

A Development of Service Model for Mapping the Ecology of Scientific Research using National Science & Technology Information Service

Nam Gyu Kang¹, Min Woo Park^{1*}, Myung Seok Yang¹, Kwang Nam Choi¹,
Tae Hyun Kim¹, Won Kyun Joo¹ and Oh Seok Kwon²

¹NTIS Center, Korea Institute of Science and Technology Information (KISTI),
Yuseong-gu, Daejeon, Korea; pminwoo@kisti.re.kr

²Chungnam National University, Yuseong-gu, Daejeon, Korea

Abstract

Recently there is an increasing demand for a service that can analyse national scientific research information. Such service can be used it to help solve problems and make decisions on a national level. With such demand in mind, this study analyses the state of the art of domestic and global knowledge maps as well as the NTIS-provided knowledge map in order to improve former knowledge maps and to propose a service model for developing map of the ecology of scientific research. For this purpose different types of knowledge maps that can be drawn out from the NTIS R&D information were investigated. This paper proposes four types (Map of researchers, map of research achievements, map of research institutes, map of research trends) as a service of map of ecology of scientific research.

Keywords: Achievements Map, Institutes Map, NTIS Knowledge Map, Researchers Map, Research Trends Map

1. Introduction

NTIS has been lively collecting information on national R&D projects, project outcomes, researchers, and research equipment and facilities ever since 2008, and as a portal service it has been providing gathered information to the government administrations as well as to the general public. The service was widely and efficaciously used for supporting researchers, making policies, and drawing out the research budget for government administrations. (<http://www.ntis.go.kr>)

With rapid growth and expansion of commercial information retrieval systems, there is an increasing demand for a service that can analyse and visualise information supplied by NTIS to be used for solving national problems and making political decisions. In response to such demand, NTIS provided various knowledge maps such as map of research outputs and map of researchers, but these independently developed NTIS maps with

narrow purpose call for further expansion, integration, linking and adjustment¹.

Therefore this study analyses the state of the art of domestic and foreign knowledge maps along with the NTIS-provided knowledge map in order to propose a service model for implementing new knowledge map (tentatively named, map of the ecology of scientific research).

2. State of the Art of Domestic and Foreign Knowledge Maps

Various domestic and foreign knowledge maps have been analysed and compared in four aspects of Data scope, ②Analysis scope, ③Visualisation method, and ④Purpose in order to draw out a service model for mapping the ecology of scientific research. ①Data scope involves categorising data resources necessary for forming the knowledge map by data availability from the particu-

*Author for correspondence

lar institute and by types of data attributes (structured/unstructured). ②Analysis scope investigates analysis methods used to examine relations between different objects. The aspect of ③Visualisation method focuses on different types of knowledge maps, and finally the ④Purpose investigates range of outputs available from the given knowledge map.

2.1 State of the Art of Foreign Knowledge Maps

The science map established by the Japanese National Institute of Science and Technology Policy (NISTEP) extracts different research sectors from journal papers in two-dimensional map as illustrated in Figure 1. This can help highlight correlations amongst different research sectors and figure out density of core papers in the particular field. Also it is helpful in understanding interdisciplinary research fields and the scope and intensity of national R&D activities⁵.

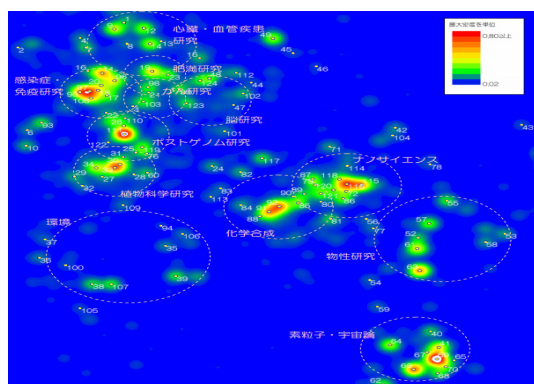


Figure 1. Science map.

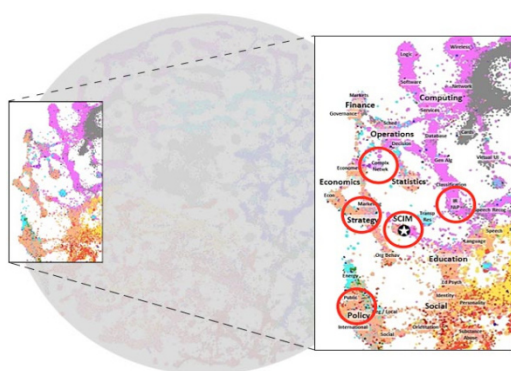


Figure 2. Map of science.

Map of Science (<http://www.mapofscience.com>) analyses co-citations from Scopus and the USPTO (United States Patent and Trademark Office) database and illustrates each research field as a node and citation relationships as links as seen in Figure 2. This map based on co-citations is useful in finding commonly cited papers and discovering the root of the literature in the particular research field.

SJR (SCIMAG Journal & Country Rank, <http://www.scimagoir.com>) provides knowledge map based on co-citation relationships from the Scopus DB as seen in Figure 3. Again the research field is defined as a node where the size of each node depends on number of publications in the particular field and each link is weighted by number of co-citations. This map is very country specific, so it is useful for understanding research trends of each specific nation.

Intellect Space (<http://www.intellectspace.com>) uses profiles of major companies and their employees to form a map where each node is defined either as the company or

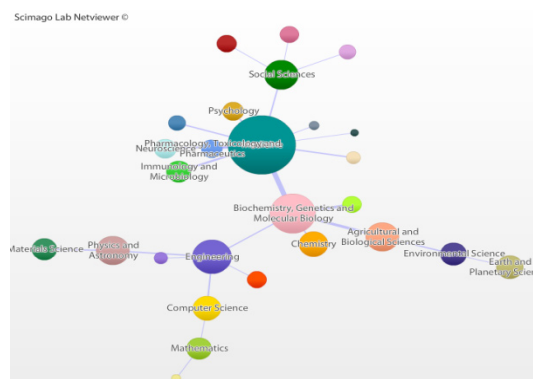


Figure 3. SJR.

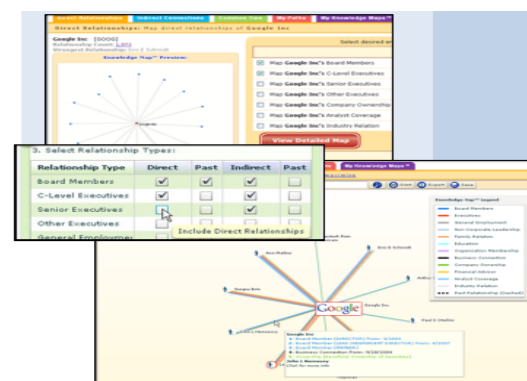


Figure 4. Intellect space.

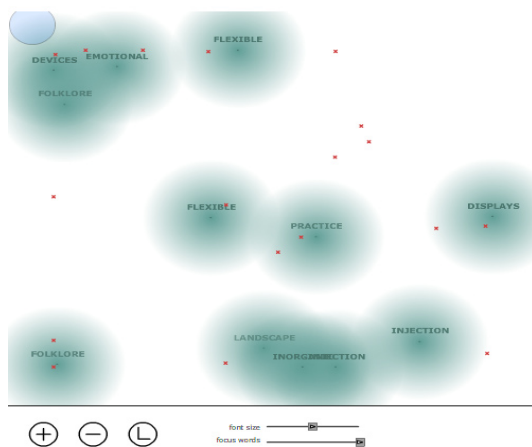


Figure 5. IST-world.

the employee and the links illustrate either employee-to-employee, employee-to-company, or company-to-company relationship as seen in Figure 4. This map is resourceful for R&D, sales, and marketing for a company with new product, and is also useful in understanding human resource network and inter-corporate network.

IST-World (<http://www.ist-world.org>) analyses and provides relationships among different co-researchers and the relations among different research-themes using information collected from Google Scholar and others. The co-researcher map creates the network by defining each researcher as a node and connecting the nodes with links weighted by number of co-authorships. You can easily dig out for core co-authorships by adjusting the critical values in the map, so the map comes in handy when wanting to understand cooperative research network from the researcher's point of view. The theme map analyses all different themes from an individual's publication, and clusters collected themes with relevant themes from other publications as seen in Figure 5⁶. (Istworld European RTD MPA)

Science Metrix (<http://www.science-metrix.com>) provides a bubble chart-type of knowledge map using the average relative citations (ARC) and specialization index (SI) from the Scopus database as seen in Figure 6. The research accomplishments can be visually compared by different research fields or by different countries using this map⁷.

There are also numbers of other knowledge bases that makes use of geological information. A report published by the EC (European Commission) visually captures

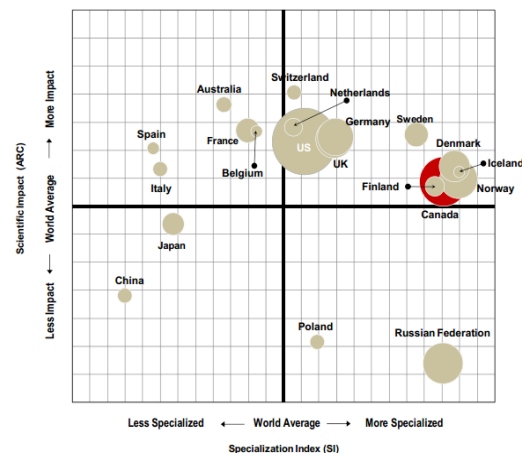


Figure 6. Science metrix.

R&D activities of different research institutes by drawing a knowledge base of particular research field by defining each node as research institute in that specific field throughout Europe where the size of each node was respective to the accomplishments of each institute. Also the Science Metrix provides number of publications and co-authorships by different countries, so it is very useful in figuring out international cooperative network.

2.2 State of the Art of Domestic Knowledge Maps

This section observes the structure and purpose of different knowledge maps based on domestic cases. The report published by Korean STEPI (Science and Technology Policy Institute) made use of various knowledge maps of patent and papers to quarry for new technologies and understand research trends, strengths, and weaknesses of a particular institute in particular field for the purpose of planning out national R&D investment. The methods majorly employed by STEPI were co-word analysis, co-classification analysis, co-appearance analysis, and citation analysis (bibliographic coupling, co-citation analysis). Also knowledge maps of different fields were illustrated as different layers to illustrate the interdisciplinary factor under the assumption that significant research areas of a given sector are likely to be highly correlated with other core research areas of a different sector as seen in Figure 7^{3,4}.

The National Research Foundation of Korea (NRF) provides a knowledge map that is useful for setting up R&D funding policies during the planning stage of R&D.

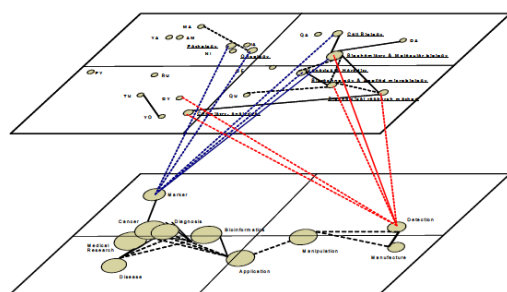


Figure 7. Layer-structured map of convergence factor based on co-word and co-classification analysis.

This knowledge map uses research project information of the foundation along with the information from NCR and JCR to illustrate two-mode relationships such as research area-keyword, research area-research, and research area-institute to understand the research trends by different institutes and cooperative network of researchers, and to discover core researchers in the particular field as seen in Figure 8⁸.

The investigation of cases of domestic and foreign knowledge bases mentioned in this paper can be summed up as followed in the four aspects of Data scope, ②Analysis scope, ③Visualisation method, and ④Purpose. First it can be seen that the scope of data is expanding from structured data only including internal institutes to unstructured data also including outside institutes. With the increased complexity of data structure various network analysis methods are required to be employed in order to systematically analyse object relationships. For visualisation aspects network map, geographical chart, and contour map are often utilized and more visualisation methods are in development for newer applications. The purpose of knowledge maps range from understanding research theme and core technology to analysing cooperative relationships among core researchers, policymaking, and digging for new and converging technologies.

3. Analysis of the NTIS Knowledge Map for Improvements

The NTIS-provided knowledge maps offer map of researchers that display co-researcher relationship, map of science and technology that indicate convergence factor of different disciplines, and map of publications

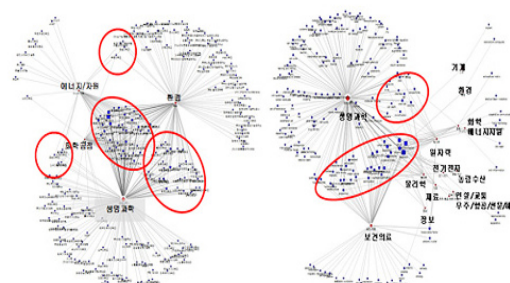


Figure 8. Two-mode knowledge map.

that illustrate evolving of research themes based on the publication keywords. This section aims to understand the characteristics of such NTIS knowledge maps and look for rooms of improvement, and apply the results in drawing out a map of ecology of scientific research^{2,9}. (<http://www.ntis.go.kr>)

The NTIS map of researchers can be divided into the map of researchers by different research field, individualized researcher map, and partner lookup service map as seen in Figures 9–12. The map of researchers by research field visualises similarity of research themes of top researchers and partnerships by matching major keywords with research themes in 364 specific research fields, which are obtained from survey of forecast of science technology conducted by KISTEP (Korea Institute of Science and Technology Evaluation and Planning) as seen in Figures 9, 10. The map of researchers by research field can be divided into ①a research theme-based map that places researchers on circles of research fields respective to matching percentage of keywords of researchers' publication to the keywords of that specific field and ②a researcher relationship-based map that visualises partnership network of major players in the particular field. The theme-based research map should be more effective if visualised in table format and not planetary circles as it pertains to ranking information. The relationship-based map suffers from effectively illustrating nodal relationship when there are too many nodes in one screen.

The individualized researcher map illustrates network of partners from the point of view of a particular researcher, and each node is defined either academic, industrial, or public institute accordingly to the researcher's organisation as seen in Figure 11. This map that



Figure 9. Research theme-based map.

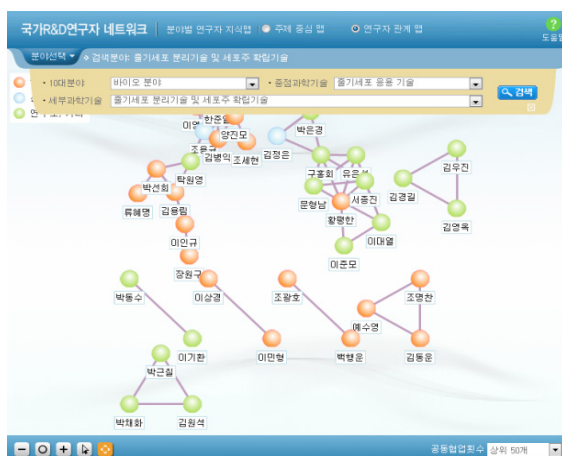


Figure 10. Researcher relationship-based map.

illustrates partnerships among researchers can be co-used with relationship-based map of researchers in Figure 10 to maximise usability.

The partner lookup service is another one of NTIS knowledge based service, and it visualises partner relationships of researchers based on the keyword entered by a user as seen in Figure 12. The limitation of this service lies in the fact that it only displays top fifty researchers per keyword ranked in order by their research and publication achievements. Since this service also focuses on providing cooperative relationships among researchers it can be linked with the relationship-based map of researchers mentioned earlier.

The science and technology map visualises convergence factor of different disciplines by year based on the national standard classification of science and technology as seen in Figure 13. Each node in this map stands

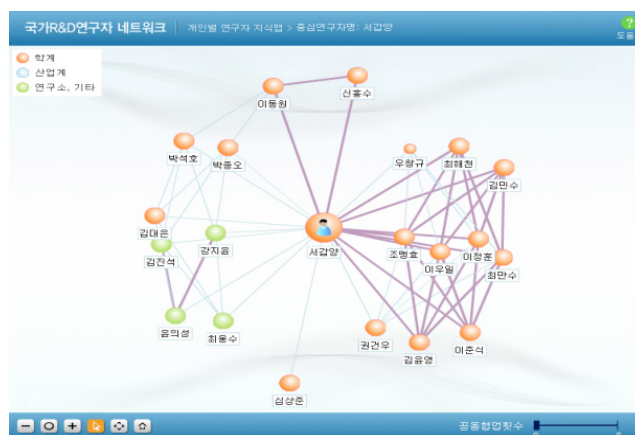


Figure 11. Individualised map of researchers.

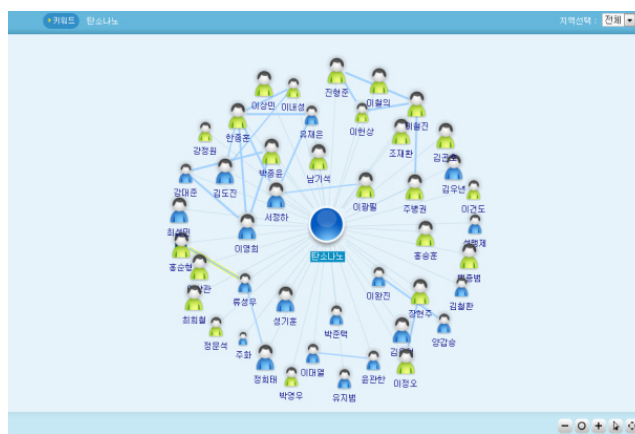


Figure 12. Partner lookup service.

for each classification of science and technology, and nodal links stand for research projects belonging to two or more classifications. Selecting the link will show the yearly achievements and current principal researcher of the particular interdisciplinary research. Selecting the node will draw out major keywords and their relations with the project belonging to the particular classification. This map is advantageous for visualising national interdisciplinary R&D projects, but is limited by the fact that it solely depends on national classification of science and technology. Therefore, it can be suggested that the map should include research achievements beyond the national classification of science and technology.

The map of publications visualises relationship of publications of national R&D projects by looking up related keywords from the user-selected keyword as seen in Figure 14. This map creates its links considering the

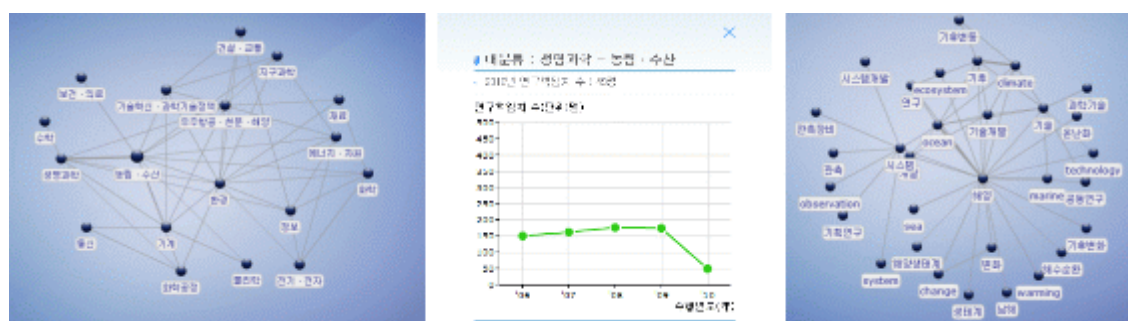


Figure 13. Map of science and technology.



Figure 14. Map of publications.

number of co-appearances of the keywords, and provides information on the national R&D project and its publications based on the co-appearance of the keywords when the link is selected. This map suffers from readability when number of nodes increase, but is useful in extracting relevant keywords for suggesting additional lookup keywords in the service. It can also extract more useful keywords if the target scope of publications expands from papers to patents, R&D reports, and other research achievements.

Various knowledge bases provided by NTIS were investigated, and three rooms of improvement were discovered. First is the necessity of merging redundant knowledge maps that provide similar information. The purpose of each service should be specifically defined in order to be distinguishable among map of researchers, individualised map of researchers, and partner lookup service where each node represents the researcher in all three cases. Second is the linking of different knowledge bases for the purpose of providing fuller information to the user. Currently the NTIS knowledge maps are all separately provided, so connecting of these knowledge maps will certainly increase the value of individual services. Last is the enhancement of design for more effective

visualisation because the small space of knowledge map can obstruct with the readability and cause inconvenience in browsing within the screen. The design should be enhanced to better the user experience and readability while preventing potential mislabeling of the node and links.

4. Development of Map on Ecology of the Scientific Research using NTIS

4.1 Map on Ecology of the Scientific Research using NTIS

This study aims to remove, merge, and link redundant knowledge maps, and to propose new knowledge map based on the analysis of domestic, foreign and NTIS-provided knowledge maps. For this purpose different types of knowledge maps that can be drawn out from the NTIS R&D information were investigated. The national R&D information was first classified by researchers, projects, achievements, institutes, keywords, and fields. Twenty knowledge maps such as map of researchers by

Table 1. Knowledge maps by different types of R&D information

	Researchers	Projects	Achievements	Institutes	Keywords	Fields
Researchers	Lookup researchers and partners	Researchers' participating projects	Researchers' achievements	Researcher's institute	Relationship between the keyword and researcher	Relationship between the research field and researcher
Projects	–	Similar projects, Related projects	Relationship between the project and achievements	Institute conducting the project	Relationship between the keyword and project	Relationship between the research field and project
Achievements	–	–	Similar achievements, Citation of achievements	Institutes' achievements	Relationship between the keyword and achievements	Relationship between the research field and achievement
Institutes	–	–	–	Inter-institute partnerships	Relationship between the keyword and institute	Relationship between the research field and institute
Keywords	–	–	–	–	Map of science and technology, Map of publications	Relationship between the research field and keyword
Fields	–	–	–	–	–	Map of science and technology, Similar research fields

different research fields and map of partnerships could be drawn out as listed in Table 1. This paper groups such twenty knowledge maps into four types (Map of researchers, map of research achievements, map of research institutes, map of research trends) and proposes them as a service of map of ecology of scientific research.

The map of researchers proposed in this study will get rid of the redundancy in previous NTIS map of researchers and merge similar functions to be provided as a combined service. The map of achievements will have to precisely define the relationships among achievements such as journal papers, patents, project reports, and commercialisation, and the map of research institutes will expand the previous partner lookup service to a partner institute lookup service with geological information. Since the map of institute is likely to be concentrated in single particular geographic area, a method should be developed to design around it. The map of research trends will have to incorporate not only the internal data of NTIS but also the outside data in order to seek out for highly deemed technologies and highlight interdisciplinary relationships.

4.2 A Service Model for Mmap on Ecology of Scientific Research using NTIS

4.2.1 Map on Ecology of the Scientific Research using NTIS

A map of researchers should be formed to target user groups of government administration, research administering institutes, and researchers. The government administration can use the information for spreading the budget and evaluating research accomplishments, and use the map to understand core research cluster and key players in the given field. The administering research institutes can use the service for figuring out the spread of research funds in different fields and finding major research group and researcher information in the particular field. Researchers can also use the service to find major research group and researchers in the particular field to lookup potential research partners. Therefore the map of researchers should not be visualised only about a particular researcher, but should be broadly visualised about the particular field¹⁰.

In the map of researchers the researchers are represented as nodes and the links connecting the nodes

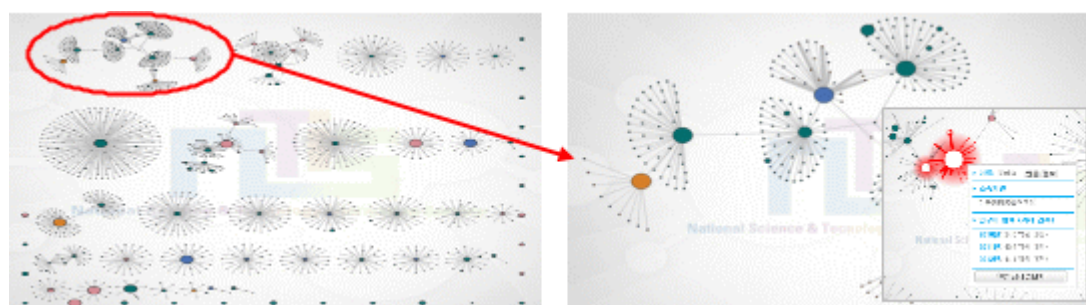


Figure 15. Map of researchers.

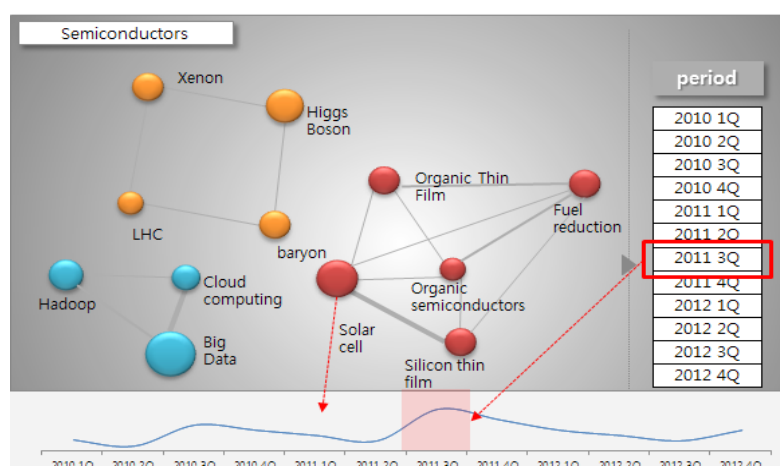


Figure 16. Map of achievements.

represent the relationship between the principal researcher and participating researchers. The size of the node is respective to the scale of funding and color of the node distinguishes academia, industry, and public institute whereas the thickness of link represent number of projects being conducted. A concentrated group of nodes connected with non-discontinuous links as seen in Figure 15 represent a particular research group, and the links are connected only when the principal researcher or the researcher is related. Clicking the node will display the researcher's institute, participating projects by year, and available research budget of the selected researcher.

4.2.2 A Service for Map of Achievements

An NTIS map of achievements should intuitively visualise research accomplishments in the specific field of interest for its users. The government administration and research administering institutes can use the service to make policies based on the research achievements and attain

research budgets. Researchers can use the achievement map to lookup research accomplishments and browse through core achievements in different research fields.

The achievement map is selectively provided for a particular research field, and the nodes represent major keywords of the accomplishments while the links represent level of correlation between different keywords. The size of the node is determined by the technological significance of the keyword while the thickness of link is determined by the level of correlation between the keywords. You can select a specific field and period in order to browse for achievement keywords and their relationships during the selected period as seen in Figure 16. Also selecting specific keyword will illustrate the intensity of research achievement of that keyword over time.

4.2.3 A Service for Map of Institutes

An NTIS map of institutes will visualise institutes with their respective geological information while providing

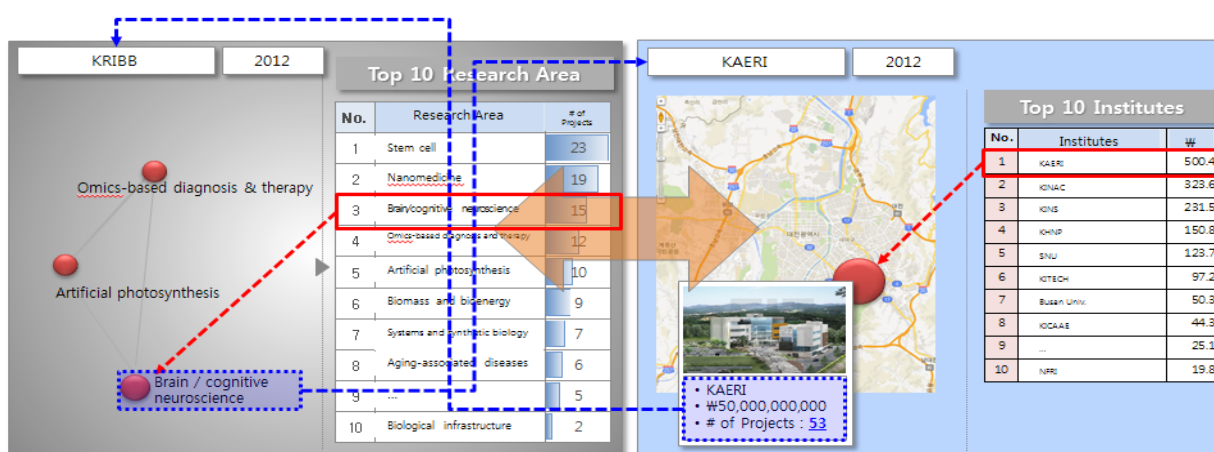


Figure 17. Map of achievements.

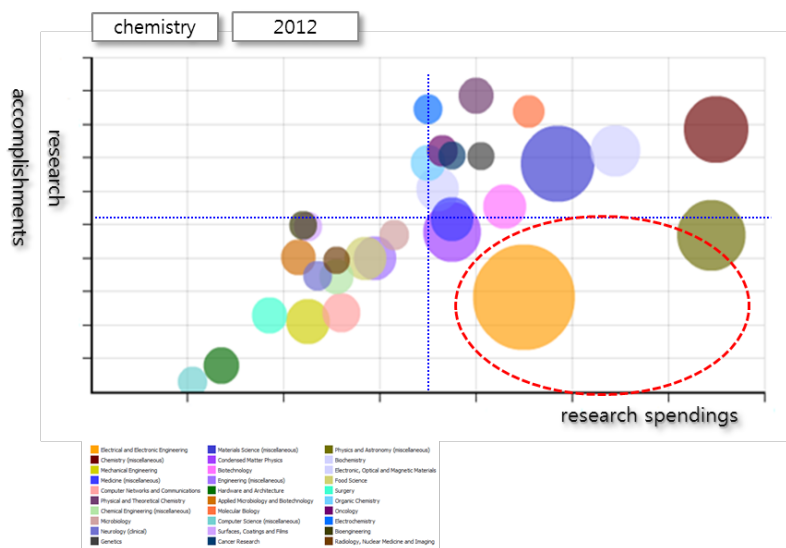


Figure 18. Map of research trends

information on the research project and accomplishments of the institute. The government administration can use the service to understand core research area of each institute and refrain from making redundant investments, and research-administering institutes can use the service to obtain partnership information amongst different research institutes. Researchers can also use the service to lookup potential partner institute based on desired location.

When the researcher selects a particular research area the service pulls out a geological map with major research institutes in that particular research area as nodes. The

color of the node is used to distinguish among academia, industry, and public institute, and the size of each node is respective of the institute's available research funding as seen in Figure 17. When the user selects a particular node the total available research budget and number of conducting research projects are printed, and it also becomes linked with the map of research fields. The map of research fields are filled with nodes that represent major research areas of the selected institute and nodal links that highlight the correlation level between different research fields. When the user selects the research area node, the total of research funding and project numbers

are provided for the selected research area. Also the NTIS map of institutes will respond to the selection of specific research area in the map of research fields.

4.2.4 A Service for Map of Research Trends

NTIS users can use the map of research trends to review technological trends and browse for highly competitive new technologies in a particular research area. Government administrations can use the map of research trends as a basis to form R&D budget planning and to form policies to stimulate specific research area. Research administering institutes can systematically mine for and manage new competing technologies to be shared among academia, industry, and public institutes. Researchers can use the trend map in setting their research roadmap.

The NTIS map of research trends shows research funding distribution and research achievements of particular research sector, and each node represents specific research area and the size of node is respective to the number of research projects in that area. The research trend map is divided into four quadrants to plot research accomplishments against research spending as seen in Figure 18. Users can select a particular node to lookup number of projects, research budget, research achievements per year about that particular research area, and selecting research achievement will show list of research achievements in that area for further lookup.

5. Conclusion

The state of the art of domestic and foreign knowledge maps as well as the NTIS-provided knowledge maps were investigated and analysed for rooms of improvement, and a service model for mapping the ecology of scientific research was proposed based on the investigation results. However this study only suggests four knowledge map types such as map of researchers, map of research achievements, map of research institutes, and map of research trends for mapping the ecology of scientific research, and does not really go into details with specific actions items.

Therefore, methods on selecting research areas, obtaining foundational data, extracting data, network algorithm, and visualisation all necessary for forming the ecological map are left out for future studies.

6. Acknowledgement

This research was supported by the Sharing and Diffusion of National R&D Outcome funded by the Korea Institute of Science and Technology Information.

7. References

1. Lee B, Lee JY, Kim D, Noh KN, Yang MS, Kwon O et al. Morphological classification of knowledge map for science and technology and development of knowledge map examples in the view of information analysis. *The J Korea Cont Assoc.* 2013; 13(11):461–76.
2. Yang M, Kang N, Yun-Jeong Kim Y, Choi K, Kim Y. Development of a national R&D knowledge map using the subject-object relation based on ontology. *J Korean Soc Inform Manag.* 2012; 29(4):123–42.
3. Lee W. Development of methods for discovering and indicating emerging technologies through an analysis of science and technology Information. Science and Technology Policy Institute; 2005.
4. Yoon M. Strategic planning methodology for national R&D projects of emerging technology. Integrated procedure of TRM and KM. Science and Technology Policy Institute; 2005.
5. S&T GPS. Japanese Science Map. 2006. Available from: <http://now.go.kr>.
6. IST world. EUROPEAN RTD MPA. Available from: <http://www.ist-world.org>.
7. Science-Metrix. A Bibliometric Analysis. 2009.
8. Yang D. A study on establishment of knowledge map necessary for innovating R&D planning. National Research Foundation of Korea; 2012.
9. NTIS. Available from: <http://www.ntis.go.kr>.
10. Yang MS. Analysis of network of partnerships of national R&D researchers. Workshop on Information Management & Network Analysis; 2014.