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Original Article

Network analysis of scientific collaboration in North Korea

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Abstract

Purpose: Although North Korea invests in scientific research, few selected research results are published to international journals. However, the latest peaceful political developments around North Korea have increased concerns about how they will support international scientific cooperation. This study aims to analyze the scientific collaboration and intellectual structure of North Korean researchers.

Methods: We conducted a co-word analysis with author keywords and author names using the Web of Science records for 1976–2018 to observe the changes in research trends in North Korea. The structure of the median centrality of words and the parallel nearest neighbor clustering methods were used to visualize the results.

Results: The analysis of 55 final keywords confirms that the corresponding network is composed of 17 sub-clusters under four areas. As a result of the investigation of 56 final author names, the corresponding network is composed of 15 sub-clusters under four areas.

Conclusion: As more accurate information is needed about collaboration partners to ensure successful cooperation, this analysis result can support getting an overview of North Korea's research community and their research network.

Keywords

Co-word analysis; Network analysis; North Korea; Scientific collaboration; Scholarly communication analysis

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Introduction

North Korea has maintained a very secretive status and remains isolated globally. Although North Korea has invested in scientific research, few selected research results have been published in international journals. However, North Korean leader Kim Jong-un announced that he intends to boost North Korea's economy through science and education by having 'a scientific and technical power and a talent power' at a China visit in April 2018 [1]. With this movement, some scientists expect North Korea to open the door for more international research collaboration.

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There have been mentions of North Korea's position and research areas in specific academic fields. However, very few studies have examined research articles published by North Korean researchers with bibliometric analysis [2-4]. Bibliometric analysis is a research method that helps to clarify research trends and specific research areas within a particular academic field. However, bibliometric research about North Korea has some challenges due to the small number of published articles and the misclassification of various names for South Korea and North Korea [2]. As North Korea may be known as the Democratic People's Republic of Korea, North Korea, DPRK, or DPR Korea, the author searched for "North Korea," "DPR Korea," and "North Korea" in the address field on the Web of Science [3]. Jeong and Huh [4]'s study result showed that Kim Il Sung University researchers had published the most articles and their main areas of research were physics, mathematics, materials science, chemistry, and engineering. China, Germany, and Australia were the main cooperating countries and the funding agencies were mainly Chinese. However, these studies primarily used quantitative and suggested statistical results.

In this paper, network analyses with author keywords and the co-authors of articles that were published by North Korean researchers are conducted. The limited number of published articles from North Korea means that co-word analysis and co-author analysis, which identify patterns in sub-areas with titles, abstracts, and keywords, would be a better methodology than citation analysis. From this result, visualized networks of core subject areas and primary authors of North Korea could be presented. This could bring a more in-depth view from learning more about science research in North Korea by analyzing the North Koreans' scientific literature. Furthermore, this study result could provide the possibility of cooperation for those looking for opportunities to enter into research collaborations with North Korean researchers.

Methods

In this study, co-word analysis is carried out to identify the intellectual structure of studies from North Korea. All available data from Core Collection of Science Citation Index Expanded, Social Science Citation Index, and Arts & Humanities Citation Index in the Web of Science were collected and analyzed. Detailed information of published articles for 1976–2018 was collected through a country code search using the keyword "North Korea" (Dataset 1). After that, author keywords and the authors of each data were extracted to perform co-word analysis. To visualize the results, the structure of the median centrality of words and the parallel nearest neighbor clustering (PNNC) analysis of words were observed. The same process was conducted with author names.

Basic preprocessing and information extraction of data were performed with Bibexcel ver. 2014-03-25 (Persson O, available at: https://homepage.univie.ac.at/juan.gorraiz/bibexcel/index.html). In addition, COOC, which is a co-occurrence matrix generation program, and WNET (Lee JY, Seoul, Korea), which performs weighted network analysis, were used to obtain matrices for co-occurrence matrices, determine weighted network centrality through co-occurrence analysis using author keywords, and extract authors from the data. In addition, the network was visualized through NodeXL (Microsoft, Seattle, WA, USA) to understand its structure and scholarly communication.

First, to understand the detailed subjects and scholarly relations among authors in a field, a country code search was conducted with the keyword "North Korea." As a result, 638 data was collected in total as of December 6, 2018. There is some misclassification of papers among South Korea and North Korea, so the authors' affiliation addresses were checked manually.

Second, author keywords (DE: Author Keywords) and authors' full names (AF: Author's Full Name) were extracted using Bibexcel for co-word and co-author analysis. The collected keywords and names were capitalized with the first letter of each word. The number of keywords and names were defined with frequency of 3 and 5 respectively. Fifty-five keywords and 57 authors were selected as the final data for co-occurrence analysis as shown in Table 1.

Third, in the case of authors with a family name, data were collected with the full registered names to prevent other names being misidentified as the same author when initialized. As a result, 2,156 author names in total were identified. Afterward, for the convenience of analysis, only the authors of frequency ≥ 5 were considered as the final analysis targets. Only those 59 authors were manually rechecked and one author whose full name and initials were confirmed was revised, finally confirming the final author list with 56 authors (Table 2).

In a co-occurrence matrix that applies the frequency, relationships do not appear between the key node and the non-key node [5]. Therefore, it is not suitable for network analysis when it needs to express the weight of the strength's connection [6]. For network analysis in this paper, second-order Pearson's correlation coefficient matrix (Pearson's matrix) was used.

Pearson's matrix can measure the similarity of co-occurrence patterns between two keywords and a third keyword [7]. The result of the Pearson's correlation coefficient has a value between 1 and -1, where 1 indicates entirely related, 0 means that there is no association, and -1 means that they are completely inversely related. The higher the value, the higher the topic relevance between the two words and lower the value, the lower their connection.

Network analysis was performed to visualize the relationship between the keywords and authors to classify them into clusters according to similarity. For this, the Pathfinder network (PFNet) technique was applied to Pearson's matrix and a network was constructed that left only essential links for each node. Afterward, PNNC was applied to subdivide the networks and the NodeXL program was used for visualization.

Results

Keyword network analysis

Analyzing the PNNC cluster of the co-occurrence word network using the Pearson's matrix obtained from the 55 final keywords confirmed that the corresponding network was composed of 17 sub-clusters under four areas as shown in Table 3.

To identify the relationship between keywords, the PFNet was applied to Pearson's matrix. Afterward, two types of centrality were measured to clarify which node is the main or core node within the network. First, the relative Triangle Betweenness Centrality (rTBC) is the centrality that measures a broad relationship by connecting other keywords and influential positions within the network. Second, relative Nearest Neighbor Centrality is the centrality of how much of an intermediary role it plays among other nodes within the network. The top 10 keywords for each centrality were compared to corroborate the core keywords (Table 4). Due to having the

Table 1. Fifty-five final keywords with frequency >3

No.	Name	Frequency	No.	Name	Frequency
1	Incline matrix	7	29	Surface roughness	3
2	Sers	6	30	Sphalerite	3
3	Incline	6	31	Pressure boundary condition	3
4	North Korea	6	32	Ent-kaurane	3
5	Korean peninsula	5	33	Iterated function system (Ifs)	3
6	Quantum dot	5	34	Ti_2AlN_b-based alloy	3
7	Mixed boundary condition	5	35	Democratic People's Republic of Korea	3
8	Pahs	5	36	Surface plasmon resonance	3
9	Existence	5	37	Metal nanocomposites	3
10	Navier-Stokes equations	5	38	Korea	3
11	Ionic liquid	5	39	Variable exponent	3
12	Mechanical properties	5	40	Lattice matrix	3
13	Keratin	4	41	Compressible Navier-Stokes equations	3
14	Stability	4	42	Xlpe cable insulation	3
15	Microstructure	4	43	Surface plasmons	3
16	Electronic structure	4	44	Labiatae	3
17	Serds	4	45	Cloud computing	3
18	Cosmology of theories beyond the standard model	4	46	Uniqueness	3
19	Switching	4	47	Water treeing	3
20	Water	4	48	Density functional theory	3
21	Integrated pest management	4	49	China	3
22	Surface plasmon	4	50	Conjugate symmetry	3
23	Plutella xylostella	3	51	DPRK	3
24	Pieris rapae	3	52	Spark plasma sintering	3
25	Waveguide	3	53	Fe_2TiSi	3
26	MCM-41	3	54	Fe_2TiSn	3
27	Hydroxyethyl starch	3	55	Fractal interpolation function	3
28	Water hammer	3			

Table 2. Fifty-six final author names with frequency ≥5

No	Name[a]	Frequency	University	Department	Country
1	Choe Chunsik	7	Kim Chaek University of Technology		North Korea
2	Han Song Chol	14	Kim Chaek University of Technology	Math	North Korea
3	Jang Yong Man	6	Kim Chaek University of Technology	Nat Sci Ctr	North Korea
4	Jin Hak Son	6	Kim Chaek University of Technology		North Korea
5	Ju Hyonhui	5	Kim Chaek University of Technology	Dept Math	North Korea
6	Ju Kyong Sik	5	Kim Chaek University of Technology	Inst Adv Sci	North Korea
7	Kim Chol Jin	6	Kim Chaek University of Technology	Dept Chem	North Korea
8	Kim Nam Chol	13	Kim Chaek University of Technology	Dept Phys	North Korea
9	Choe Song Il	5	Kim Chaek University of Technology	Dept Phys	North Korea
10	Ho Kum Song	6	Kim Chaek University of Technology	Dept Phys	North Korea
11	Ko Myong Chol	7	Kim Chaek University of Technology	Dept Phys	North Korea
12	Ri Chol Song	6	Kim Chaek University of Technology	Dept Phys	North Korea
13	Sin Chung Sik	6	Kim Chaek University of Technology	Dept Phys	North Korea
14	Sin Jun Sik	7	Kim Chaek University of Technology	Dept Phys	North Korea
15	Im Song Jin	17	Kim Chaek University of Technology	Dept Phys	North Korea
16	Ryo Hyok Su	7	Kim Chaek University of Technology	Dept Phys	North Korea
17	Yu Chol Jun	19	Kim Chaek University of Technology	Mat Sci Dept Computat Mat Design	North Korea
18	Jong Un Gi	9	Kim Chaek University of Technology	Mat Sci Dept Computat Mat Design	North Korea
19	Ri Gum Chol	10	Kim Chaek University of Technology	Mat Sci Dept Computat Mat Design	North Korea
20	Sim Kyong Ho	6	Kim Chaek University of Technology	Dept Mat Engn	North Korea
21	Choe Song Hyok	7	State Academy of Sciences	Inst Lasers	North Korea
22	Hong Hakho	6	State Academy of Sciences	Inst Math	North Korea
23	Kim Ds	6	State Academy of Sciences	DPRK INST BOT	North Korea
24	Kwon Yong Hyok	7	State Academy of Sciences	Inst Lasers	North Korea
25	Kim Jongnam	10	State Academy of Sciences	Inst Geol	North Korea
26	Kim Kwang Hyon	19	State Academy of Sciences	Inst Lasers	North Korea
27	Kim Myongchol	10	State Academy of Sciences	Inst Geol	North Korea
28	Yang Jonghyok	10	State Academy of Sciences	Inst Geol	North Korea
29	Kim Tujin	8	State Academy of Sciences	Inst Math	North Korea
30	Choe Chol Ung	8	University of Science	Dept Phys	North Korea
31	Li Hx	8	Beijing Normal University	Dept Math	Peoples R China
32	Wang Guofeng	7	Jilin University	Coll Elect Sci & Engn	Peoples R China
33	Li Lin	6	Northeastern University	Coll Sci	Peoples R China
34	Jiang Pingkai	10	Shanghai Jiao Tong University	Dept Polymer Sci & Engn	Peoples R China
35	Li Jian Bo	9	Cent South University	Forestry & Technol	Peoples R China
36	Zhang Yanbin	6	Chinese Academy of Sciences	Inst Geol & Geophys	Peoples R China
37	Ri Songil	5	Jilin University	Sch Math Sci	Peoples R China
38	Kang Jin U	12	Nanjing University	Dept Phys	Peoples R China
39	Duan Jingkuan	5	Shanghai Jiao Tong University	Shanghai Key Lab	Peoples R China
40	Huang Xingyi	5	Shanghai Jiao Tong University	Shanghai Key Lab	Peoples R China
41	Kim Chonung	11	Shanghai Jiao Tong University	Shanghai Key Lab	Peoples R China
42	Chang Xulu	8	Wuhan University	Coll Life Sci	Peoples R China
43	Fang Chengxiang	8	Wuhan University	Coll Life Sci	Peoples R China
44	Hao Zhong Hua	6	Wuhan University	Sch Phys & Technol	Peoples R China
45	Jiang Fan	7	Wuhan University	Coll Life Sci	Peoples R China
46	Peng Fang	10	Wuhan University	Coll Life Sci	Peoples R China
47	Ren Lvzhi	6	Wuhan University	Coll Life Sci	Peoples R China
48	Wang Qu Quan	8	Wuhan University	Sch Phys & Technol	Peoples R China
49	Zhang Yumin	9	Wuhan University	Coll Life Sci	Peoples R China
50	Zheng Congyi	5	Wuhan University	Coll Life Sci	Peoples R China
51	Darvin Maxim E	8	Charité - Medical University Berlin	Dept Dermatol Venerol & Allergol	Germany
52	Lademann Juergen	7	Charité - Medical University Berlin	Dept Dermatol Venerol & Allergol	Germany
53	Herrmann Joachim	13	Max Born Institute	Nonlinear Opt & Short Pulse Spectro	Germany
54	Husakou Anton	7	Max Born Institute	Nonlinear Opt & Short Pulse Spectro	Germany
55	Kronfeldt Heinz Detlef	6	Technical University of Berlin	Inst Opt & Atom Phys	Germany
56	Jong Kwanghyok	5	Abdus Salam International Centre for Theoretical Physics		Italy

[a]Family name first.

Table 3. Parallel nearest neighbor clustering cluster grouping of keywords within the network

Area	Sub-cluster	Keyword	Area	Sub-cluster	Keyword
A	1	Incline	D	12	Keratin
		Incline matrix			Pahs
		Lattice matrix			Serds
	2	Compressible Navier-Stokes equations			Sers
		Stability			Water
B	3	Quantum dot		13	DPRK
		Surface plasmon			North Korea
	4	Switching		14	China
		Waveguide			Cloud computing
C	5	Existence			Conjugate symmetry
		Mixed boundary condition			Cosmology of theories beyond the standard model
		Variable exponent			Density functional theory
	6	Navier-Stokes equations			Electronic structure
		Pressure boundary condition			Hydroxyethyl starch
		Uniqueness			Ionic liquid
D	7	Mechanical properties			Korea
		Microstructure			Korean peninsula
	8	Democratic People's Republic of Korea			MCM-41
		Integrated pest management			Sphalerite
		Pieris rapae			Surface plasmons
		Plutella xylostella			Water hammer
	9	Spark plasma sintering		15	Fractal interpolation function
		Surface roughness			Iterated function system (Ifs)
		Ti_2AlN_b-based alloy		16	Metal nanocomposites
	10	Ent-kaurane			Surface plasmon resonance
		Labiatae		17	Water treeing
	11	Fe_2TiSi			Xlpe cable insulation
		Fe_2TiSn			

Table 4. Centrality comparisons among top keywords within the network

Rank	Keyword	rTBC (0–1)	Rank	Keyword	rNNC (0–1)
1–14	China	0.53389	1–2	Pieris Rapae	0.05556
	Cloud Computing	0.53389		Plutella Xylostella	0.05556
	Conjugate Symmetry	0.53389	3–9	Existence	0.03704
	Cosmology Of Theories Beyond The Sm	0.53389		Incline Matrix	0.03704
	Density Functional Theory	0.53389		Pressure Boundary Condition	0.03704
	Electronic Structure	0.53389		Serds	0.03704
	Hydroxyethyl Starch	0.53389		Sers	0.03704
	Ionic Liquid	0.53389		Ti_2AlN_b-Based Alloy	0.03704
	Korea	0.53389		Uniqueness	0.03704
	Korean Peninsula	0.53389			
	MCM-41	0.53389			
	Sphalerite	0.53389			
	Surface Plasmons	0.53389			
	Water Hammer	0.53389			

rTBC, relative Triangle Betweenness Centrality; rNNC, relative Nearest Neighbor Centrality.

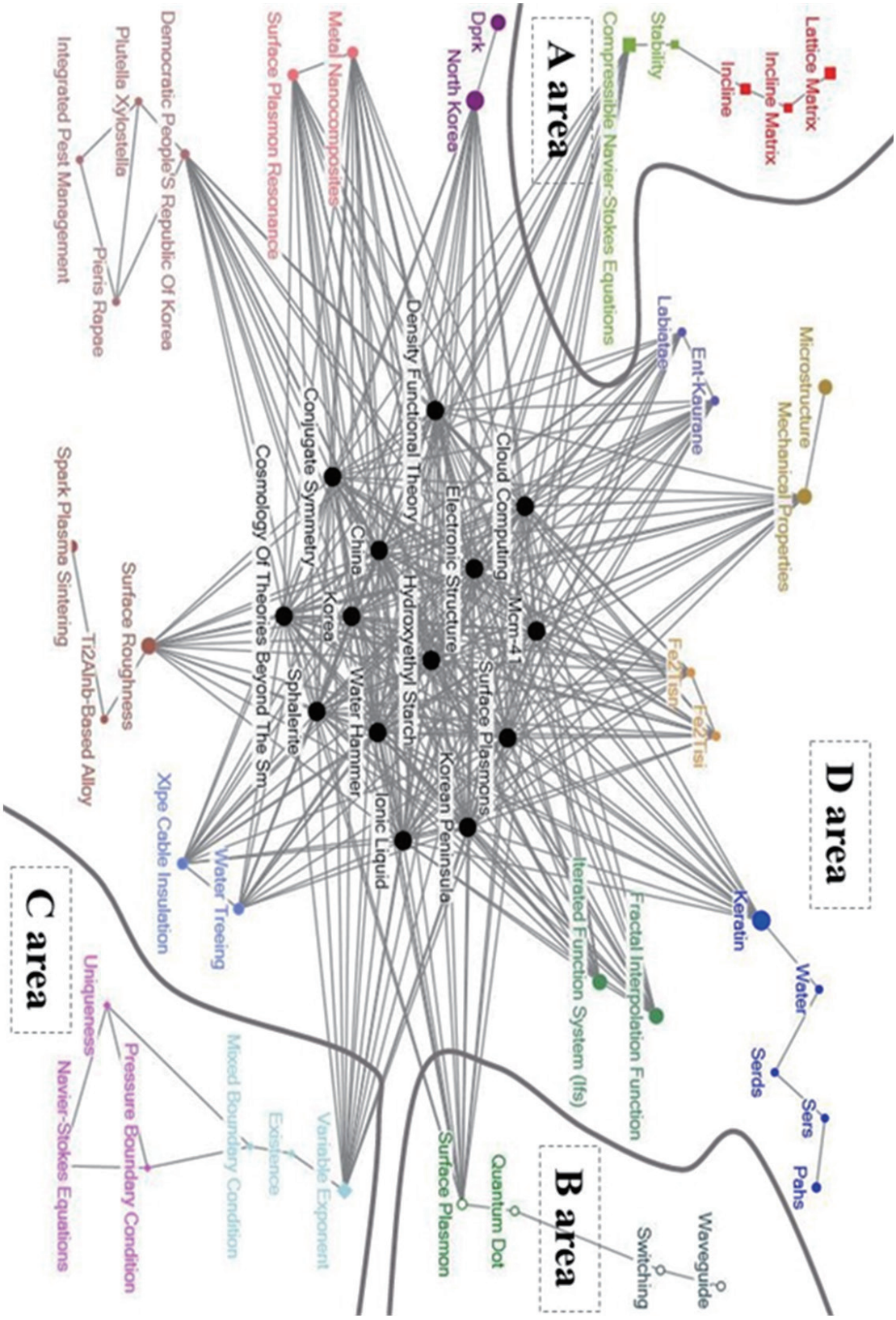

Fig. 1. Network visualization based on parallel nearest neighbor clustering clusters with 55 keywords.

Table 5. Parallel nearest neighbor clustering cluster grouping of authors within the network

Area	Sub-cluster	Author[a)]	Area	Sub-cluster	Author[a)]
A	1	Jang Yong Man	C	9	Choe Chol Ung
		Jong Un Gi			Han Song Chol
		Ri Gum Chol			Hong Hakho
		Yu Chol Jun			Jong Kwanghyok
	2	Choe Song Hyok			Ju Hyonhui
		Herrmann Joachim			Kang Jin U
		Husakou Anton			Kim Ds
		Kim Kwang Hyon			Kim Tujin
	3	Ho Kum Song			Li Hx
		Im Song Jin			Li Lin
		Ri Chol Song			Ri Songil
	4	Choe Song Il		10	Duan Jingkuan
		Hao Zhong Hua			Huang Xingyi
		Kim Nam Chol			Jiang Pingkai
		Ko Myong Chol			Kim Chonung
		Li Jian Bo		11	Choe Chunsik
		Wang Qu Quan			Darvin Maxim E
	5	Sin Chung Sik			Lademann Juergen
		Sin Jun Sik		12	Kronfeldt Heinz Detlef
B	6	Kim Jongnam			Kwon Yong Hyok
		Yang Jonghyok		13	Jin Hak Son
		Zhang Yanbin			Kim Chol Jin
	7	Chang Xulu	D	14	Ju Kyong Sik
		Fang Chengxiang			Ryo Hyok Su
		Jiang Fan		15	Sim Kyong Ho
		Kim Myongchol			Wang Guofeng
		Ren Lvzhi			
		Zheng Congyi			
	8	Peng Fang			
		Zhang Yumin			

[a)]Family name first.

Table 6. Centrality comparisons among the top authors within the network

Rank	Author	rTBC (0–1)	Rank	Author	rNNC (0–1)
1–11	Han Song Chol	0.56431	1–5	Yu Chol Jun	0.05455
	Kang Jin U	0.56431		Kim Nam Chol	0.05455
	Choe Chol Ung	0.56431		Jiang Pingkai	0.05455
	Li Hx	0.56431		Chang Xulu	0.05455
	Kim Tujin	0.56431		Fang Chengxiang	0.05455
	Kim Ds	0.56431	6–10	Yang Jonghyok	0.03636
	Li Lin	0.56431		Kim Jongnam	0.03636
	Hong Hakho	0.56431		Darvin Maxim E	0.03636
	Ri Songil	0.56431		Husakou Anton	0.03636
	Jong Kwanghyok	0.56431		Ho Kum Song	0.03636
	Ju Hyonhui	0.56431			

rTBC, relative Triangle Betweenness Centrality; rNNC, relative Nearest Neighbor Centrality.

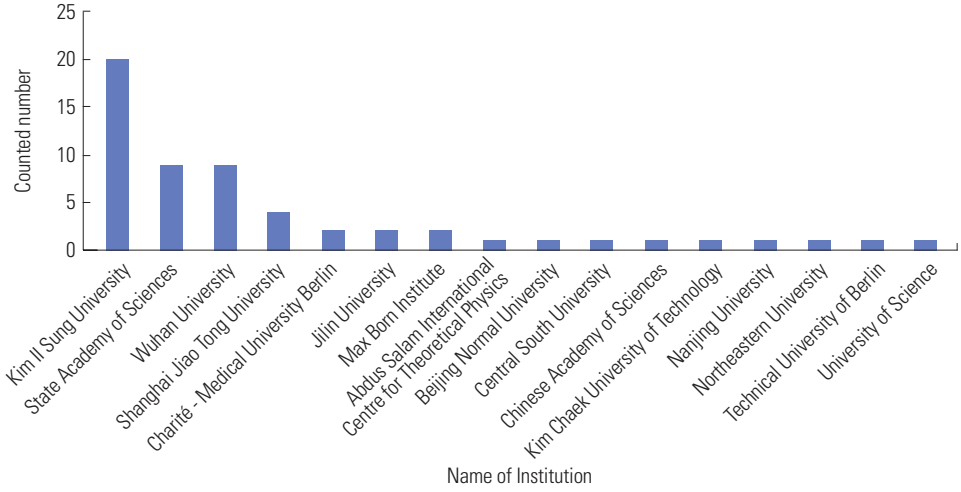

Fig. 2. The institution distribution of authors within the network.

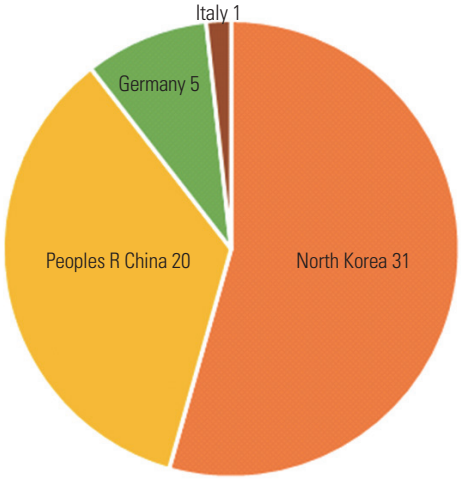

Fig. 3. The country distribution of authors within the network.

same ranks, 14 and nine keywords were analyzed for each centrality.

For visualization, the rTBC of keywords was set to the size of the nodes. In addition, to express the PNNC cluster, the areas were set with the shape of the node and the clusters were to the color of the node (Fig. 1).

Author network analysis

The results of analyzing the PNNC cluster of the co-occurrence word network using the Pearson's matrix obtained from 56 final authors confirm that the corresponding network is composed of 15 sub-clusters under four areas as shown in Table 5.

The same analysis that was used for keyword network analysis was conducted to identify the relationship between keywords. After applying PFNet to Pearson's matrix, rTBC and relative Nearest Neighbor Centrality were measured and the top 10 authors for each centrality were compared (Table 6).

In addition, to clarify the distribution and relationships among the authors based on country and institution, author affiliation addresses were extracted (Figs. 2, 3).

For visualization, the rTBC of the author was set to the size of the nodes. In addition, to express the PNNC cluster, areas were set with the shape of the node and the clusters were the color of the node (Fig. 4). Number of publication in Fig. 5.

Discussion

North Korea is one of the most closed-off countries in the 21st century, even with its recent interactions with other nations. Although limited research articles by North Korean researchers have been published and are available to the public, bibliometric analysis can be useful for getting an overview of the academic intellectual structure in North Korea.

Based on the tendency of increasing publications from North Korea as shown in Fig. 5, it is expected that the North Korean government will encourage researchers to publish research results in international journals [3]. North Korean researchers have expanded their publications to more than 50 articles since 2015.

Although the country's research has focused on enhancing military strength, North Korean researchers have been publishing in other fields such as materials science, physics, and mathematics [8].

Based on keyword analysis results, the most researched academic topics were incline, compressible Navier-Stokes equations, quantum dot, switching, existence, Navier-Stokes equations, mechanical properties, Democratic People's Republic of Korea, spark plasma sintering, Ent-Kaurane, keratin, DPRK, China, fractal interpolation function, metal nanocomposites,

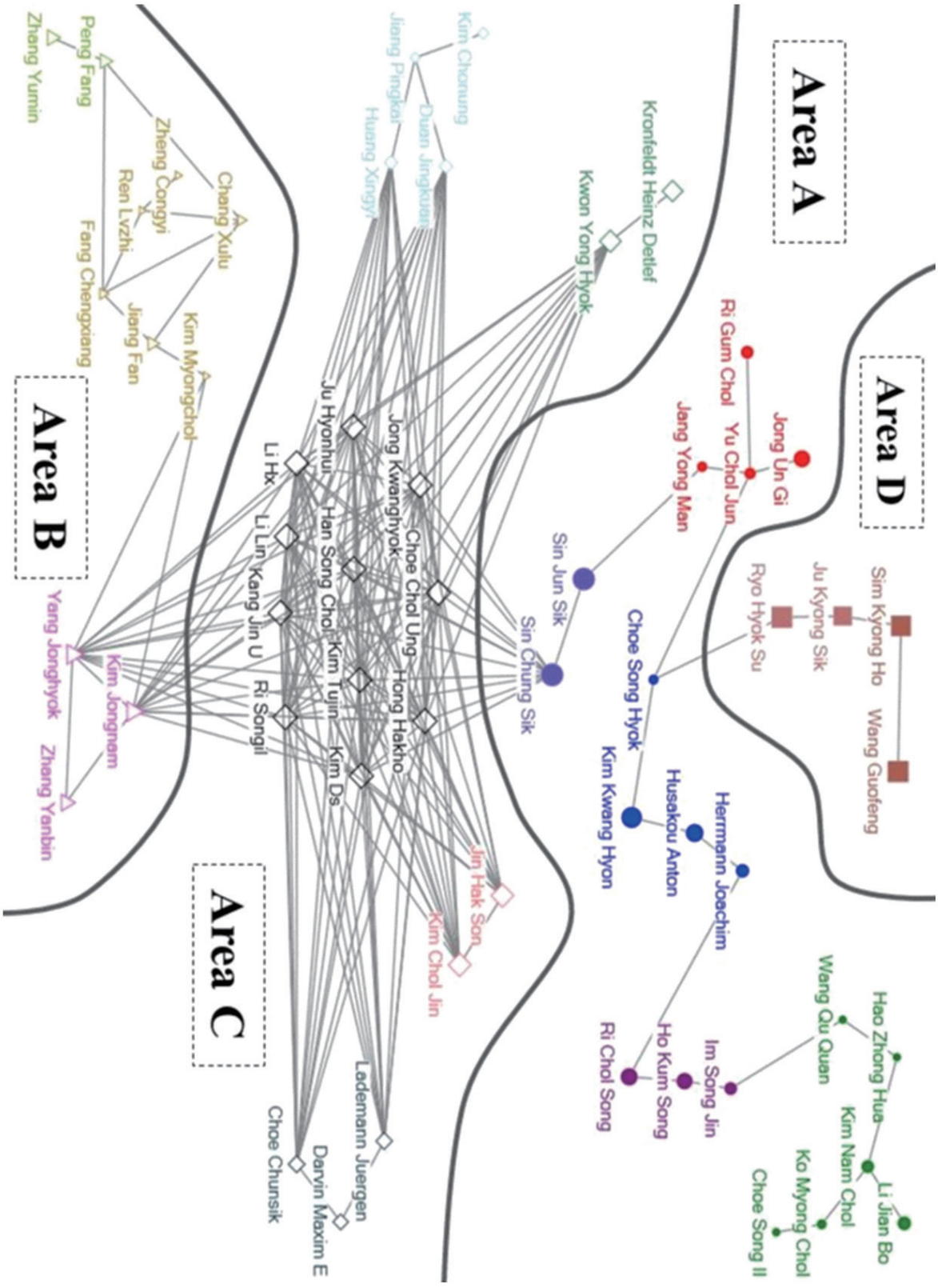

Fig. 4. Network visualization based on the parallel nearest neighbor clustering clusters with 57 authors.

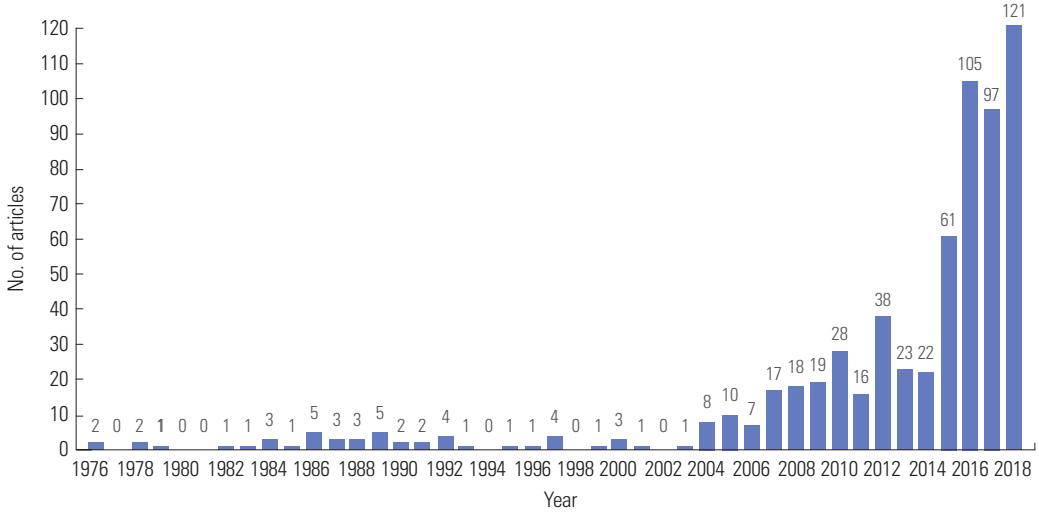

Fig. 5. Number of publication from North Korea searchable in Web of Science Core Collection by year.

Fe_2TiSi, and water treeing. The top three subject areas were mostly related to physics, chemistry, and mathematics.

The representative authors of sub-cluster were Jang Yong Man, Choe Song Hyok, Ho Kum Song, Choe Song Il, Sin Chung Sik, Kim Jongnam, Chang Xulu, Peng Fang, Choe Chol Ung, Duan Jingkuan, Choe Chunsik, Kronfeldt Heinz Detlef, Jin Hak Son, Ju Kyong Sik, and Sim Kyong Ho. Among these 15, eleven were from North Korea, three were from China, and one was from Germany. This shows that China most frequently conducts collaborative research with North Korea. All the eleven authors who have high betweenness centrality were included in C-9 sub clusters.

This study has some limitations: it lacks content analysis to clarify the specific relationships among subject areas and this study does not represent the research intellectual structure and author analysis within North Korea since this includes articles that were collaboratively created with foreign nations.

However, since very few studies have focused on North Korea's research areas and authors, the results can lead to further research focusing on domain-oriented study to explore North Korea's future research trends and changes.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Data Availability

Dataset 1. Original dataset for bibliometric scholarly network of North Korea is available from the Harvard Dataverse at: https://doi.org/10.7910/DVN/273J7G.

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