collection

Our analysis is based on the data gathered from the Web of Science (WOS) database. WoS contains records of editorials, journal articles, proceedings, etc., and has millions of records. The data is collected using the "LiDAR" keyword, resulting in 19,281 papers in total. WoS has more than 100 categories for LiDAR research. The papers covering the use of LiDAR in ground vehicles are selected only. Additional filters are applied to restrict the papers to 3326. Excluding papers written in other than English, 3294 papers are selected. By omitting papers with incomplete data, missing data, and those irrelevant, 709 papers are selected.

B. Analysis Tools

UCINet is the primary used for SNA in this study. The adjacency matrix is made in the first step which is later used to make symmetrical networks using UCINet. Structural patterns are later analyzed using SNA. Centralization, density, effectiveness, etc. are among the used measures.

1) Degree centrality:

Degree centrality is the simplest of SNA measures. It is the total number of links/ties that a node has. Higher ties of a node mean a higher degree and nodes with a higher degree have advantaged positions. They possess more central positions in the network.

2) Betweenness centrality:

Betweenness centrality views a node in an influential position if it falls on a path between other pairs of the network. In other words, moving from a node *j* to another node *k*, the proportion of times when a node *l* falls between these nodes is its betweenness centrality. Nodes with higher betweenness have more power as more nodes depend on it to make connections.

3) Eigenvector centrality:

The eigenvector approach focuses on finding the most central node in a network. It makes use of 'eigenvalue', which is the location of each node with respect to each dimension. The collection of these eigenvalues is called, an 'eigenvector'. Eigenvector centrality shows how close a node is to other highly close nodes.

III. Results and Analysis

A. Co-Authorship Network Analysis

Using the publication data gathered from WOS, the adjacency matrix is formed for the co-authorship network. This matrix is then imported to UCINet to calculate the social network measures. Table 1 shows the results for network measures for the top 10 countries.

1) Degree, Betweenness and Eigenvector Centrality

The USA, UK, and China are the most central countries where degree centrality is concerned. The USA has the highest number of co-authored papers in the field of LIDAR with other countries. Its degree centrality is 338, thus contributing 19.27% of the total network.

The USA is followed by the UK, China, Germany, Australia, Italy, Canada, Brazil, France and Japan in the given order. Among the top 10 countries, China and Japan are the only Asian countries that make up the list. Table 1 contains the top 10 countries with respect to degree, betweenness, and eigenvector centrality.

TABLE I. Centrality Values for Co-Authorship Network

Rank	*Country*	*Degree*	*Country*	*Betweenness*	*Country*	*Eigenvector*
1	USA	338	USA	527.004	USA	0.614
2	UK	185	Germany	226.103	China	0.408
3	China	133	UK	223.96	UK	0.398
4	Germany	98	Australia	132.479	Brazil	0.241
5	Australia	84	Sweden	119.916	Germany	0.209
6	Italy	83	France	106.244	Canada	0.205
7	Canada	74	Canada	84.966	Australia	0.168
8	Brazil	63	China	79.72	Italy	0.165
9	France	62	Netherlands	79.31	France	0.129
10	Japan	50	South Africa	72.848	Japan	0.112

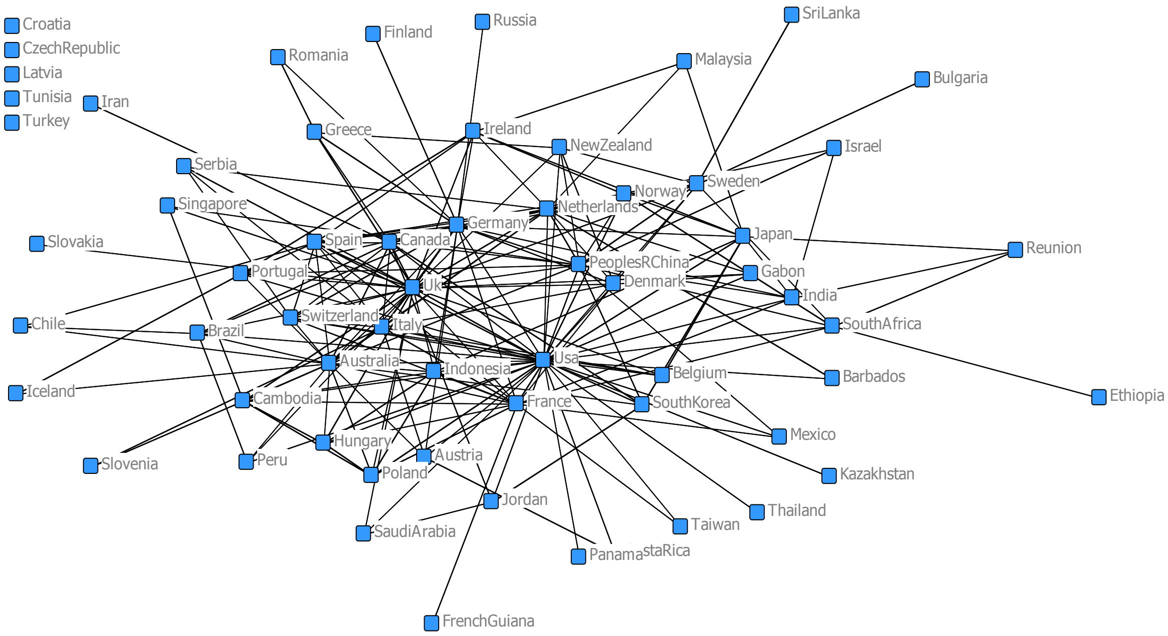

Fig. 1. International co-authorship map of LIDAR technology

It shows that Germany performs better in terms of betweenness centrality and moves to 2nd place. Similarly, Australia is now in 4th place instead of 5th. In addition, we have new countries including Sweden, Netherlands, and South Africa in the betweenness centrality list. So, in terms of betweenness centrality, the USA, Germany, and the UK secure the first 3 positions, thus working as brokers and possessing more control over the scientific community. The USA also holds the top position even for eigenvector centrality, followed by China and the UK respectively. Japan which was excluded from the betweenness centrality list, is again at 10th position, similar to its position in degree centrality.

Fig. 1 shows the network of international co-authorship in LIDAR technology. It depicts that most of the countries in the network are connected to the USA, UK, and China which have the highest degree and eigenvector centrality. The USA has more ties with China, the UK, Brazil, Germany, Japan and France.

On the other hand, the UK is more connected to the USA, Italy, Brazil, and Gabon, while China has more connections with the USA, Canada, Germany, and the Netherlands, respectively. The network map given in Fig.1 portrays that the USA, UK, and China hold the central and most influential positions in the co-authorship network and exert more pressure on the connected countries.

Additionally, Table 2 represents the countries and their effectiveness in terms of their 'structural hole'. It further corroborates the results of Table 1, as it contains the same countries that hold the central position in terms of degree and eigenvector centrality.

B. Co-Institutional Network Analysis

Similar to co-authorship network analysis, a separate adjacency matrix for the co-institutional network is made using the available publication data. UCINet is then used to calculate the social network measures and visualize the network. A total of 894 institutions are selected while collecting data from WOS for co-institutional network analysis.

1) Degree, Betweenness and Eigenvector Centrality

Results affirm that the California Institute of Technology has the highest degree centrality with a minimal difference from the Carnegie Institution for Science which holds the 2nd position in this list. University of Leeds, UK secures 3rd position followed by the University of New Hampshire, United States Geological Survey, Wuhan University China, NASA, University of Waterloo Canada, Texas A&M University, and United States Forest Service respectively. California Institute of Technology holds the first place in the betweenness centrality list as well, while 2nd place is now occupied by Wuhan University which is in 6th place in-degree centrality.

TABLE II. STRUCTURAL HOLE VALUES FOR CO-AUTHORHSIP NETWORK

Rank	*Country*	*Effectiveness*
1	USA	32.782
2	UK	22.274
3	Germany	19.442
4	Australia	17.363
5	France	12.569
6	Netherlands	11.666
7	Canada	11.489
8	China	10.344
9	Italy	10.305
10	Sweden	10.075

University of California Los Angeles performs better with respect to betweenness centrality and is moved to 3rd position. Surprisingly, two institutes from South Korea including Yonsei University and Seoul National University are also able to hold 7th and 8th positions in this list. The University of Waterloo and the University of New Hampshire are unable to maintain their positions in the top 10. However, the USA holds the major portion in the top 10 list, accounting for 70% of co-institutional networks in terms of degree and betweenness centrality. However, in terms of eigenvector centrality, the first position is held by the University of Waterloo, Canada, and China holds 7 positions in the top 10 list. Canadian institutions hold 3 positions in the top 10 eigenvector list. Fig. 2 shows the network map for the co-institutional network. Since, it is not possible for 894 institutions to be displayed, in this case, the top 50 institutions with respect to degree centrality are selected and displayed here.

Table 3 shows the structural hole values for the top 10 institutions with respect to their effectiveness in co-institutional networks. The important thing to note is that the rank of the institutions is almost similar to that given in the degree centrality list. Like degree centrality list, the California Institute of Technology, Carnegie Institution of Science, and the University of Leeds hold the top 3 positions.

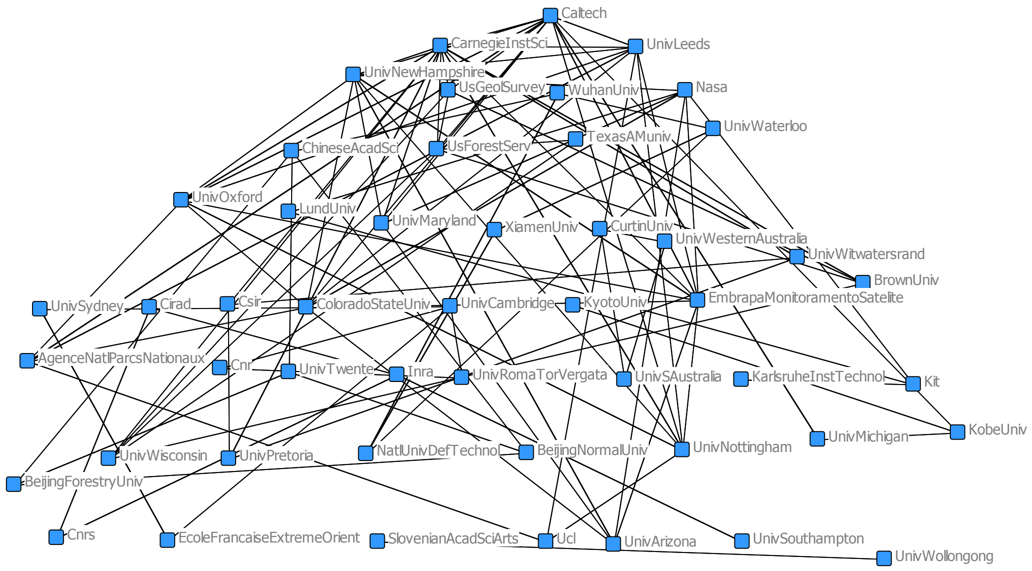

Fig. 2. Internation co-institutional network map for LIDAR research area

TABLE III. STRUCTURAL HOLE VALUES FOR INTERNATIONAL CO-INSTITUTION NETWORK

Rank	***Institution***	***Effectiveness***
1	California Institute of Technology	43
2	Carnegie Institution for Science	35
3	University of Leeds	30
4	United States Geological Survey	24
5	NASA	23
6	University of New Hampshire	23
7	University of Maryland	21
8	University of Oxford	21
9	United States Forest Service	20
10	Brown University	19

IV. CONCLUSION

This paper investigates the structural patterns and changes in the network of LiDAR research area. SNA is performed to evaluate the influence and control of authors and institutions. Results of the study show that the largest number of papers in LIDAR technology are co-authored by USA, UK, and China. Other countries in this list are Germany, Australia, Italy, Canada, Brazil, France, and Japan with respect to degree centrality and structural hole values. The network map for co-authorship shows that the USA, UK, and China hold influence. For the co-institution network, the USA holds 70% of the network in terms of both degree and between centrality. California Institute of Technology, Carnegie Institution for Science, and University of Leeds occupy the top 3 positions in degree centrality. Besides the USA, two South Korean institutes; Yonsei University and

Seoul National University also hold central positions in betweenness centrality. However, in terms of eigenvector centrality, China and Canada possess the central positions with the University of Waterloo leading the list, followed by Xiamen and Wuhan University of China.

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