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〈**Original Paper**〉

Identifying Knowledge Structure of Patent and Innovation Research

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The global intellectual property system is currently being revolutionized by changes in innovation and the quantitative expansion in patenting. There is an expectation of applying the results of academic patents studies to the reformation of the intellectual property system. On the other hand, the rapid quantitative expansion in academic knowledge is posing difficulties for the application of conventional techniques to extract required knowledge or apply a suitable synthesis. This article has the purpose of effective implementation of large volumes of knowledge for policy formation and examines the methodology for identifying academic growth fronts, important research domains or comprehension of the academic landscape. We conducted a panoramic analysis of intellectual property rights (IPR) researches in the work published from 1956 through citation network analysis. As a result, 3,833 academic papers were extracted as the largest connected component of the network of IPR. We specified five main clusters and twenty-five sub-clusters in the network. Through a time series analysis, we identified young or recently growing research fields. Our findings prove that the citation network analysis allows us to accurately and comprehensively detect papers discussing important issues in the area of intellectual property rights and innovation.

■ KEYWORDS Intellectual Property System, Citation Network Analysis, Academic Landscape

I. INTRODUCTION

The intellectual property system centering on patents when viewed globally is undergoing a far-reaching revolution. Quantitative problems include the increasing difficulty of reducing backlogs and maintaining patent quality due to the increase in patent applications including applications by non-residents. These developments are occurring against a background of the internationalization of innovative activities, the acceleration of innovation and intensifying competition in strategic areas such as sustainable energy technologies or next-generation IT. Conspicuous qualitative problems include changes in innovation such as increasing science linkage (Bonaccorsi and Toma, 2007, Motohashi and Yun, 2007, Kanda et al., 2008), the increasingly complicated relationship between products, patents and scientific knowledge (Miyazaki and Islam, 2007, Shibata et al., 2010), the development of open innovation (Chesbrough, 2003, Kirschbaum, 2005, Pykalainen, 2007, van de Vrande, 2009) and globalization of knowledge circulation (Smith and Sharif, 2007, Sasaki et al., 2010). The basis of the patent system is being rocked by structural change in the basic assumptions which are based on the above premises. There is an increasing recognition that the current intellectual property system which has formed the basis of current patent law may no longer be necessarily capable of promoting innovation.

In the current fact-changing and complicated situation, empirical knowledge, case studies and brief sur-

* 本論文は，日本知財学会誌編集委員会による複数の匿名レフェリーの査読を経たものである.

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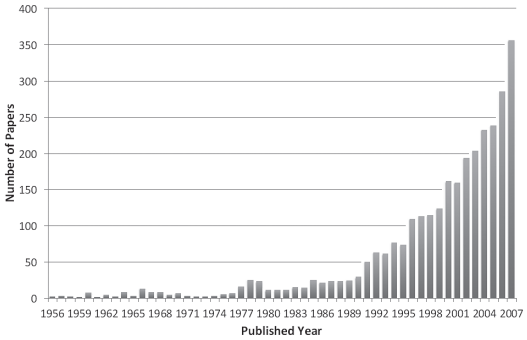
Fig. 1 Number of papers including "patent" or "intellectual property" in the title or abstract



vey are not sufficient for the knowledge base of intellectual property system reform. Policy makers have to increasingly rely on accumulated academic knowledge which includes quantitative evidences, detailed findings and in-depth legislative debate. But grasping the current status of academic research on the intellectual property rights has become a rudimentary task for policy makers because of the growing body of publications as shown in Fig. 1. Generally, there are two approaches to obtaining comprehensive perspective on academic research. One straightforward manner is the expert-based approach, which utilize the implicit knowledge of domain experts. The other is the computer-based approach, which analyzes explicit knowledge such as journal paper and letters (Kajikawa and Takeda, 2008). To meet policy makers' need a computer-based approach can be used to complement the expert-based approach because it is compatible with the volume of information (Börner et al., 2003 ; Boyack et al., 2005). A citation-based approach, which is computer-based, operates on the assumption that citing and cited papers have similar research topics. By analyzing this citation network, we can comprehend the structure of a research domain constituting larger volume of papers than we can read (Kajikawa et al., 2007). In previous works, a citation-based approach has been applied to emerging academic research fields such as water resource management (Thelwall et al., 2006), biomass and bio-fuel (Kajikawa and Takeda, 2008), organic LEDs (Kajikawa and Takeda, 2009), secondary battery (Shibata et al., 2009) and translational research in cancer and cardiovascular medicine (Jones et al., 2011).

The aim of this paper is to offer a meta structure of academic knowledge (academic landscape) on patent and innovation research to assist effective policy discussion for intellectual property system reform. With citation-based approach, this paper analyzes the academic landscape of patent and innovation research to understand the current structure and trend of research, and to detect major sub-research fields and core papers within it. In the next section, we present our methodology.

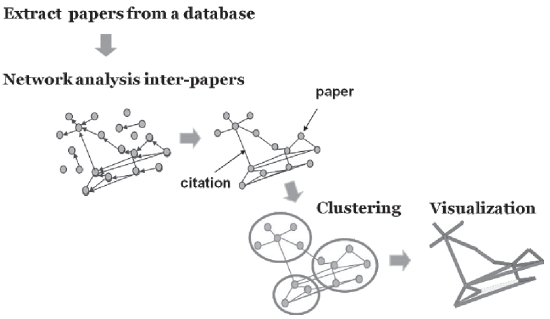
II. METHODOLOGY

An analysis of citation information in academic papers was initiated by Garfield (1955) and currently represents a useful tool for extracting important papers or hot topics from a large volume of bibliographic information (Börner et al., 2003). A paper is used as a node and when a citation relationship between papers is formed by tracking a linkage between nodes, it is possible to construct a citation network. When it is considered that the authors of such papers cite another paper in the recognition of some relationship to the contents of their own paper, such a network can be said to demonstrate a linkage between respective content. To give a more precise example, Small (2006) specified research domains undergoing sharp growth in recent years such as research conducted in relation to carbon nanotubes or infectious diseases such as SARS by using a bibliographic database to create a mapping or segmentation (clustering) using citation information and, in particular, by identifying the average age of papers associated with large numbers of citations. Shibata et al. (2007) proposes a method for rapid detection of emergent research fronts and papers associated with a high possibility of future citation by using a complicated network analysis and by modeling citation behavior. Kajikawa et al. (2007) and Hashimoto et al. (2009)

enable visualization of sustainability and innovation research fronts by using citation network analysis and natural language processing in order to create a landscape of related concepts. Shibata et al. (2011) identified important papers from citation relationships in relation to solar cells which are attracting attention around the world. Most previous studies discussed non-weighted, non-directed network.

This paper uses such network analysis as a tool to create a landscape of intellectual property rights and innovation research which has undergone conspicuous recent development. More specifically, papers containing the words "patent" or "intellectual property" in the title, keywords or abstract were extracted from a database (Social Science Citation Index (SSCI) and (Arts & Humanities Citation Index (AHCI)). As a result, 9,458 papers from 1956 to 2008 were extracted having 13,053 links between the papers. Next, these data were used to construct a network using respective papers as nodes and citation relationships as links. In this manner, the largest document group (largest connected component) connecting citation relationships were 3,833 papers. Then thirdly, clustering was conducted by applying a Newman method (Newman, 2004) to those results. This method is a method of creating cohesive clustering so that the ratio of links contained in the cluster is sufficiently increased in relation to the ratio of link between clusters, that is to say, so that both the inter-cluster and intra-cluster link density contrasts are increased. In this manner, clustering enables the identification of document groups having dense citation relationships, in other words, document groups recognized by researchers and having close content relationships. After clustering the network, we analyzed the characteristics of each cluster by titles and abstracts of papers that are frequently cited by other papers in the cluster, and also major journals, in which the papers in the cluster were published. Fourthly, the results were recreated visually. A Large Graph Layout (Adai et al., 2004) was used as an algorithm for visualizing the network. The

Fig. 2 Analysis Steps in Citation Network Analysis



method is a graphic method based on spring models and assumes an attractive force between node having mutual links or, if that is not the case, a repulsive force, and applies a coordinate calculation to each node. In other words, cluster groups having dense citation relationships are in proximity to each other and papers without citation relationships are arranged separately. The relative position of cluster groups is visualized by using the same color to display of citation relationships associated with the same cluster. In this manner, the visual distance can be used to comprehend the level of the citation relationship between clusters. A calculation of the average age of the cluster can be performed from the date of publication of papers contained in each cluster. A low average age demonstrates that the cluster is a research front and that a large number of papers have been published in recent years relative to the past. Fig. 2 illustrates the steps in the above analysis.

III. RESULTS

A. Characteristics and Cluster Structure of Intellectual Property Domains

Initially, the journal classification of the Web of Science was used to analyze all papers with respect to the associated academic field. Papers were present from various fields including law, business, information science, economics and engineering as shown in Table 1. Although the highest number of papers was from law, it can be seen that no academic field was particu-

Table 1 AREAS OF STUDY

	Academic Field	# of Papers
1.	Law	3,002
2.	Information Science & Library Science	1,851
3.	Business	1,619
4.	Economics	1,372
5.	Management	1,010
6.	Computer Science	798
7.	Planning & Development	491
8.	Engineering	459
9.	Multidisciplinary Sciences	342
10.	Social Sciences	304

larly prominent. Thus, we can consider that the research on patent and innovation research is apparently multi-disciplinary field.

Next, clustering method was used to categorize the largest connected component with 3,822 papers into 54 clusters. We regarded papers not citing other papers in the component as digressional. 3,184 papers are contained in just the top 5 clusters having a particularly large number of papers and account for 83% of the largest connected component. Thus, it can be determined that verification of these five clusters is sufficient for identification of a broad landscape related to intellectual property fields.

Consideration of the papers contained in the five clusters shows that although specific content characteristics can be extracted, there remains a high level of variety. We characterized each cluster by the titles and abstracts that are frequently cited by other papers in the same cluster. We also use the information of major journals in which the papers in the cluster were published. This does not mean that all papers in the cluster study the same topics as covered in these frequently cited papers. In fact, each paper studies its own topics, and each paper has its own unique focus. However, as a first approach, it is reasonable to treat these inter-cited papers as a cluster to investigate the brief structure of a research domain and to consider the frequently cited papers in the cluster as a representative of the same. As a result, top five clusters are named as Patent Innovation & Econometrics (C1), Institution & Legal System (C2), Technology Management and Patent (C3), Academic Activity & Patent (C4) and Patent Meta-Information (C5). C4 is the youngest group (average year of publication, 2002.61) and C5 is the oldest one (average year of publication, 1982.01). The gap of average publication year between C4 and C5 is 20 years.

C1 : Patent Innovation & Econometrics

The principal journals in the largest cluster are influential journals into systems research such as *Research Policy* and *Scientometrics*. In these clusters, there are many papers discussing the usefulness of using patent information as an indicator of corporate innovation or as an economic indicator, or papers discussing the economic value of patents themselves. These can be said to be a research group constituting a portion of innovation research[1]. This cluster is termed "patent innovation and econometrics".

C2 : Institution & Legal System

The principal journals in the second large cluster are the *Texas Law Review* and *Stanford Law Review*. The paper groups associated with this cluster include many papers discussing recent trends in the law and the legal system or trends in intellectual property law including patent and copyright law. Key topics include nature and function of patent system, law and policy of intellectual property licensing, pharmaceutical patent and information security and law. Furthermore, the field is also characterized by the large volume of the individual papers. This cluster is termed the "institution and legal system".

C3 : Technology Management & Patent

This cluster is related to the patent system or patent management in the intellectual property creation cycle for the creation, protection and exploitation by companies or universities. The principal journals are *Research Policy* and *RAND J ECON*. This field is mainly

related to discuss regarding optimization of length of rights or the technical scope of patents, the exploitation of licenses and the corporate management of intellectual property. This field also contains papers related to open innovation, globalization and patents. It is termed "research related to technological management

Table 2 CLUSTER STRUCTURE

Cluster name	# of papers	Ave. Year	Hub papers
C1 Patent Innovation & Econometrics	1120	2001.65	PATENT STATISTICS AS ECONOMIC INDICATORS—A SURVEY
C1-1 Patent as Indicator	315	2002.14	PATENT STATISTICS AS ECONOMIC INDICATORS—A SURVEY
C1-2 Patent Value	290	2002.09	A PENNY FOR YOUR QUOTES—PATENT CITATIONS AND THE VALUE OF INNOVATIONS
C1-3 Science Linkage	246	2000.64	THE INCREASING LINKAGE BETWEEN US TECHNOLOGY AND PUBLIC SCIENCE
C1-4 Strategy & Technology	117	2000.66	TRADE IN IDEAS—PATENTING AND PRODUCTIVITY IN THE OECD
C1-5 Market Value & Patent	48	2001.92	MARKET VALUE, R-AND-D, AND PATENTS
C2 Institution & Legal System	902	1999.80	ON THE COMPLEX ECONOMICS OF PATENT SCOPE
C2-1 IP Law Policy (Patent)	344	1999.40	ON THE COMPLEX ECONOMICS OF PATENT SCOPE
C2-2 IP Law Policy (Copyright)	287	2001.52	A PROPERTY RIGHT IN SELF-EXPRESSION—EQUALITY AND INDIVIDUALISM IN THE NATURAL LAW OF INTELLECTUAL PROPERTY
C2-3 Information Security & IP Law	135	2000.48	LEGAL HYBRIDS BETWEEN THE PATENT AND COPYRIGHT PARADIGMS
C2-4 Pharmaceutical Patent	38	1992.97	PLANTS, POVERTY, AND PHARMACEUTICAL PATENTS
C2-5 IP for IT	28	1991.57	CREATING A NEW KIND OF INTELLECTUAL PROPERTY—APPLYING THE LESSONS OF THE CHIP LAW TO COMPUTER-PROGRAMS
C3 Technology Management & Patent	641	1982.50	INNOVATION, IMITATION, AND INTELLECTUAL PROPERTY-RIGHTS
C3-1 IP in Global Economics	151	2001.77	INNOVATION, IMITATION, AND INTELLECTUAL PROPERTY-RIGHTS
C3-2 Optimal Patent Design	145	2000.46	OPTIMAL PATENT LENGTH AND BREADTH
C3-3 IP Piracy Matter	139	2001.02	THE INTERTEMPORAL, CONSEQUENCES OF UNAUTHORIZED REPRODUCTION OF INTELLECTUAL PROPERTY
C3-4 Patent Races	57	2000.54	A MODEL OF GROWTH THROUGH CREATIVE DESTRUCTION
C3-5 Protection & Exploitation	47	1997.21	IMITATION COSTS AND PATENTS—AN EMPIRICAL-STUDY
C4 Academic Activities & Patent	287	2002.61	THE GROWTH OF PATENTING AND LICENSING BY US UNIVERSITIES : AN ASSESSMENT OF THE EFFECTS OF THE BAYH-DOLE ACT OF 1980
C4-1 Univ. Technology & Licensing	69	2004.22	THE GROWTH OF PATENTING AND LICENSING BY US UNIVERSITIES : AN ASSESSMENT OF THE EFFECTS OF THE BAYH-DOLE ACT OF 1980
C4-2 Life-Science & Patent	54	1999.31	UNIVERSITIES AND THE MARKER FOR INTELLECTUAL PROPERTY IN THE LIFE SCIENCES
C4-3 Effect by R&D of Univ.	34	2003.62	PUTTING PATENTS IN CONTEXT : EXPLORING KNOWLEDGE TRANSFER FROM MIT
C4-4 Technology Transfer	30	2003.30	TECHNOLOGY TRANSFER AND PUBLIC POLICY : A REVIEW OF RESEARCH AND THEORY
C4-5 Patents & Commons	22	2005.39	WITHHOLDING RESEARCH RESULTS IN ACADEMIC LIFE SCIENCE—EVIDENCE FROM A NATIONAL SURVEY OF FACULTY
C5 Patent Meta-information	234	1982.01	ONLINE PATENT SEARCHING—THE REALITIES
C5-1 IP History & Culture	33	1984.64	UNITED-STATES PATENT OFFICE RECORDS AS SOURCES FOR THE HISTORY OF INVENTION AND TECHNOLOGICAL PROPERTY
C5-2 Patent Searching	32	1987.72	ONLINE PATENT SEARCHING—THE REALITIES
C5-3 Leterature (Chemical)	31	1979.45	CHEMICAL-ABSTRACTS AS A PATENT REFERENCE TOOL
C5-4 Patent Documentation	27	1968.81	PATENT CITATION INDEXING AND NOTIONS OF NOVELTY SIMILARITY AND RELEVANCE
C5-5 European Patent	25	1987.92	LEGAL MONOPOLY IN LIBERAL ENGLAND—THE PATENT CONTROVERSY IN THE MID-19TH CENTURY

and patent".

C4 : Academic Activities and Patent

This cluster includes many papers regarding the relationship of intellectual property and academic activities at universities. Key topics include effect by university R&D, technology transfer and licensing from universities, commercialization of university developed technologies, university related life science patent and scientific commons. The principal journals are *Research Policy* and *Scientometrics*. The oldest publication date for a paper is 1984 and it can be seen that papers have been published after the enactment of the Bayh-Dole Act (1980). Thus, overall it can be seen to be a relatively new field and all of the sub-clusters have an average publication year of approximately 2000. It is termed "academic activities and patent."

C5 : Patent Meta-Information

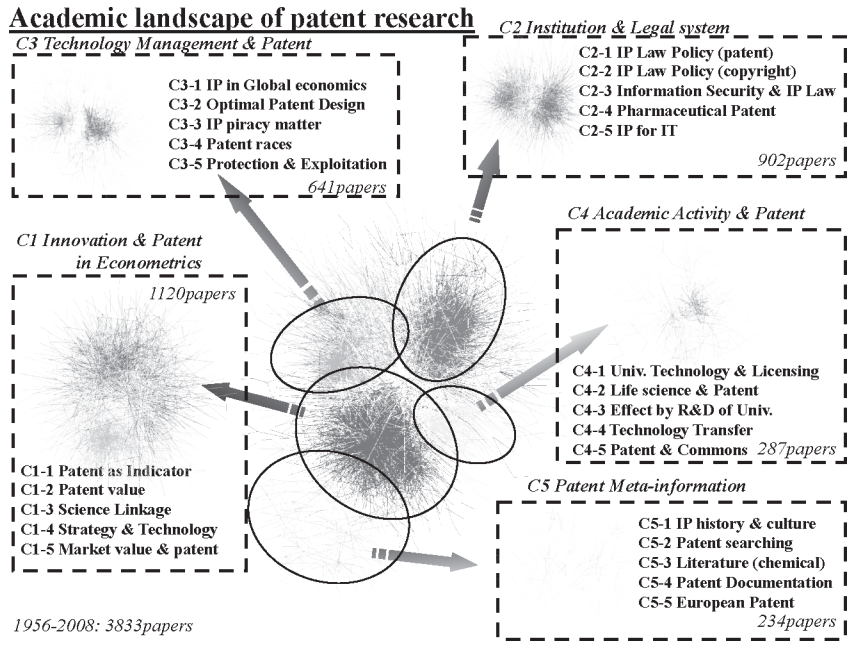
This field contains many papers discussing electronic libraries of patent publications, patent journal information, online search systems and economic indicators acquired from patent information using these sources. The principal journals are *J CHEM INFORM COMPUT SC or NACHR DOK*. Although there was a relatively active publication period from 1975 to 1980, this may be due to the fact that changes were made to the system to enable full-text searching after 1976 whereas records prior to 1975 can only be searched with respect to date, patent number or patent classification. This field is termed "research related to patent meta-information."

When the same method was used to further categorize these five clusters into five sub-clusters, a landscape was created in the form of a layered structure. A landscape of the academic field related to the intellectual property field was created by verifying the total of 30 clusters comprising 5 clusters and 25 sub-clusters. Table 2 shows the layered structure and characteristics of the principal 5 clusters. Hub papers are the most frequently cited papers within a sub-cluster.

B. Visualization

Fig. 3 is a schematic map of the overall clusters.

Fig. 3 Academic landscape of patent and innovation research



The horizontal and vertical dimensions of the figure do not have any meaning. Since the figure is created using a spring model, strongly linked clusters are disposed in proximity not only by document unit but also by cluster unit.

As shown by the figures, C1 (Patent Innovation & Econometrics) and C3 (Technology Management and Patent) are in the center of the citation relationship. On the other hand, there is a valley between the academic fields of C1 (Patent Innovation & Econometrics) and C3 (Technology Management and Patent), and C2 (Institution & Legal System) and C5 (Patent Meta-Information). C4 (Academic Activities and Patent) is positioned slightly separated in the overall arrangement. In contrast, C1 (Patent Innovation & Econometrics) and C5 (Patent Meta-Information) are adjacent to each other and can be viewed as research areas which mutually interact. In reality, the patent journal information in C5 is essential for C1 research.

The relationship between the research areas is clear from the visualization and a number of valleys are evident between the research domains. These valleys demonstrate insufficient mutual recognition or exchange. In particular, there is a necessity for fusion of legal system research centering of research into the legal system and econometric approaches or information science.

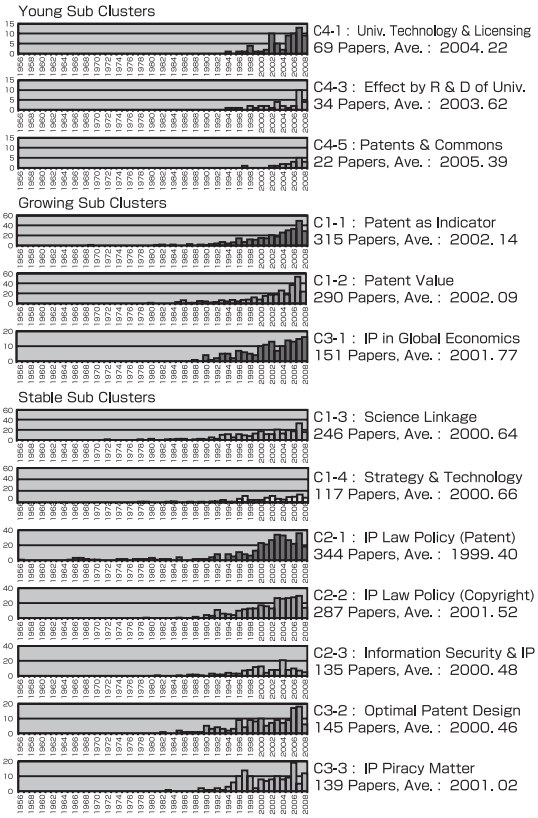
C. Time Series Analysis

The application of time series analysis enabled separation of the sub-clusters into young, emerging domains, domains undergoing rapid growth, domains characterized by stable research and domains with stagnation of research. A representative research example is shown in Fig. 4.

The most recent cluster of the 5 principal clusters and 25 sub-clusters is C4-5 : Patents & Commons. The earliest publication of a paper classified into this sub-cluster was in 1997. The average year of publication in this cluster is 2005.4. This sub-cluster is a document group in which debate is conducted regarding scientific commons, the merits of patenting research results at universities. Since the number of papers is still small, this cluster is categorized as a "young cluster." In the same manner, C4-1 : Univ. Technology & Licensing (average year of publication : 2004.2) and C4-3 : Effect by R&D (average year of publication 2003.6) are young clusters.

A representative example of the document group undergoing rapid growth in recent years is C1-1 : Patent as Indicator (average year of publication 2002.1). Mid 1990s, although there were less than seven publications per annum, by 2004, this had grown to more than 20 publications. Other domains undergoing similar growth are C1-2 : Patent value (average year of publication 2002.1) and C3-1 : IP in Global Economics (average year of publication 2001.8). All of these sub-clusters have an average year of publication which is later than 2000. This fact demonstrates

Fig. 4 Time series analysis



that in these domains the amount of academic knowledge in the 7 years from 2001 is approximately equal to the previous 45 years. Domains characterized by stable research when taking into account trends in time series development on an annual basis are C1-3 : Science Linkage (average year of publication 2000.6), C1-4 : Strategy and technology (average year of publication 2000.7), C2-1 : IP law policy in patents (average year of publication 1999.4), C2-2 : IP law policy in copyrights (average year of publication 2001.5) C2-3 : Information security and IP Law (average year of publication 2000.5), C3-2 : Optimal patent design (average year of publication 2000.5) and C3-3 : IP piracy matter (average year of publication 2001.0). Domains characterized by stagnation of research correspond to all the C5 sub-clusters. The average year of publication is extremely old in comparison with other domains and in particular, the average year of publication for C5-4 : Patent Documentation is 1968.

IV. DISCUSSION

Our analyses indicate that patent research can be divided into five clusters and 25 sub-clusters by content. We counted the number of research papers and calculated the average publication year of research papers by cluster and by year. Values indicate the accumulation of knowledge and the growth rate of patent research by academic field. We also created an academic landscape depicting the distance between clusters by content.

In general, although we search for research papers of our interest by query and journal name, this search method may not be effective in case the query is not present in the author keywords or in the abstract of research papers. Searches become even more difficult when different academic fields use different words to imply the same meaning. Moreover, a sub-cluster with similar contents may also contain research papers from a number of different journals. In fact, we discovered 104 journal names from research papers in C-1 and 117 journal names from research papers in C-2. Therefore, using journal names does not work effectively for comprehensively extracting research papers of our interest. To resolve the issue, we clustered research topics with similar contents by using citation information. We would like to demonstrate that such approach allows for an accurate and comprehensive extraction of knowledge, even in the domain of intellectual property rights and innovations.

Designing and reforming intellectual property rights have generated various kind of discussion. Examples of popular issues include patent scope and length, balancing patent protection and use of patent rights, patent value, and patent quality. With respect to patent quality, discussion focused on legal stability recently. Many discussions have been carried out on patent scope and length in two steadily growing sub-clusters of intellectual property studies : C1-2 (Patent Value) and C3-2 (Optimal Patent Design). Topics include “complex economics of patent scope,” “optimal patent length and breadth,” “patent rights and cost of imitation,” and “patent scope and innovation in the software Industry.” Research papers that discuss balancing patent protection and use of patent rights are included in C3-2 (Optimal Patent Design) and C3-5 (Protection and Exploitation). Topics include “optimal patent with compulsory licensing,” “imitation cost and patents,” “limiting patentee’s market power without reducing innovation incentives,” and “future development and effects of pharmaceutical drugs in developing countries.” Research papers discussing patent value are included in C1-2 (Patent Value) and C1-5 (Market Value and Patent), and are almost non-existent in other clusters. Patent values are typically measured by patent backward citations.

On the other hand, we cannot easily identify research papers directly addressing patent quality issues, which become increasingly important topics recently. With respect to legal quality issues, we searched in C2 (Institution and Legal System) by focusing on frequently cited papers and discovered only small number

of papers. This discovery explains why the topic did not form a sub-cluster despite being an important issue.

The aforementioned results revealed that we can accurately and comprehensively search for journal papers of our interest by using a specific keyword listed in a domain, rather than methods using query or journal names.

Next, we will examine whether our search method is effective in identifying papers related to new subjects that are becoming increasingly popular in intellectual property reform issues. Compared to existing subjects that have been studied for years, new subjects have attracted relatively small number of studies and have not established a knowledge domain. Therefore, extraction of papers on new subjects is considered relatively difficult in general. Since policy discussions and academic activities influence each other, it is understood that there is a correlation between their temporal quantitative variations. Therefore, information on the average publication year may lead us to the right direction in finding related research papers as well as sub-cluster names. Among various existing policy agendas, we would like to discuss "Intellectual Property Plan 2010" by the Japanese government as an example. Devised by the Cabinet Office, this plan is the highest-ranked policy agenda for intellectual property comprising three strategies. Among them, Strategy 3, "How to Promote Intellectual Property across Industries," corresponds to our analyses on research papers. The other two strategies cover contents and international standards. Strategy 3 lists four objectives :

1. Promoting intellectual property in small and medium ventures and regional communities.
2. Achieving the best industry-academia-government collaboration in the world.
3. Improving infrastructure to support open innovations and accelerate overall innovations.
4. Setting an international intellectual property system that allows us to efficiently file and protect patents at low cost.

As for Objective 2, simply looking at the cluster names allows us to identify many research papers on industry-academia-government collaboration in C4-1 ～C4-4 and C1-3. These clusters are further split into sub-clusters by key topics such as licensing, life-science, effect by R&D, technology transfer, and science linkage. Among those sub-clusters, C4-1, C4-3, and C4-4 contain various recently published papers. Based on the commonly known relationship between innovative drug development and universities, we also searched in C2-4 (Pharmaceutical patent) for research papers on university-industry research collaboration and found many. Topics include "commercialization of university-developed biomedical technologies," and "optimal control over intellectual property rights by faculties." Our investigation found that a majority of research papers with highest citation frequency are included in these sub-clusters. In order for an effective prior art investigation to take place in response to the growth of university-industry research collaboration, the development of a seamless search system is underway. The seamless search system allows simultaneous searching for patents, academic papers and other non-patent publications, and ultimately identifies connections between patents and academic studies or other publications by content. Research papers discussing patent search exist in C5 (Patent Meta-information) and the average publication year is very old. This elucidates the fact that academic studies on seamless search in intellectual property have stagnated despite the recent advancement of text mining and link mining approaches. The concept of open innovation forms a part of Objective 3 and is included in C4-1, C4-4, and C4-5 (Patent & Commons) based on sub-cluster names. The topics include "market economy and scientific commons" and "the dynamics of commercialization of scientific knowledge." C4-5 has the latest average publication year, but includes only 22 papers. Research papers on commons or collective action show also in C1 when examining fre-

quently cited papers.

Many research papers on International Intellectual Property System exist in C3-1(IP in Global Economics). Topics include an empirical study that examines how differences in the level of patent protection affect trading and investments. C3-1 has the latest average publication year among sub-clusters in C3. After investigating other sub-clusters, it was found that C1-1 also contains some research papers on international technology diffusion. These research papers, however, do not discuss intellectual property system or customs. Instead, they analyze the characteristics and changes of innovation pattern.

On the other hand, we are unable to search for research papers on small and medium ventures or regional communities by sub-cluster name or average publication year. On investigating journal papers with highest citation frequency, it was found that many papers on regional business and innovation environments were contained in C1-1. Topics included "geographic localization of innovation", "regional network and knowledge spillover." These papers discuss the characteristic and evolvement of innovations, thus forming the background of intellectual property system. However, few research papers discuss intellectual property system specifically.

Sub-clusters discussing recent institutional issues are either growing in size or are considered new. By using cluster names and average publication years, we are able to accurately and comprehensively search for papers that deal with even new issues if they discuss in depth issues in the intellectual property system as well as in technology management. Our research also found that a similar search method is not effective in identifying research papers on innovation activity analyses in C1-1, which uses patent as indicators. We believe this is because authors in this academic field tend to cite papers discussing specified institutional issues and technology management topics rather than research papers analyzing innovation trends and characteristics.

Overall, our findings prove that an academic landscape allows us to accurately and comprehensively detect papers discussing institutional issues in the area of intellectual property rights and innovations.

V. CONCLUSION

The results of the academic landscape demonstrates that in the domain of Intellectual Property Rights and Innovation, overall there are 9,458 papers and that 3,833 important papers exist even when examining only the largest connected component. Approximately, half of those papers were published after 2000 and are therefore considered to be research papers reflecting the recent changes in the innovation environment. In the component, we identified 5 major clusters and 25 sub-clusters of knowledge domain. We also specified hub papers as frequently cited papers within each sub-cluster.

Then, we searched for research papers discussing central issues by using the following information : research area names provided in clusters and sub-clusters, the average publication years of research papers in clusters and sub-clusters, and frequently cited papers within sub-clusters. As a result, our search method detected a set of related research papers more accurately and more thoroughly than the search method using query and journal names. Our search method also worked somewhat effectively for finding research papers discussing new issues, which are relatively difficult to find. We were able to retrieve a large number of research papers across the board in the following areas : Scope and length, balancing protection and use of rights, patent value, and industry-academia-government collaboration. On the other hand, we faced difficulty finding papers providing information on institutional issues such as intellectual property in small and medium ventures and regional communities, and legal quality of patents because such topics have not yet structured or split into sub-clusters.

As shown in Table 1, Patent and Innovation Research is a multi-disciplinary academic field where a number of different journals discuss similar topics using different notations. Such nature, therefore, prevents us from identifying related research papers by keyword and journal names. Our search method has successfully demonstrated that by analyzing frequently cited papers, major journals of each cluster, and average publication year, it is possible retrieve a set of related research papers without missing an important one. This also suggests that our research method helps minimize the risk of policy assessments being influenced by specific marginal academic opinions. It has been demonstrated that the limitations on implementation of knowledge caused by the recent "knowledge explosion" can be overcome to a certain extent.

In order to complement the issue of difficulty in identifying citation analysis as sub-clusters, we will consider using full-text information together with our research method in the future to extract research papers by content.

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NOTE

1 Research conducted by Hashimoto et al. (2009) using the same database showed that one of the sub-clusters of "Innovation Fundamentals" which is the largest research domain in innovation studies is "intellectual property rights" and contains 701 documents.

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