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Identify Potential Opportunity for Research Collaboration Using Bibliometrics

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ABSTRACT

Research has become more complex and interlinked. Collaboration is now the key for managing innovation and R&D activities. This study aims to discover the potential opportunity for research collaboration using bibliometrics. The analysis reveals both existing and potential (hidden) research networks which can lead to future development among potential groups of experts in the field.

JEL Classifications: *M10, O32*

Keywords: *research collaboration; bibliometric analysis; social networks; decision support*

I. INTRODUCTION

In recent decades, there has been a notable shift toward R&D that crosses disciplines and organizational boundaries. One reason is because of the complexity and scope of the problems that society is currently facing (e.g., global warming, emerging infectious diseases, and loss of natural resources). These problems require innovative solutions that integrate knowledge from different disciplines. The concept of networking R&D is therefore increasingly important. However, the main challenge in initiating any cross discipline development is how to identify the potential groups of experts for collaboration and which areas of expertise they specialize in. One common expert identification method is based on social connections, i.e., ask people and follow referrals until finding someone with appropriate expertise. However, this could be a time-consuming and biased task. Fortunately with the availability and accessibility of research literature and the advancement in information retrieval, natural language processing, and machine learning, potential experts can be identified automatically from such information sources.

This study aims to apply bibliometric analysis of research publications to discover potential research collaboration among key researchers. To address this challenge, two research questions are needed to be answered: (1) who are the key researchers/ practitioners in the specified field? and (2) are there any forms of collaboration or linkages among these experts in the field?

The analysis can identify experts whose relationships have already been established as well as for those who never know each other, yet seem to share similar research interests. The latter case can be considered as a hidden network in which the collaboration among those experts can also be initiated.

II. LITERATURE REVIEW

A. Bibliometric Analysis

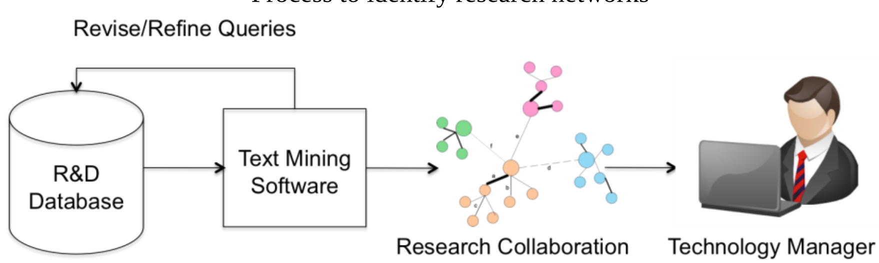
Bibliometrics is the use of statistical and mathematical methods to study publication patterns (McBurney and Novak, 2002). It uses the counts of publications, patents, and citations to develop science and technology performance indicators. These indicators are used to measure research outputs (Narin and Olivastro, 1994). In other words, the number of publications or citations created by a research unit may be used to estimate the output of that research group.

Fundamental work in bibliometrics originated in the 1960's. Derek de Solla Price (Price, 1963) and Eugene Garfield (Garfield, Sher, and Torpie, 1964) were pioneers to develop bibliometric indicators. Later on in the 1970's, Henry Small improved the method with the development of co-citation analysis (Small, 1973). A bibliometric analysis is based on three principles: Activity measurement by counting publications, impact measurement by counting subsequent citations of a publication and linkage measurement involving co-citations and keywords used from paper to paper (Kongthon, 2004). A bibliometric analysis can provide a macroscopic view of the entire field in the global context of related and neighboring fields. The understanding of the bigger picture will allow an individual to rationally choose a specific starting point for more detailed investigations (Kostoff *et al.*, 2001). Bibliometric methods are used to infer knowledge from a body of literature (Porter and Cunningham, 2005; Porter, Kongthon, and Lui, 2002), as well as to communicate the development and evolution of knowledge in a given field (Daim, Rueda, and Martin, 2005), review research and development progress (Daim and Gerdsri, 2009), and explore a research community (Gerdsri, Kongthon, and Vatananan, 2013). Bibliometric analysis has been applied in various areas such as marketing (Baumgartner and Pieters, 2003), technology management (Pilkington, 2004; Porter and Cunningham, 2005), topics in modern science (Saka and Igami, 2007), research profiling (Nerur, Rasheed, and Natarajan, 2008) and mapping the evolution of the intellectual structure in operations management (Porter and Detampel, 1995).

Bibliometrics are used in several cases to reveal the insights on some complex issues. It supports decision making which merely personal experience and knowledge are not enough for deciding appropriately. For example, bibliometrics is used to evaluate scientific research performance by using publication and citation data to identify promising scientific research areas. The results can then be used for making better investment decisions and enhancing the effectiveness of R&D management (Porter, 2007). The decision that government offices usually need to make is, for example, which researchers and research projects should be funded? Since research performance can be evaluated through bibliometrics, the application of these tools can therefore benefit several parties, such as government labs, policy makers, university research directors, and even researchers (Reuters, 2008).

In this paper, bibliometric analysis is applied through a text mining approach to discover potential for research collaboration. Figure 1 illustrates the analysis process used in this study. First, we start collecting bibliographic abstracts from selected databases. After we download the target records, we then import them into the analytical text mining software, VantagePoint, to represent the linkages among experts through keywords they shared in their publications. Then, the results will be reported to a technology management team to analyze the potential for collaboration with those groups of experts.

Figure 1
Process to identify research networks



B. Constructing Areas of Expertise Based on R&D Publications

The Organization for Economic Co-operation and Development (OECD) emphasizes the creation and diffusion of both codified and tacit knowledge as a key element supporting the economic growth of nations (OECD, 2008). Codified knowledge is information that can be easily transferred through documentation, academic papers, or technical notes, whereas tacit knowledge is information which can be effectively transferred among individuals with a common social interaction and physical proximity.

To promote the exchange and transfer of tacit knowledge among individuals, the concept of research networking has become increasingly important. One of the methods that can help reveal the networks among researchers is to analyze their publications including journals, conferences, as well as patents.

Besides structured documentation like journal publications, several scholars have addressed the opportunities for identifying people's expertise from heterogeneous sources such as email messages, enterprise's documents, discussion forums, web pages, and social networks. Campbell *et al.* (2003) and Balog and Rijke (2006) suggested the potential experts and their expertise indications by searching and analyzing email messages. Several studies proposed an expertise retrieval approach to identify a list of experts and also to identify areas of expertise that a person is knowledgeable about.

Tang *et al.* (2007) constructed a researcher network knowledge base by extracting information from his/her homepage and publications from the Digital Bibliography & Library Project (DBLP). Pflugrad *et al.* (2014) generated expert profiles for rare diseases by analyzing MEDLINE. The most frequent Medical Subject Headings (MeSH) terms were used to describe the author's areas of expertise. Liu *et al.* (2008) applied a semantic web application to build a semantic repository of academic experts by analyzing homepage, publication database, research-scholarly activity, courses-teaching experience, and honors/awards.

C. Development of Social Communities and Networks

As the world is globalized, the development of social communities and networks has become more and more important. Many activities can now be pursued regardless of geographical limitation as they were in the past. Notable examples of social networks include Facebook or Linkedin communities. In a social network, relationships between individuals can be family, friendships, business relationships and some common interest relationships. Through a social network, people from different countries can join activities with others from around the world.

To discover research communities, bibliometrics can provide insights to identify existing or nascent social communities and networks for both explicit and implicit relations among researchers (Garner *et al.*, 2012; Porter *et al.*, 2012). For explicit relations, co-authorship network analysis is considered to be the most straightforward way to describe collaborative behaviors among members of a research community (Melin and Persson, 1996; Newman, 2004). Previous studies have applied co-authorship networks to identify the patterns of collaboration among researchers in many different scientific communities, such as economics (Krichel and Bakkalbasi, 2006), digital library research (Liu *et al.*, 2005), Turkish social science (Gossart and Özman, 2009), and technology road mapping (Gerdsri, Kongthon, and Vatananan, 2013). The VP Institute website [www.VPInstitute.org] is rich in various research profiling endeavors, many of which include networking analyses.

In addition to the explicit relations in the network, bibliometric analysis can show implicit (hidden) relations in the social network. These hidden relations mean that members in the network may not have a direct interaction with each before, yet they seem to share common interests. Knowing the hidden relations may result in the development of possible collaborations in the future. The discovery of both explicit and hidden social networks can benefit the development of emerging research areas where the communities and joint activities have not been structurally formed yet.

III. THE PROPOSED METHOD: IDENTIFYING POTENTIAL RESEARCH COLLABORATION THROUGH BIBLIOMETRIC ANALYSIS

Our analysis starts with the collection of bibliographic data from relevant R&D databases. Each bibliographic abstract presents prominent research meta-information contained in fields such as: (1) author(s), (2) topics, including keywords, subject indexes or classification codes, (3) affiliations of the author(s), (4) location where the research was conducted, such as country, (5) source of publication such as the journal or conference where the research was published, and (6) date of publication.

To answer our first research question regarding who are the key researchers/practitioners in the specified field, we can create a list of the top authors who published the most papers in the field. Then our second research question is to identify any forms of research collaboration among these experts. We assume there are two types of collaborations as follows:

1. Direct relationships, which can be determined by analyzing co-authorship networks. The more the authors publish papers together, the stronger the collaboration network.
2. Indirect (or hidden) relationships -- suggest potential for future research collaboration. We can identify such indirect relationship by constructing networks of experts who share the same topics or keywords, even though they are not co-authoring. The more topics or keywords these experts share in their publications, the stronger confirmation that they work in a very similar research area. Although, they do not have an existing direct relationship, the discovery of such "hidden" connections may lead to the establishment for future collaboration.

We can display these relationships in term of a network linkage as illustrated in Figure 2. Each node represents a researcher. The size of the node represents the number of papers published by each researcher. Hence, the biggest node potentially represents a research principal and a smaller node represents a research team member. A link between nodes represents collaboration between two researchers. A solid line indicates a formal, direct relationship and a dashed line indicates an indirect one. Moreover, the thicker the line, the stronger the relationship is. By mapping researcher connections, technology policy or innovation managers can use them as technical intelligence to identify collaboration opportunities and determine a plan to support and promote such collaborations. Based on our assumption, we can generalize collaborations into six cases as summarized in Table 1. Technology managers can use this table as a guideline to analyze the condition of either existing or hidden research collaborations.

IV. A CASE EXAMPLE: USE OF BIBLIOMETRICS TO DISCOVER THE PROFESSIONAL COMMUNITIES AND SOCIAL NETWORKS IN THE FIELD OF BIOMEDICAL ENGINEERING IN THAILAND

Biomedical engineering (BME) is the interdisciplinary linking engineering, medicine, and biology together. The results can be presented in a form of equipment devices, materials, algorithm, and systems for medical applications. As defined by IEEE Biomedical engineering society, there are nine sub-research areas of biomedical engineering as follows: bioinstrumentation; biomaterials; biomechanics; cellular, tissue and genetic engineering; clinical engineering; medical imaging; orthopedic bioengineering, and rehabilitation engineering (Biomedical Engineering Society, 2009)

Thailand has included biomedical engineering as one of the strategic direction. Currently, the healthcare industry in Thailand relies heavily on medical equipment which imported from aboard while the local development of BME related industries has been mainly focused on consumable products such as hypodermic syringe, cotton, etc. However, to align with the national strategic direction in promoting the healthcare sector and enhancing the access to better healthcare services by the poor, the future development of BME fields in Thialand must focus more on the development of value-added products and services such as portable EKG units, CT scanners, medical informatics system etc. To do so, the local BME community needs to reach out to more experts from other related fields besides engineering so that they can work together tackling interdisciplinary problems inherent in the BME research.

Figure 2
Research network diagram

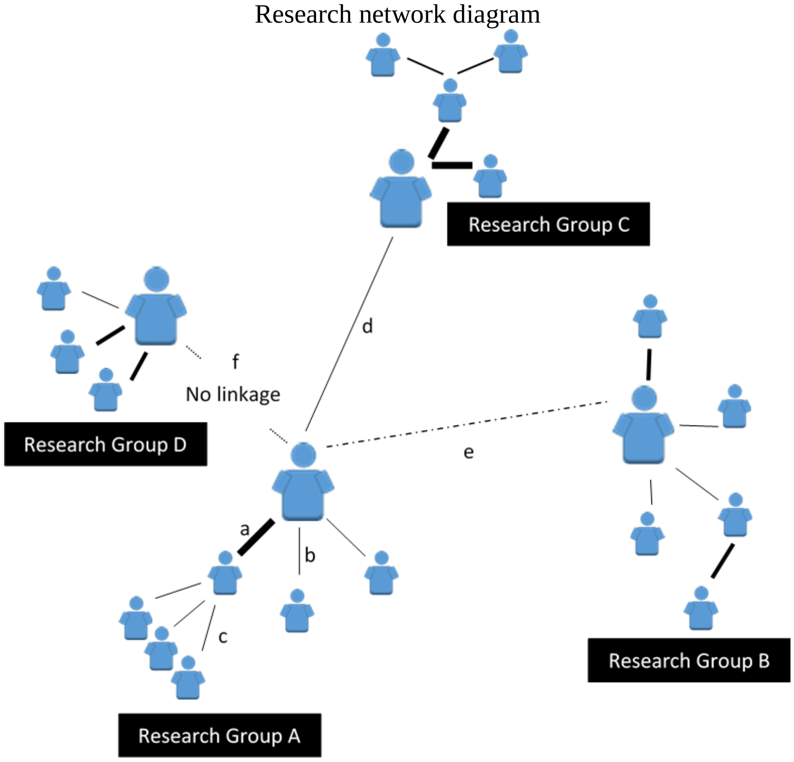


Table 1
Different linkages and relations

Linkage	Relations
a	Direct relationship between the two researchers in group A. Their collaboration is strong as the two are co-authoring in quite a number of publications. For example, this linkage can represent the relationship between the research principal and a senior researcher within an ongoing team.
b	Direct relationship between the two researchers in group A. Their collaboration is not as strong as the case shown by linkage a. However, the two are co-authoring in some publications. For example, this linkage can represent the relationship between the research principal and a younger researcher who has just joined the research team.
c	Direct relationship in conjunction with expansion of the research team where the senior researcher has started to form his/her own team.
d	Direct relationship through known collaboration between two different research groups as the research principals of group A and C work together from time to time.
e	Indirect (hidden) relationship where the two research teams (groups A and B) have not done any work together. They may not even know each other but they publish work on closely related topics. As they share similar interests, it may lead to the potential for future collaboration (or competition).
f	No relationship between two research teams (group A and D). The smaller team (group D) could represent an independent research team who works on some emerging topics within the same research area as group A, but for the time being they do not share anything in common. The works of group D might start gaining more and more interest from the field as the topics continue to emerge. This may lead to future collaboration between the two groups.

In 2015, Thai government has approved “The Talent Mobility” program aiming to enable mobility of researchers at government agencies and universities, to assist the private sector in technological upgrading and innovation. The researchers are authorized to work full-time or part-time with industry for up to 2 years. This initiative is expected to enhance Thailand’s competitiveness.

Even though there are some BME research and development for healthcare industry in the country, it is still at the early stage of development. The professional communities and networks are not well structured yet. Individual researchers mostly do not link well with the colleagues from other organizations including companies, universities, research institutes, and government agencies. One key initiative which recently put in place was the formation of Thailand Biomedical Engineering (BME) Consortium mainly led by four main universities and government research institutes. The role of this consortium is to serve as a platform for collaboration and cooperation among consortium members so that their knowledge and information can be shared and exchanged.

In addition to the research and development activities, Thailand BME Consortium also initiates and facilitates educational programs for both undergraduate and graduate degree on biomedical engineering in Thailand. Also, Ministry of Science and Technology, and the Office of The Civil Service Commission continuously support scholarships for Thai students to further their education in this field. The following section presents the case analysis demonstrating how bibliometrics has been applied to reveal both existing and potential (hidden) research networks which can lead to future development among potential groups of experts in the field. The processes of conducting these bibliometric analysis are as follows:

- *Step 1: Download bibliographic abstracts*

The SCOPUS database during year 1980 – 2012 was selected for the analysis. The search string that we use in our query is "(TITLE-ABS-KEY(biomed OR biomechanics OR "tissue and genetic engineering" OR bioinformatics OR biosensors OR "medical imaging" OR "drug delivery") AND AFFIL(thailand)), where "TITLE" is article title; "ABS" is article abstract, "KEY" is keywords; "AFFIL" is affiliation. There are 1,217 publications found from the search.

- *Step 2: Identify top authors and construct a research network graph*

VantagePoint software is used to perform our analysis. The program can help identify top authors and discover the relations and linkages of these experts who had co-authored and who are interested in similar research areas.

- *The identification of the BME existing and hidden social networks in Thailand.*

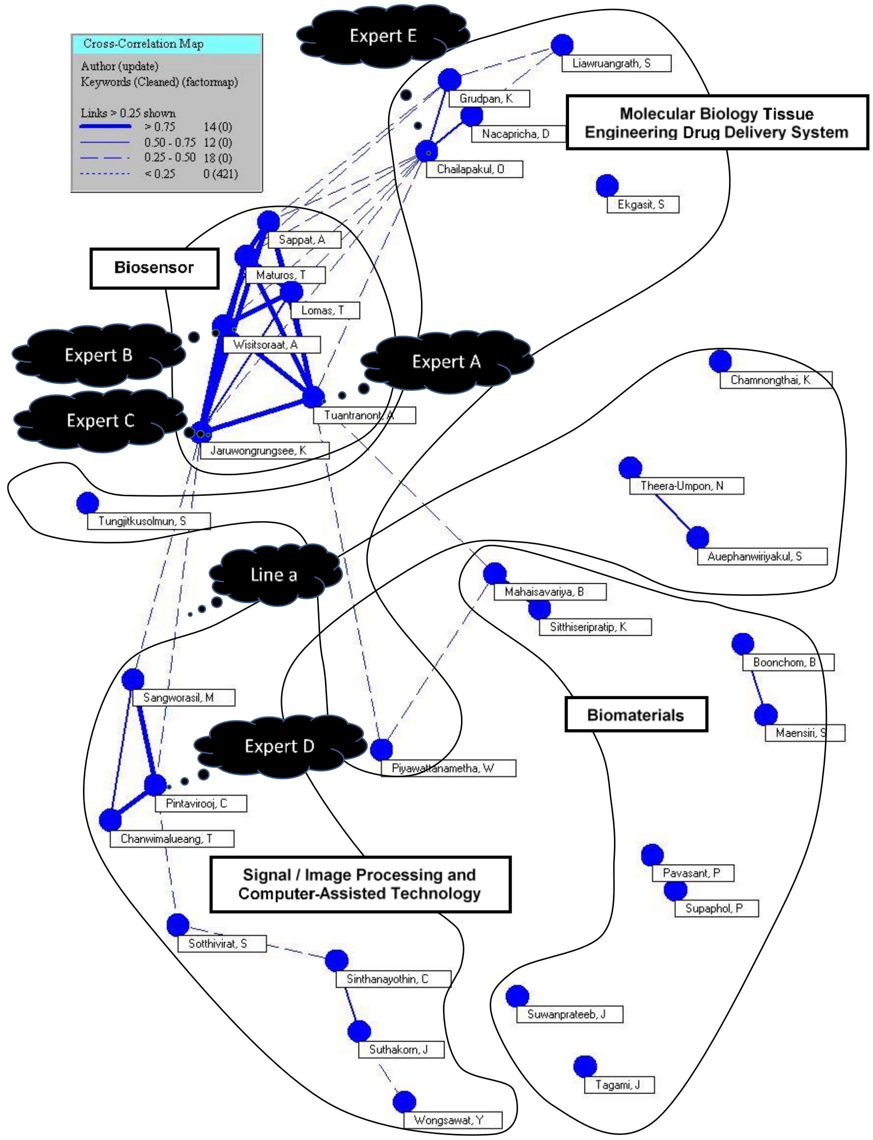
Results obtained from the bibliometrics reveal existing and hidden relationships among Thai BME researchers. Figure 3 illustrates the existing relationships based on co-authorship which is displayed by the thick solid lines in the diagram, while the dashed lines represent hidden relationships based on their shared topics of interest. From Fig. 3, the results show that there are four major areas identified, namely: (1) molecular biology, tissue engineering, and drug delivery systems, (2) biosensors, (3) signals, image processing, and computer-assisted technology, and (4) biomaterials. More details on this case study can be found in Gerdsri, Kongthon, and Puengrusme (2017).

V. MANAGERIAL DISCUSSION ON SOCIAL NETWORK ANALYSIS

Comparing the four areas, the results show that the interactions among experts in the area of Biosensors are well established as presented by solid lines connecting multiple players within strong groups of experts. Expert A and Expert B seem to be the research principals leading the respective group as their nodes are the center of interactions.

For the area of Signals/ Image Processing and Computer-Assisted Technology, the results show that interactions among key researchers are still not fully established (unlike Biosensors) as presented by thin lines and long dash lines connecting players. Nevertheless, Expert D can be considered as the center of collaboration in this area. The analysis also shows the extended relationship among players connecting one researcher to another down through the relationship chain starting Expert D. This circumstance can be explained as this group of experts may share similar concepts of Signaling and Image Processing but each expert has applied it to different applications. The representation of expert networks in this case can help technology managers to know whom to contact if they seek to set up research collaboration between the areas of Biosensor and Signal Processing. Technology managers may start establishing the connection between Expert C and Expert D first. Although, Experts C and D have not worked together before, the analysis shows that they share similar interests through common keywords used as presented by a dashed line linking them (line a). With collaboration between the two, each expert can also help expand the collaborations to other experts in his or her network.

Figure 3
Existing and hidden interaction of engineering experts involving in BME research and development



Similarly, for the area of Molecular Biology and Tissue Engineering, the results show that interactions among key researchers are still not fully established as presented by thin lines and long dash lines connecting players. Nevertheless, Expert E can be considered as the center of collaboration in this area. If technology managers want to initiate the research collaboration between the areas of Biosensor and Molecular Biology. Expert E should be considered to be a potential gatekeeper as the analysis shows that Expert E share similar interests with many Biosensor researchers presented by a dashed line.

For the area of Biomaterials, the results also show that interactions among key researchers are fragmented. Many researchers in this area seem to be stand-alone. They do not share any common keyword as there is no line connecting among them. This analysis would inform technology managers to explore the causes of this issue which it could be because of emerging areas or lack of strategic focus.

If technology managers would like to strengthen the whole BME community and attempt to synergize the research efforts in order to complete a certain mission in which the four research areas have to contribute. Technology managers can begin by forming a spearhead team of researchers representing all four areas. The members of spearhead team can be Expert A, B, C, D, E, and F.

The results from this study can contribute to the knowledge of discovering the social network of existing and potential collaboration among the groups of experts. Results of the case example shown in Figure 3 help understand not only the existing interactions among experts in the community but also offer some insight about the potential interactions that could be initiated among researchers unaware of shared interests and/or complementary capabilities. Through the identification and development of networks, research communities can identify potential reviewers of a paper for a journal or a proposal to a funding program. Policy makers would know which leading organizations or groups of experts to contact for providing support and incentives to promote the activities in each research area. Or perhaps, policy makers can work with them to set up a Center of Excellence (COE) in their areas of specialization. With this approach, the allocation of limited research funding can be more effective as it can be strategically directed to targeted research organizations instead of spreading across many organizations. Moreover, the redundancy of funding among different research organizations can be minimized.

With the analysis results, it would be useful for supporting Thailand's initiative as when talent mobility manager wants to search for an expert from the Talent Database, a manager has to perform a keyword search in a particular field of expertise.

VI. CHALLENGES IN APPLYING BIBIOMETRIC ANALYSIS: LESSONS LEARNED FROM THE CASE EXAMPLE

The challenges can be addressed from two aspects. One is about the challenges in using bibliometric analysis and the other one is about the challenges in applying the analysis for Thailand.

The drawback of bibliometric (a keyword search) is that one can only find records containing the query terms. For instance, if the user wants to search for experts in "data mining", the current database would return records where the field of expertise contains the term "data mining" but not records with related terms such as "machine learning" or "pattern recognition". Moreover, with the keyword search, only the list of experts will be retrieved. The associations between co-authorship patterns cannot be detected.

For developing countries like Thailand in particular, the number of experts in science and technology who have their works presented in international publications is still limited. Thus, using only the international publication database to support the analysis may represent only the top portion of Thai researcher community. As, many Thai scholars also have their works published in the national (Thai language) publications. By attempting to get the comprehensive analysis, both international and national publication databases should be consolidated.

Prior to the year 2011, most of the Thai research institutes created and maintained their own research/researcher databases. In 2011, The National Research Council of Thailand and Thailand Research Organizations Network which includes National Science and Technology Development Agency, Thailand Research Fund, National Science Technology and Innovation Policy Office, Health Systems Research Institute and Agriculture Research Development Agency cooperatively developed the Thai National Researcher Repository (TNRR). TNRR aims to provide access to research output created by researchers from government agencies, universities, and research institutes. However, TNRR was still constructed based upon voluntary responses from researchers to create and update their profile (Kongthon *et al.,* 2017). This type of manually database creation is difficult and expensive. We found that the database is incomplete and the area of expertise field has been left blank for a great number of researchers. Therefore, in this paper, we focus our efforts on using only R&D literature from international publication databases as explained in the analysis process section.

VII. CONCLUSIONS

This study can contribute to the knowledge of discovering the network of existing and potential collaboration among the groups of experts using bibliometric analysis. Through the identification and development of networks, policy makers and innovation managers would know which leading organizations or groups of experts to contact for providing supports and incentives to promote the activities in each research area as well as the collaborations among different areas. However, for developing countries such as Thailand where the number of knowledge workers is quite limited, a complete national researcher profile database is essential to locate experts in various fields in order to foster collaborative opportunities.

ENDNOTES

1. VantagePoint is a text-mining software for discovering knowledge in search results from patent and literature databases (http://www.thevantagepoint.com/).
2. SCOPUS is produced by Elsevier; it contains abstracts and citations from journal articles and conference papers from several thousand sources providing coverage of scientific, technical, medical and social sciences fields and arts and humanities.

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