Analysis of Co-authorship Network in the field of Korean nuclear science and technology

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1. Introduction

Nuclear safeguards have been in place since the 1950s to ensure that nuclear materials and technology are only used for peaceful purposes. Further, safeguards inspections are conducted regularly by the International Atomic Energy Agency (IAEA) at nuclear facilities worldwide in member states that are signatories of the Treaty on the Non-Proliferation of Nuclear Weapons (Non-Proliferation Treaty, NPT). In addition, each signatory of the IAEA Additional Protocol (AP, INFCIRC/540) is required to declare annually a general description of their nuclear fuel cycle–related research and development (R&D) activities that do not involve nuclear material to the IAEA.

A useful methodology for discovering additional declarable information to address these challenges is by searching for open-source information, such as news articles or scientific publications [1]. The IAEA has also stated that it is useful to use open-source information to achieve its safeguards objectives [2].

In this research, to achieve safeguards goals, collaborative trends in the field of Korean nuclear science and technology were investigated by analyzing the relationship between articles written by Korean authors. In other words, the structural characteristics of the number of network connections, network density, diameter, and average path distance reported by co-authors of scientific articles with Korean authors in the field of nuclear science and technology when compared to other academic fields.

2. Analysis of the co-authorship network and results

2.1 Method

Co-authorship relations represent the social side of the generative activity of researchers. Collaborative patterns of joint studies were identified in terms of network structure by forming a network of co-authors using social network analysis. In this research, the term "co-authorship network" is defined as the "interrelationship between scholars who co-authored a thesis and the community network of researchers." In the co-authorship network, nodes are the authors and the edges are established between nodes who coauthored an article. The social network analysis estimates the network's connection degree, density, path distance, and connection centrality.

In this research, the network's degree of connection refers to the total number of connection relationships in a node, and is an important indicator that shows the node's centrality inside the network. The network's density shows the overall degree of connectivity between nodes inside the network. The greater the number of connections between nodes inside the network, the denser it is. The path distance shows the distance between the nodes, which is estimated by the number of steps from one node to another. Finally, the network's diameter refers to the longest distance from among the shortest path distances between two random nodes [3][4].

2.2 Data collection

In this work, scientific articles were collected to create a co-authorship network in the Republic of KOREA. Scientific articles published by Koreans between 2016 and 2021 were collected from the Web of Science to obtain the latest research data. The search conditions used on the website were "Timespan = 2016–2021, Document Types: ARTICLE, Categories: Nuclear Science and Technology, Countries: South Korea," and a total of 1,991 articles were selected from the search results. So, the collected articles always include at least one Korean author, and may include authors from other countries.

2.3 Network analysis results

We created a network from collected data by using the Gephi open source software. Gephi is a popular network analysis software owing to its visualization flexibility and its ability to work with various data formats [5].

In addition, to understand the relative status and characteristics of the newly created co-authorship network in the field of nuclear science and technology, it was compared with results of preceding research conducted on co-authorship network of other academic fields in Korea <Table 1> [6][7][8].

Table 1. Comparison of the topology of co-authorship network by research field

Research field	Nuclear science and technology	Climate change	IT	Library information
Period of analysis	2016-2021	2012-2016	2002	2000-2009
Number of target papers	1,991	1,112	-	2,164
Number of authors (a number of Node)	4,433	4,468	1,176	886
Number of co-authors (a number of Edge)	5,804	41,861	2,748	2,285
Number of authors per paper	4.66	18	4.67	2.58
Network density	0.001	0.003	0.004	0.003
Diameter	27	24	9	14
Mean distance	10.215	7.76	2.6	11.06
Main component %	3,417 (77.08%)	2,089 (46.7%)	92 (7.82%)	535 (60.4%)

The trend that appears to be more prominent in nuclear science and technology network when compared to climate change, IT, and library information fields is that the percentage of nodes within the Main Component group, which is the group of nodes that have been connected at least once, is very high. This means that 77.08% of authors who have written a thesis in the field of nuclear science and technology in Korea are related to authors who have at least once participated as co-authors. Even when compared with the library information field, although the number of authors, co-authors, and authors per paper is lower, the Main Component percentage remains higher.

When compared with climate change network, which have a similar number of authors, nuclear science and technology network were found to have a lower density. In addition, the same result is obtained when compared with other fields. This shows that in the field of nuclear engineering, one large group of researchers collaborates with each other, and in the remaining cases, only at most two or three researchers collaborate with each other.

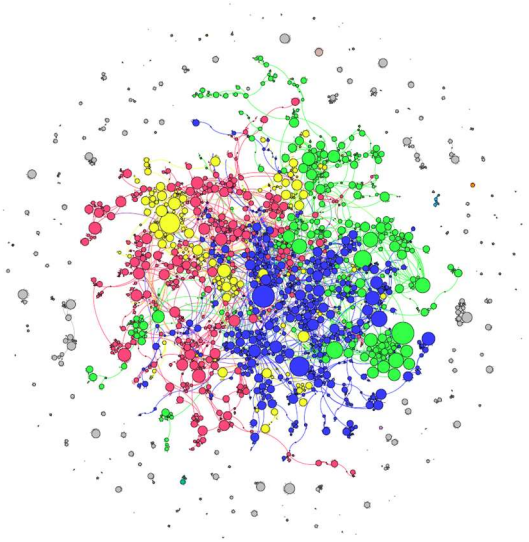

Fig 1. Co-authorship network (2016-2021).

Fig. 1 shows the image of the co-authorship network that we obtained from the Gephi software. From Fig. 1, we can easily understand that groups are formed by one large body of researchers. In other words, with the exception of researcher nodes marked in grey, all researchers belong to one group.

In addition, it can be noted that there are researchers who are actively conducting studies, even in large groups. In the figure above, the size of nodes shows the number of times that a researcher has collaborated with other researchers. Further, it can be noted that large nodes are gathered around bigger nodes. In other words, there are several groups that have been actively conducting research during the last five years, and these groups form small groups to carry out the research.

3. Conclusions

Based on the Additional Protocol agreement between the ROK and the IAEA, the ROK has to declare the state of nuclear fuel cycle–related research and development (R&D) activities among the nuclear science and technology field. However, it is very difficult to identify all nuclear-related R&D activities conducted in a state, and to provide a declaration under the additional protocol. Therefore, the IAEA requires each member state to create a legal framework to effectively implement the declaration under the Additional Protocol of their nuclear activities and to actively promote it.

We analyzed co-authorship network using the Gephi software to find a way to promote effectively. Based on the results obtained, we found that many authors form a single large group. In addition, it was found that several groups have been formed inside one large group. In this respect, it was verified that it is necessary to establish the safeguards promotion method, which targets some major institutions and some major research groups. In other words, nuclear science and technology network have a smaller society than other fields.

The results of this study could be applied to safeguards measures to identify nuclear fuel cycle-related activities under the IAEA additional protocol in the republic of Korea. In particular, the results of this study can be used to make an effective and efficient promote policy. And as the next step, future research will aim to classify the authors who conduct study related to nuclear fuel cycle activities in the field of nuclear science and technology.

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