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Study on Data Analysis Methods for Supporting Road Mapping Approach in Academia

By

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Contents

List of Figures

List of Tables

Abstract

This dissertation is a report on data analysis methods for supporting Road Mapping Approach (RMA) in academia. Recently Road Mapping sees its application as a strategic planning tool for research and as a methodology for knowledge management and supporting knowledge creation in academia. This study first focused on relation among scientific research of technology creation in academia, technology development in industry and policy making in government to make clear applications of RMA in academia for research of technology creation, in industry for technology development and in government for policy making, then we addressed ontology and triple helix analysis for supporting Road Mapping Approach (RMA) to help researchers (in scientific research fields such as materials science, physics science and chemistry science) find new interests, new research topics by answering three questions: where are you, where do you want to go and how to get there, and also promote cooperation on technology development among industry, government and academia. After carrying a case-study (support RMA in a specific research field of fuel-cells technology development) out for making sure what kinds of support researchers need and how to support them for RMA in a specific research field based on a framework designed, a computer-based support system was proposed on this study.

(This study was a project under the JAIST 21st COE program)

Keywords

Road Mapping Approach (RMA), scientific research, triple helix of academia-industry-government, ontology extraction, network, similarity measure and support system

研究概要

本学位論文は大学におけるロードマッピングを支援するためのデータ分析法に関する研究のレポートである。ロードマッピングは技術経営（MOT）の重要なマネジメントツールとして認識され、最近急速に関心を呼んでいる。近年のロードマッピングは戦略的な計画を立てるツールとしてだけではなく知識マネジメントと知識クリエションの支援ツールとしてもよく使われている。多層構造を有し、市場、製品、技術開発、コア・コンピタンスなどの相互関係と発展のシナリオ化に特徴があり、方法論的にも進歩している。本研究では、まず、産・学・官におけるロードマッピングの相違を取り上げ、技術開発に関する産・学・官連携の現状を明らかにした。次に、産・官におけるロードマッピングと異なり、大学の技術系研究者（特に材料研究科、物理研究科、化学研究科など）が新しい研究課題また新しい方向を決める時のロードマッピングを支援するため、コンピュータベースのデータ分析とその結果の応用のフレームワークをデザインした。その後に、大学における輸送用燃料電池技術開発研究ロードマッピングを支援する事例研究を行った。最後に、事例研究から判明した大学におけるロードマッピングを支援するためのデータ分析とその結果の応用などを参考にし、支援システムを構築した。

（本研究は JAIST における COE プログラムの下で行った）

ケーワード

ロードマッピングの支援、技術開発に関する科学研究、産・学・官連携、オントロジの抽出、ネットワーク、相似性判断、支援システム

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I sincerely thank all my friends and colleagues who always supported me in times of need, and also appreciate to stuffs from COE center (JAIST) in making a wonderful environment and giving so many chances of workshops and conferences.

Finally I am indebted to my family for their forever affection, patience and encouragement when all the time I needed through all my years school.

Chapter 1

Introduction

This dissertation is a report on a study of data analysis methods for supporting Road Mapping Approach (RMA) in academia. This study first focused on relation among scientific research of technology creation in academia, technology development in industry and policy making in government and the triple helix of Academia-Industry-Government. Then addressed ontology and triple helix analysis to support scientific researchers in academia who are doing scientific research in a research fields such as material science, information science, etc., help researchers find new interests, new research topics by answering there questions: where are you, where do you want to go and how to get there, and also promote cooperation on technology development among industry, government and academia. After doing a case-study out for making sure what kinds of support researchers need and how to support them in a specific research field, a computer-based RMA was proposed in this study.

(This study was a project under the JAIST 21st COE program)

1.1 What is Road Mapping Approach (RMA)

Motorola Inc. first introduced the concept of a 'roadmap' in the 1970s as a kind of strategic planning tool. Today the term roadmap is used liberally by planners in many different types of communities. It appears to have a multiplicity of meanings, and is used in a wide variety of contexts: by commercial organizations, industry associations, governments, and academia, (see Kostoff and Schaller 2001). Perhaps the most widely accepted definition of a roadmap was given by Robert Galvin, former CEO of Motorola (see Galvin 1998):

"A roadmap is an extended look at the future of a chosen field of inquiry composed from the collective knowledge and imagination of the brightest drivers of change in that field".

Road Mapping, the process of making roadmaps, is also characterized as follow (see Bennett 2005):

"a disciplined process for identifying the activities and schedules necessary to manage technical (and other) risks and uncertainties associated with solving complex problems".

This study addresses some data analysis methods for supporting Road Mapping for scientific researchers in academia when they want to find new interests, new research topics of technology creation which are related what they are doing now.

1.2 What is Triple Helix

The "triple helix" is a spiral model of innovation that captures multiple reciprocal relationships at different points in the process of knowledge capitalization. Etzkowitz & Leydesdorff use the notion of the triple helix of the nation state, academia and industry to explain innovation, the development of new technology and knowledge transfer (see Etzkowitz and Leydesdorff 2000). They argue that:
"The Triple Helix overlay provides a model at the level of social structure as a historically emerging structure for the production of scientific knowledge"

This study put forward the idea of triple helix for data collecting and network constructing to help researchers make a crystal picture for their assignments in a specific research field.

1.3 What is ontology

In both computer science and information science, an ontology is a data model that represents a set of concepts within a domain, and the relationships between those concepts. It is used to reason about the objects within that domain. In philosophy, ontology is the study of being or existence. It seeks to describe or posit the basic categories and relationships of being or existence to define entities and types of entities within its framework. Ontology can be said to study conceptions of reality (see Quine 1969, Kriple 1963 1980, and Guarino 1995,1998).

This study introduces four-level ontology extraction as the first step of data analysis of data collected from industry, government and academia.

1.4 Contribution

RMA sees its application in academia for research and as a methodology for knowledge management and supporting knowledge creation. Also recently more and more technology development projects are done successfully by triple helix of Academia-Industry-Government both in industry and government. The basic idea of this study is to introduce the idea of ontology and triple helix analysis to support RMA for scientific researchers' work on technology creation in academia, especially when they are considering about new research topics and new interests which are related to what they are doing. The major contributions presented in this dissertation are summarized as follows:

- Reviewing resemblance and distinction of application between RMA in industry (government) and academia.
- Introduce a new idea for design RMA support for scientific researchers in academia.
- Development of a computer-based RMA support and a real case for

evaluation

1.5 Outline

The rest of this dissertation is organized as follows:

In Chapter 2, we show RMA in industry and government for technology development and some real cases. Then we introduce applications of RMA in academia.

In Chapter 3, we mention applications of RMA support with the idea of triple helix and ontology for scientific researchers in academia based on the interview with scientific researchers from 3 universities. Then framework of a computer-based RMA support will be presented at the end of this chapter.

In Chapter 4, we report on a case-study for answering why, when, what and how to support RMA for scientific researchers designed in chapter 3. And also present some data analysis methods which are addressed in this approach in detailed.

In Chapter 5, we present the lessons learned from a case-study and functions design for a Road Mapping Support System including its evaluation.

In Chapter 6, the last chapter, the contributions and achievements of this dissertation are summarized. Conclusions and opportunities for further search are also presented.

Chapter 2

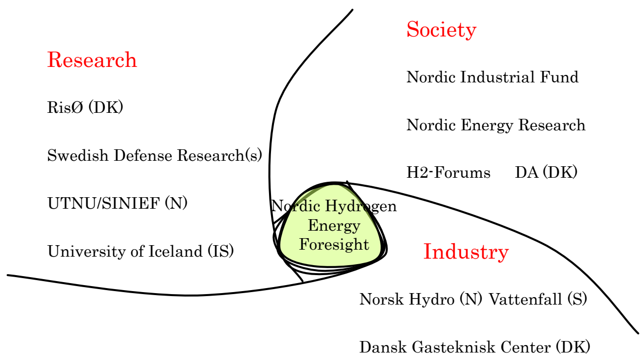
RMA in industry and government and its applications in academia

In this chapter we first explain the problem addressed in this study from the present conditions of cooperation among Academia, Industry and Government. Then we present RMA in industry and government for technology development and some real cases. At the end of the chapter we introduce RMA applications and supports in academia.

2.1 Introduction

2.1.1 Cooperation among Academia-Industry-Government for technology development

Recently, more and more technology development projects have been done successfully by cooperation among academia, industry and government especially in information science, environmental science and aeronautical science. For example, in recent years, increasing concerns about energy security and environmental issues encourage the society to look for new technologies and fuel option. But what will the future energy system really like? Will it be a hydrogen-based system? If it will, how long will it take for the transition from current energy systems to the future energy system? The answers to those questions depend on the triple helix of academia-industry-government relations, which is thought to be a key component of any national or regional innovation strategy (see Etzkowitz & Leydesdorff 1997). If we look at those international programs of the UN (United Nations), the OECD (Organization for Economic Co-operation and Development), the World Bank and the EU (European Union), most of them rely on academia-industry-government relations to achieve their goals (see Gibbons et al. 1994). Figure 2.1 gives an example of a triple helix of academia-industry-government, describing the Nordic Hydrogen Energy Foresight- a research project involving 16 partner organizations, including R&D institutes, energy companies and industry, from the five Nordic countries- Denmark, Finland, Iceland, Norway and Sweden (see Nordic H2 Energy Foresight 2005)



Source: Nordic H2 Energy Foresight, summary report 2005

Fig 2.1 An example of a triple helix of academia-industry-government

After exploring these cases, we found some problems in this cooperation as shown in Figure 2.2:

In government, policy makers consider about how to support technology development based on the reports from industry and academia, then they well give support such as subsidy to the projects which they let academia and industry do. In industry, support from the technology development and marketing sections will help technology developers' work to obtain patents. Accomplishment in books and papers published by researchers in academia can also help technology developers. But after patents granted, it will be protected as business secrets.

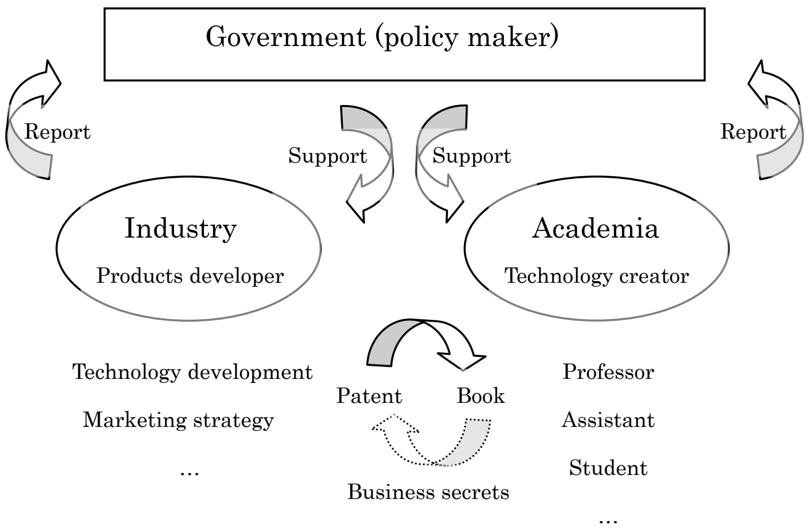


Fig 2.2 Cooperation among Academia-Industry-Government

The problem we addressed in this study is for researchers in academia who are doing scientific research about technology creation, how they can get and analyze the data and information they want and where they can get such support from.

2.1.2 Roadmap and Road Mapping

The roots of applying the concept of a roadmap as a strategic planning tool can be tracked back to the late 1970s and early 1980s, when Motorola and Corning developed systematic Road Mapping Approach (see Probert and Radnor 2003). The Motorola approach has been more widely recognized (see Phaal et al. 2004), leading the spread of road mapping practice in Philips (see Groenveld 1997), Lucent Technologies (see Albright and Kappel 2003), etc. Therefore, it is widely believed that Motorola was the original creator and user of roadmaps (see Probert and Radnor 2003; Willyard and McClees 1987). So the most widely accepted definition of a roadmap was given by Robert Galvin, former CEO of Motorola (see Galvin 1998):

> *A roadmap is an extended look at the future of a chosen field of inquiry composed from the collective knowledge and imagination of the brightest drivers of change in that field.*

The definition of road mapping was given by Bennett R. Idaho National Engineering and Environmental Laboratory, INEEL in 2005:

Road mapping is a disciplined process for identifying the activities and schedules necessary to manage technical (and other) risks and uncertainties associated with solving a complex problem

Thus, a roadmap is not only a plan, but also a vision of future research or action. But this, in a sense, is self-evident: Every plan is a vision, only some might have not enough vision. Thus, we might as well understand road mapping as vision-enhanced planning.

Because the use of the roadmap concept has spread today far beyond its original field of strategic planning for technology and development, we often use the term *technology road mapping* in the field of management of technology (MOT); those roadmaps are commonly called technology roadmaps. Galvin (1998) pointed out that "roadmaps are working now in industry and they are beginning to gain a stronghold in science." Indeed, in recent years road mapping has been increasingly used by governments and diverse consortia to support sector-level research collaboration and decision making as well as to plan technological and scientific development, in both national and international contexts. The U.S. Department of Energy initiated a National Hydrogen Vision and Roadmap process, and published a National Hydrogen Energy Roadmap in 2002 which explored the wide range of activities, including scientific development, required to realize the potential of hydrogen technologies in solving issues of energy security, diversity, and environmental needs in the USA (see United States Department of Energy 2002). NASA also utilized road mapping to develop a technological and scientific development plan (see NASA 1998). An example of the efforts in an international context is the International Technology Roadmap for Semiconductors, developed and updated jointly by the European Semiconductor Industry Association, Japan Advanced Electrics, and Information Technology Industries Association, Korea Semiconductor Industry Association, Taiwan Semiconductor Industry Association, and the Semiconductor Industry Association (see ITRS 2004). The European Union routinely uses road mapping as one of its tools for preparing subsequent Framework Programs for international research and development.

Today the term "roadmap" is used liberally by planners in many different types of communities. It appears to have a multiplicity of meanings, and is used in a wide variety of contexts: by commercial organizations, industry associations, governments, and academia. Therefore, the basic idea in this study is to introduce RMA into academia to support scientific researchers' technology creation. The first step, we will make clear what are the similar and dissimilar points between RMA in industry (government) and academia.

2.2 RMA in Industry-Government and its applications and supports in academia

2.2.1 RMA in industry

RMA in industry is a way to identify future product or service needs, map them onto technology alternatives, and develop plans to ensure the required technologies will be available when needed (see Kenichi 2003). In this context, companies must use effective tools to plan their future. This is considered a part of technology management (MOT) in industry; in short, RMA is a way to do forecasting and planning when supporting technology development in industry (see Galvin 1998 and Toshiya 1996). A road mapping process has three general steps in industry (see Robert 1988 and Report of symposium for industry-government-university cooperation 2003):

- Decide topics of technology development.
- Share opinions and discuss to get initial conclusions
- Feedback and discuss further to get final conclusions.

The roadmap document in industry, resulting from a technology road mapping process, is the first step toward consensus on a number of topics (see Salo 2003 and Saritas 2004):

- a vision at a set time in the future;
- what new types of products (or services) will be required;
- the enabling technologies to create those products
- the feasibility of creating the needed technologies

- the technological alternatives for achieving the needed technologies;
- how to address these technology needs through R&D

The principal functions of roadmaps in industry have been representation, communication, planning, coordination, forecasting and selection (see Henderson 1998 and Robert 1988). The roadmap document addresses (see Martin 2003):

- the role of an industry's suppliers in creating the desired future
- human resources needs
- governmental and non-governmental barriers
- other topics

We collected data and information from 20 companies and we found that they use RMA with the purpose of creating more benefit and service from technology development. Four aspects of road mapping can be distinguished (see Martin 2003):

- To present a concept of the needs of technology and market;
- To forecast the trend of technology;
- To provide the data and information about technology and marketing strategy;
- To support decision makers do technology development.

Technology development in industry is a group activity. Usually, there are several groups for one topic of technology development. First, in each group they will decide their own sub-topic of technology development. Then every member will recount their opinions and grounds, every member will change his or her own opinion. At last they will get a consensus conclusion (with which every member agrees). They also invite specialists from different fields to make discussion and workshop getting their opinions. Figure 2.3 and 2.4 shows technology roadmap of robots development from TOYOTA and OLYMPUS in a conference held in Tokyo university on 4thAugust 2006 (see report of project "IRT in the future 10 years")

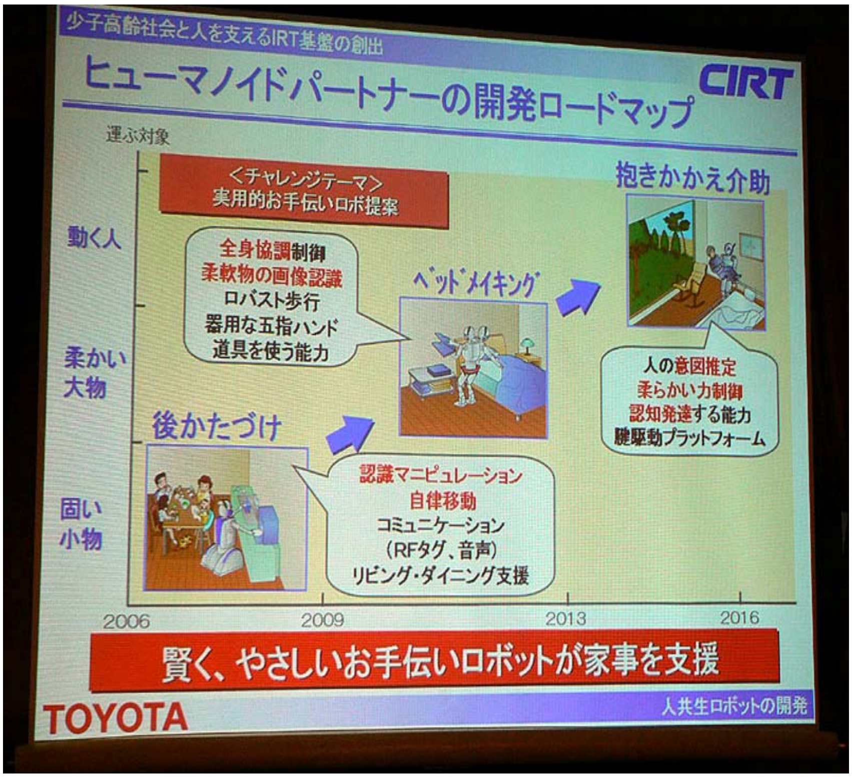


Fig 2.3 Roadmap of Robot Development from TOYOTA

(from:http://robot.watch.impress.co.jp/cda/news/2006/08/07/115.html)

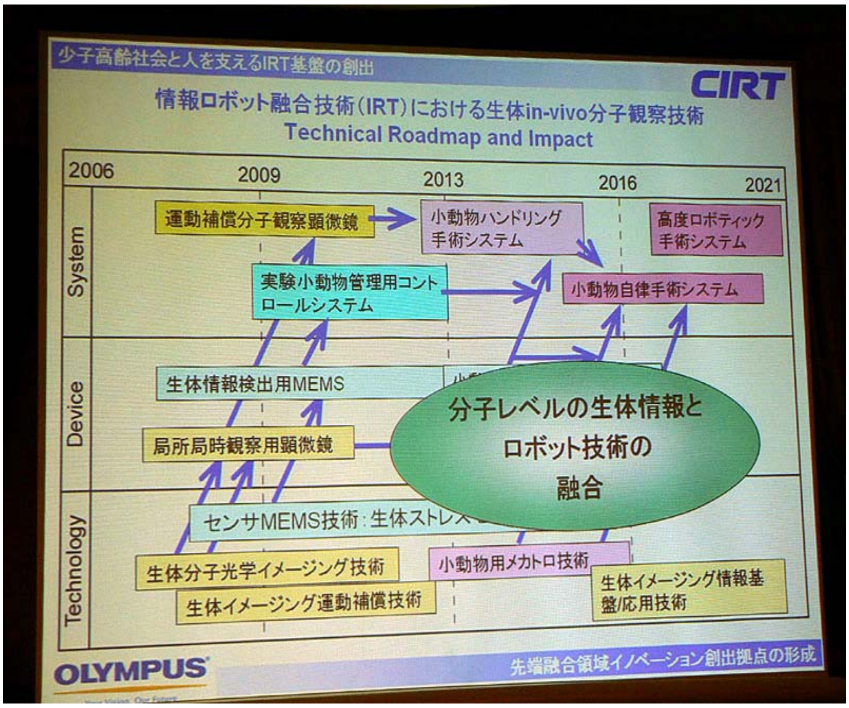


Fig 2.4 Roadmap of Robot Development from OLYMPUS

(from:http://robot.watch.impress.co.jp/cda/news/2006/08/07/115.html)

We can get a conclusion that in industry, RMA is used for technology development and product innovation as a strategic planning tool.

2.2.2 RMA in government

RMA is also used in government, with slightly different goals than in industry: that of deciding on what topics governmental support of research should be concentrated and how to coordinate governmental supported scientific research and technology creation. Industry and academia give government report for what have been done, what is the next plan, and what is the problem every year. Then government will decide that which kind of technology they will support in which kind of ways (See Australian department of industry, science and resources

2001).

The roadmap document in industry, resulting from a technology road mapping process, consensus on a number of topics (see Salo 2003 and Saritas 2004):

- To keep the balance between new needs and seeds
- To present the roles of technology development and social change
- To get and analyze data and information of projects about technology development and creation
- To address human resources in a specific research field
- To decide how to support technology development and creation

The principal functions of roadmaps in government have been representation, coordination, and planning (see Henderson 1998 and Robert 1988). A road mapping process has three general steps in government (see Robert 1988 and Report of symposium for industry-government-university cooperation 2003):

- Discuss about the report and research plan from industry and academia.
- Find cooperative projects of technology development and creation.
- Decide how to support such projects to get valuable results.

Figure 2.5 shows a technology roadmap for CO_2 decreasing projects. You can find other roadmaps in different research field for different technology development (see report of NEDO 2006)

We can get a conclusion that in government, RMA is used for pull and push technology development and creation projects as a planning tool.

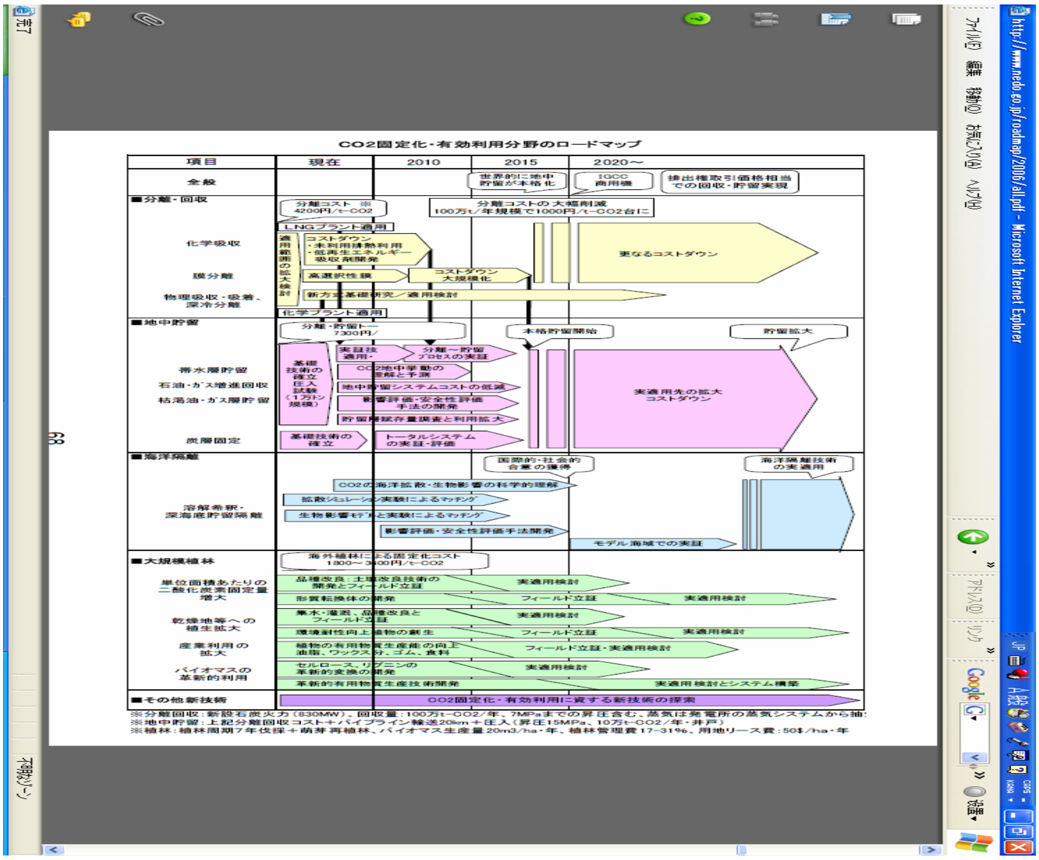


Fig 2.5 Example of Roadmap from Government

(http://www.nedo.go.jp/roadmap/2006/all.pdf)

2.2.3 Applications and supports of RMA in academia

Road mapping has been also adopted in academia. Some academic institutions developed roadmaps as strategic research plans; for example, the Berkeley Laboratory at the University of California prepared and published a research roadmap for its High-Performance

Data Centers (see Tschudi et al. 2002). Ma et al. have argued that developing personal academic research roadmaps can be very helpful for individual researchers (see Ma and Nakamori 2004). Usually, there are many linkages between development of industrial technologies and scientific research (see Narin et al. 1997). Moreover, the causation between science and technology runs both ways; the causation from technology to science is much more powerful than is generally perceived (see Rosenberg 2004 and Wierzbicki 2005). For those reasons, we will use the term science and technology roadmaps or S&T roadmaps in short, introduced by Kostoff and Schaller (see Kostoff and Schaller 2001).

Roadmaps can mean different things to different people. They are developed for diverse purposes. Phaal et al. identified eight types of technology roadmaps in terms of the intended purpose(see Phaal 2004); Kostoff and Schaller summarized dozens of different applications of roadmaps presented in a technology road mapping workshop in 1998 and found that those applications covered a wide spectrum of uses including (see Kostoff and Schaller 2001):

- Science/research roadmap
- Cross-industry roadmap
- Industry roadmaps
- Technology roadmaps
- Product roadmaps

- Product–technology roadmaps
- Project or issue roadmaps

Roadmaps can have also different formats. Phaal et al. identified the following eight types of roadmap according to their graphical formats (see Phaal 2004):

- Multiple layers

This is the most common technology roadmap format, comprised of a number of layers (and sub layers), such as technology, product, and market. A Philips-type roadmap could be an example of this format (see Groenveld 1997).

- Bars

Many roadmaps are expressed in the form of a set of bars, for each layer or sub layer. A Motorola-type roadmap is the classic example of this format (see Willyard and McClees 1987).

- Tables

In some cases, entire roadmaps, or layers within the roadmap, are expressed as tables (time vs. performance or requirements). For example, the personal academic research roadmaps introduced in Ma and Nakamori are in this format (see Ma and Nakamori 2004).

- Graphs and plots

A roadmap can be expressed as a simple graph or a plot, typically one for each sub layer. Often, the plots employed are called experience curves, related to technology S-curves (see Grübler 1996).

- Pictorial representations

Some roadmaps use more creative pictorial representations to communicate technology integration and plans. Sometimes metaphors are used to support the objective (e.g., a picture of a tree can symbolically represent an environmental commitment). A Sharp-type roadmap could be an example of this format, (see ITRI 1998).

- Flow charts

A particular type of pictorial representation is the flow chart, which is typically used to relate objectives, actions, and outcomes. A NASA-type roadmap could be an example of this format, (see NASA 1998).

- Single layer

This form is a subset of the first type, focusing on a single layer of the multiple layer roadmap. The Motorola roadmap is an example of a single layer roadmap, focusing on the technological evolution associated with a product and its features (see Willyard and McClees 1987).

- Text

Some roadmaps are entirely or mostly text-based, describing the same issues that are included in more conventional graphical roadmaps which often have text-based reports associated with them. The National Hydrogen Energy Roadmap (see United States Department of Energy 2002) and the International Technology Roadmap for Semiconductors (see ITRS 2004) are examples of this format.

According to Australian Department of Industry, Science and Resources (see Australian department 2001), there are generally three approaches for making technology roadmaps

- Expert-based approach

A team of experts comes together to identify the structural relationships within the field and specify the quantitative and qualitative attributes of the roadmap.

- Workshop-based approach

This technique is used to engage a wider group of industry, research, academic, government, and other stakeholders, to draw on their knowledge and experiences.

- Computer-based approach

Large databases are scanned to identify relevant research, technology, engineering, and product areas. High-speed computers, intelligent algorithms, and other modeling tools can assist in estimating and quantifying the relative importance of these areas and in exploring their relationships to other fields. This approach is still in its infancy, as large textual databases and efficient information extracting computational approaches have only begun to emerge.

Of course, these three approaches are not mutually exclusive and not independent. For example, when the expert-based approach is applied to making roadmaps, it is usual to organize some workshops (through local or remote meetings), while computer, intelligent algorithms, etc. can be used to provide supplemental information and knowledge to experts. Thus, during the road mapping process, it is most likely that all three of these approaches are used, though one approach might be dominant. For example, Kostoff et al. developed a road mapping process which starts from identifying major contributory technical and managerial disciplines by text mining (literature-based discovery), followed by workshops in which experts participate (see Kostoff 2004). In practice, the road mapping process should be customized according to its objectives, the organizational culture, and other contextual aspects.

RMA support in academia

A new approach of RMA support for making personal academic research roadmaps by applying ideas of Interactive Planning (IP) was suggested by Ma (Ma 2006). The approach suggests the use of a process composed of six phases: forming groups; explanations from knowledge coordinators; descriptions of present situation; analysis of current status of every member and idealized design; research schedule and study schedule; and implementation and control. Another approach was suggested by Okutsu (Okutsu 2005), based upon the idea that students from science and engineering laboratories should be asked to manage their research, since they will have to do it in the future, whether in a academia or in industries. Therefore, ATRM (Academy Technology Road Map) was proposed to help researchers, including students, with their research planning in academic science and engineering laboratories. Both these two ideas aim to support students from scientific and engineering laboratories to develop their research proposals and research plans.

In this study, however, we support RMA in a slightly different way, because we concentrate the step before researchers make their roadmaps. When, what and how to support researchers (professors and students) in academia to make their research roadmaps? To help answer such questions we did an interview with scientific researchers and students from three different schools. Almost researchers have the same opinion such as:

- It is necessary to help researchers make research plans. But it is hard to say what future research topics will be, so it will be more useful to obtain some support helping researchers to find more valuable research topics and interests.
- Researchers can easily obtain a great quantity of data and information, but sorting through that data and information to get ideas, is not a trivial problem.
- General roadmap can give researchers a different perspective and an overview of the whole research field in a time dimension, but for researchers who are doing scientific research, time dimension is not sufficient. We need more detailed information about technologies, research topics, patents and other information such as subsidy from government and industry, etc. it will be an overview of whole research field in this time.
- General roadmap can not help us to know information about what

researchers in academia, industry and government doing now, about relationships among research topics, researchers, technology, scenarios. Such information would be useful for us to find potential cooperators.

They also had some good suggestions like:

- Researchers A (Knowledge Science, a project leader) who is majoring in model structuring said that we need support to help us manage a lab including student and their research.
- Researcher B (Information Science) whose major is related to network said RMA should be a computer-based approach, searching data and information what researchers want to know, networking researchers' relation and getting roadmap automatically.
- Researcher C (Material Science) who is working on fuel-cell technology said if RMA can give some support when we want to get subsidy such as what kind of research are getting subsidy now, how many researchers are doing such research, who will be the cooperator and who will be the competitors and so on.

So, in this study, we would like to support scientific researchers (professors and students) for finding new interests and research topics, the first step in RMA, as well as to push or promote cooperation among university, industry and government on technology creation.

- Why

There are so many works for supporting students' research plan but only little for supporting decision making of new research topics. We will support all students and professors when they want to start new research topic in this study.

- When

It is necessary that support researchers to make their scientific research roadmap. Not only for plan, support in the step before making plan is also necessary. Therefore we will support them when they want to start some new projects or research topics.

- What

What kind of support

Data collecting: help researchers collect data what they want in an easy way in a specific research field.

Data analyzing: help researchers analyze data to get good results in a specific research field.

Searching: help researchers get information in an easy way based on results of data analysis.

Networking: help researchers get information of researchers' relation in a specific research field to find potential cooperators and competitors.

Mapping: help researchers know position of their research in the whole research field find cooperative projects.

There are lots of related work have been done, but in this study, we will use such data analysis methods for a new application.

- How

How to support researchers

RMA support in academia should help researchers answer following questions:

- Where are you?
- Where do you want to go?
- How to get there?

For researchers that means:

- What is the position of research topic related what researcher is dong.
- What is the position of research topic related what researcher wants to do.
- What is the relation between research topics related what they are doing and what they want to do.

Chapter 3

Design a framework of RMA support for scientific researchers in academia

In this chapter, a framework of RMA support for researchers in academia will be designed after the introduction of detailed definition and functions of RMA support.

3.1 Definition of RMA support in academia for scientific researchers

In this study, we give RMA support a different definition explained from what, why, when and how to support scientific researchers in academia.

3.1.1 Why support scientific researchers in academia

In academia, the smallest unit is a laboratory, and researchers in this study mean all members of a laboratory. For a laboratory, usually there is one professor, one or two assistants and many students. RMA designed in this study is to help professors, assistants and students. However so many works have been done for supporting students' research plans such as we explained in chapter 2.

A new RMA support approach for making personal academic research roadmaps by applying ideas of Interactive Planning (IP) was suggested by Ma (see Ma 2006). The approach suggests the use of a process composed of six phases: forming groups; explanations from knowledge coordinators; descriptions of present situation; analysis of current status of every member and idealized design; research schedule and study schedule; and implementation and control. Another approach was suggested by Okutsu (see Okutsu 2005), based upon the idea that students from science and engineering laboratories should be asked to manage their research, since they will have to do it in the future, whether in a academia or in industries. Therefore, ATRM (Academy Technology Road Map) was proposed to help researchers, including students, with their research planning in academic science and engineering laboratories. Both these two ideas aim to support students from scientific and engineering laboratories to develop their research proposals and research plans. However, we also mentioned that researchers (not only for students), said RMA support as a planning tool maybe not enough. Therefore we addressed this study for supporting scientific researchers (professors, assistants and students). It is the same with RMA support in industry and government, a decision making approach.

3.1.2 When support scientific researchers in academia

Scientific research process as Figure 3.1 shown, in a laboratory of scientific research, there are two types of difficulties that are mutually related. “Deep-woods” means that it is very difficult to determine the research direction because of the information flood. “Death-valley” means that there are a huge number of ideas which are not used in industry (see Nakamori report 2004).

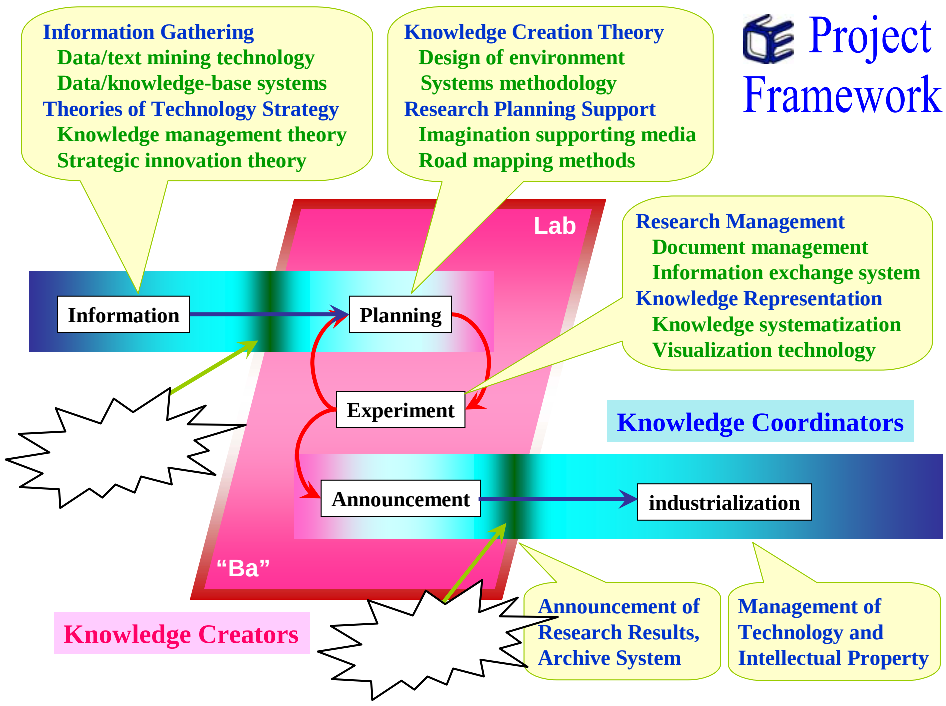


Fig 3.1 Scientific Research Process

RMA support we design in this study is to solve the problem of “deep woods": when researchers want to start a new project or new research topic RMA support will help researchers get a clear picture for their position to answer where you are, where you want to go and how to get there; and "death valley": when researchers want to start a new project or new research topic RMA support will help researchers have a clear understand for seeds and needs in a specific research field.

3.1.3 What kinds of support for scientific researchers in academia will be provided

What kinds of support for scientific researchers in academia depend on what kinds of support they need. Based on interview (mentioned in Chapter 2), we found that the problems are:

- Researchers can easily obtain a great quantity of data and information, but sorting through that data and information to get ideas, is not a trivial problem. On the other hand, researchers are very busy for scientific research and lab management. Therefore researchers need an easy way to collect and analyze data.
- Researchers don't really know their position in the research field they are (especially students). Researchers usually only concern about detailed information of technology but unconcern with information of marketing, economy and policy. That means they have a local overview for their position in a specific research field. Therefore researchers need networking support including technology, human resource, social influence etc.

- Researchers have their own ways to do their scientific works, also they are very busy. That is why it is not so many chances for researchers to discuss with others researchers from different universities and industries. Therefore researchers need cooperators for doing their scientific research. One the other hand, they also need to know who is competitor for getting subsidy or involving in projects.

Now we have a clear picture that what kinds of support researcher need, the next problem is what kinds of support we can provide. RMA support for scientific researchers will be the tools:

- Support for information searching
- Support for networking
- Support for mapping

3.1.4 How to support scientific researchers in academia

We mentioned in Chapter2 roadmaps can mean different things to different people. They are developed for diverse purposes. Phaal et al. identified eight types of technology roadmaps in terms of the intended purpose (see Phaal 2004); Kostoff and Schaller summarized dozens of different applications of roadmaps presented in a technology road mapping workshop in 1998 and found that those applications covered a wide spectrum of uses including (see Kostoff and Schaller 2001):

- Science/research roadmap

- Cross-industry roadmap
- Industry roadmaps
- Technology roadmaps
- Product roadmaps
- Product–technology roadmaps
- Project or issue roadmaps

For scientific researchers in academia, roadmap means:

- Technology maps
- Research maps

For RMA support, we will provide:

- Research topic maps
- Researcher maps
- Network maps

We also mentioned that according to Australian Department of Industry, Science and Resources (2001), there are generally three approaches for making technology roadmaps

- Expert-based approach

A team of experts comes together to identify the structural relationships within the field and specify the quantitative and qualitative attributes of the roadmap.

- Workshop-based approach

This technique is used to engage a wider group of industry, research, academic, government, and other stakeholders, to draw on their knowledge and experiences.

- Computer-based approach

Large databases are scanned to identify relevant research, technology, engineering, and product areas. High-speed computers, intelligent algorithms, and other modeling tools can assist in estimating and quantifying the relative importance of these areas and in exploring their relationships to other fields. This approach is still in its infancy, as large textual databases and efficient information extracting computational approaches have only begun to emerge.

In this study, RAM support for scientific researchers in academia will be a computer-based approach. Expert-based and workshop-based approaches are widely used in industry and government. Technology development in industry and government is a group work but scientific research in academia is an individual work. RMA support in academia should be a way for supporting individually motivated work. Also researchers in academia have some dedicated funds for research operation, but they use almost all these funds for experiment equipment, tools and materials, it is thus difficult to invite outside specialists to make a discussion group whenever they want. Therefore we design a computer-based RMA support for scientific researchers in academia.

In Chapter 2, different formats of roadmap are also mentioned (see Phaal 2004)

- Multiple layers
- Bars
- Tables
- Graphs and plots
- Pictorial representations
- Flow charts
- Single layer
- Text

In this study computer-based RMA support designed for scientific researchers will use all formats.

3.2 Functions of RMA support in academia for scientific researchers

3.2.1 Function 1---data collecting support

If researchers want to find new interests or research topic, the first step should be data and information collecting for a domain to make clear that which topic was, is and will be hot topic. Almost all researchers did have such experience, when use "google" or other searching tool, it is very often that after inputting keywords more than 10 thousand records of information will be provided. Thus, researchers will have no time for doing their scientific research. Therefore, the first function of RMA designed will be support for data collecting. It means to help researchers decide a domain which they are interested in, and provide some easy ways for data collecting such as online databases or soft wares.

Also, for solving the problem of “death valley” and “deep woods” mentioned in chapter 3.1.1. Data and information should be collected from industry, government and academia to help researchers piece out the situation of the domain they chose. It means that when researchers want to find new interests and research topics, they should know a lot about situation of the domain not only what other researchers doing but also the seeds and needs in a specific research field.

3.2.2 Function 2 ---data analyzing support

There are too many data analysis methods, first we should make clear the level of data analysis. Ackoff classified the content of the human mind into five categories (see Ackoff 1989):

- Data: symbols
- Information: data that are processed to be useful; provides answer to “who”, “what”, “where”, and “when” questions
- Knowledge: appreciation of data and information; answers “how” questions
- Understanding: appreciation of “why”
- Wisdom: evaluated understanding

Ackoff indicates that the first four categories relate to the past; they deal with what has been or what is known. Only the fifth category, wisdom, deals with the future because it incorporates vision and design. With wisdom, people can create the future rather than just grasp the present and past. But achieving wisdom isn't easy; people must move successively through the other categories. A further elaboration of Ackoff's definitions follows (see Ackoff 1989):

- Data

Data is raw. It simply exists and has no significance beyond its existence (in and of itself). It can exist in any form, usable or not. It does not have meaning of itself. In computer parlance, a spreadsheet generally starts out by holding data.

- Information

Information is data that has been given meaning by way of relational connection. This "meaning" can be useful, but does not have to be. In computer parlance, a relational database makes information from the data stored within it.

- Knowledge

Knowledge is the appropriate collection of information, such that it's intent is to be useful. Knowledge is a deterministic process. When someone "memorizes" information (as less-aspiring test-bound students often do), then they have amassed knowledge. This knowledge has useful meaning to them, but it does not provide for, in and of itself, integration such as would infer further knowledge. For example, elementary school children memorize, or amass knowledge of, the "times table". They can tell you that "2 x 2 = 4" because they have amassed that knowledge (it being included in the times table). But when asked what is "1267 x 300", they can not respond correctly because that entry is not in their times table. To correctly answer such a question requires a true cognitive and analytical ability that is only encompassed in the next level “understanding”. In computer parlance, most of the applications we use (modeling, simulation, etc.) exercise some type of stored knowledge

- Understanding

Understanding is an interpolative and probabilistic process. It is cognitive and analytical. It is the process by which I can take knowledge and synthesize new knowledge from the previously held knowledge. The difference between understanding and knowledge is the difference between "learning" and "memorizing". People who have understanding can undertake useful actions because they can synthesize new knowledge, or in some cases, at least new information, from what is previously known (and understood). That is, understanding can build upon currently held information, knowledge and understanding itself. In computer parlance, AI systems possess understanding in the sense that they are able to synthesize new knowledge from previously stored information and knowledge.

- Wisdom

Wisdom is an extrapolative and non-deterministic, non-probabilistic process. It calls upon all the previous levels of consciousness, and specifically upon special types of human programming (moral, ethical codes, etc.). It beckons to give us understanding about which there has previously been no understanding, and in doing so, goes far beyond understanding itself. It is the essence of philosophical probing. Unlike the previous four levels, it asks questions to which there is no (easily-achievable) answer, and in some cases, to which there can be no humanly-known answer's period. Wisdom is therefore, the process by what we also discern, or judge, between right and wrong, good and bad. I personally believe that computers do not have, and will never have the ability to possess wisdom. Wisdom is a uniquely human state, or as I see it, wisdom requires one to have a soul, for it resides as much in the heart as in the mind. And a soul is something machines will never possess (or perhaps I should reword that to say, a soul is something that, in general, will never possess a machine).

Data analysis is to support the process from data to information. We use qualitative analysis to analyze seeds and needs in a specific research field, and quantitative analysis to analyze situation of scientific research in academia, industry and government.

3.2.3 Function 3 ---searching, networking and mapping support

Searching, networking and mapping will support the process from information to knowledge and understanding help researchers possess wisdom.

- Searching will give an interface to researchers helping them find data and information they need by an easy way to answer where they are and where they want to go.
- Networking will help researchers to understand where they are in a specific research field.
- Mapping will help researchers integrate the results of searching and networking to give an answer about how to get there

3.3 Framework of RMA support in academia for scientific researchers

- Domain definition

For academic researchers, when they want to star new research topics or new interests, they commonly consider a specific research field, for example, biotechnology, or nanotechnology. Here we use the term *domain* to denote the field that researchers are interested in. A domain can be simply defined by one or several keywords, for example, a domain can be defined by fuel cell and vehicle as (fuel cell, vehicle). Researchers can specify a domain according to their preferences. They can specify a quite wide domain, for example, nanotechnology; or specify a relatively narrow domain, for example, compound semiconductor crystal devices.

- Data for a domain

After a domain is specified, three kinds of data sets corresponding to each dimension of the triple helix in the domain will be collected.

- Data set in the academia dimension

This data set contains mainly the information about academic publications in the domain. Such data is available in scientific databases, both online and off line.

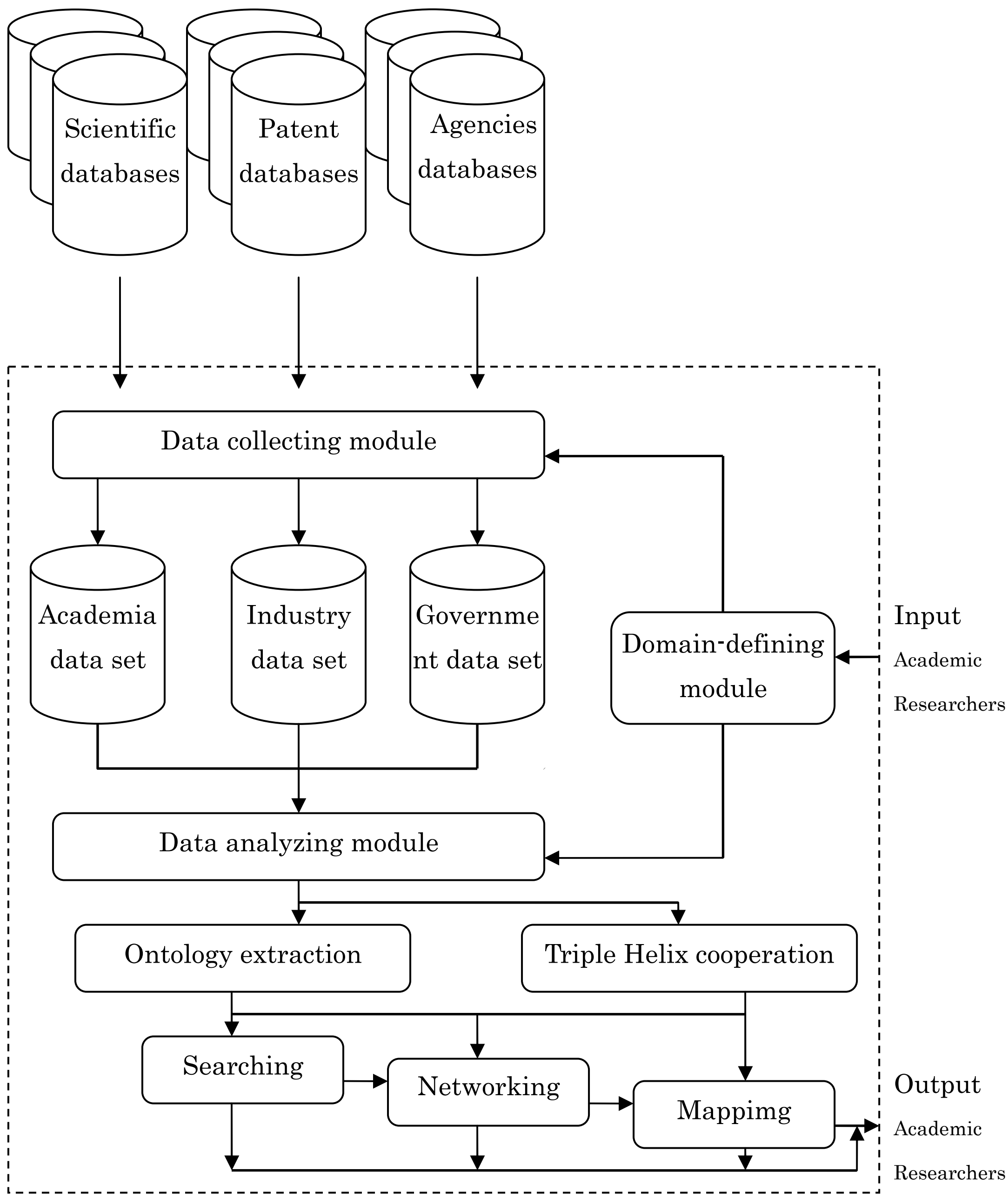


Fig 3.2 Framework of Computer-based RMA support

- Data set in the industry dimension

This data set contains the information about the patents held or being applied for by industry in the domain. Of course, some academic researchers also apply for patents. For making a fuller story, when collecting this data set, the information about the patents held or being applied by academic researchers is also included. This data commonly is available in some patent databases.

- Data set in the government dimension

This data set contains the information about the projects supported by government in the domain, which is commonly available in some government agencies' websites.

- Data analysis for a domain (detailed explanation in Chapter 4)
  - Ontology extraction

After getting these three data sets, we need to build relations among them for further analysis, and ontology is used for this purpose. After discussion with some academic researchers, we found a four-level ontology is appropriate. As shown in Figure 3.3, the bottom level of the ontology will be the most detailed information. Many system methodologies, such as KJ (see Kawakita J 1975), AHP (see Saaty 1980), and so on, can be applied to identify elements in other three levels by integrating researchers' expertise. From the bottom level of ontology to the top level of ontology, information becomes more general and general. The structure of the ontology is not a tree, it is a network, which means that information in each level can be related to several information in other levels, and vice versa.

- Triple helix cooperation

For each element in the ontology, a triple helix of academia-industry-government can be analyzed from the three data sets, as shown in Figure 3.4. The big triple helix in Figure 3.4 means the one (Lti) based on the top level of ontology. T31 and T3n, the two small ones mean the triple helixes based on two (could be more) related to Lti, and arrows denote the relations between elements in the ontology.

- Searching is to help researchers answer the questions where is your research is? Where are your new interests or new research are?
- Networking is to help researchers answer the questions where are you? Where do you want to go?
- Mapping is to help researchers answer the question how to get there? Also help researchers find cooperators or competitors

In this chapter, we designed a framework of computer-based RMA support scientific researchers in academia. How does it work? What are problems? Is it useful or not? To clear up such questions, we do a case study based on the framework designed in next chapter.

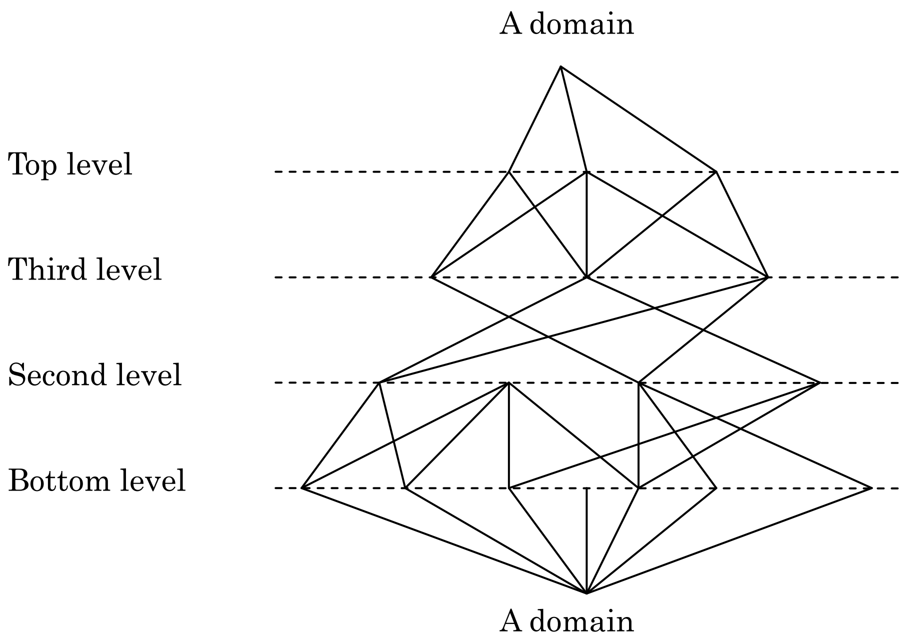


Fig 3.3 Four-level Ontology

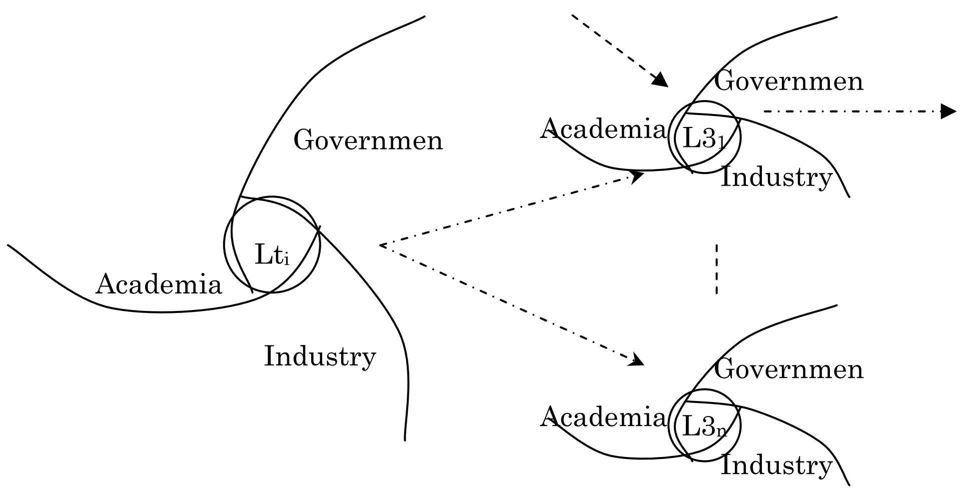


Fig 3.4 Triple Helix with Ontology

Chapter 4

Case-study
Support transportation using fuel-cells RMA for researchers

In this chapter, we do a case-study to make sure that if RMA support which we designed in Chapter 3 for scientific researchers when they want to star new research or find new interest in academia is useful or not, what kinds of method and software can be used in this computer-based approach.

4.1 Domain definition

Fuel-cell development can trace its roots back to the 1800s. A Welsh-born, Oxford-educated barrister named Sir William Robert Grove realized that if electrolysis, using electricity, could split water into hydrogen and oxygen, then the opposite would also be true. An appropriate method of combining hydrogen and oxygen should produce electricity. To test his reasoning, Grove built a device that would combine hydrogen and oxygen to produce electricity, the world's first gas battery, later renamed the fuel cell. Because of characteristics such as long durability, high efficiency and no pollution, fuel cells represent a promising energy technology for human society (see Nakicenovic et al. 2005).

It is well known that, if fuel cells could be substituted for gasoline-powered internal combustion engines, and hydrogen could be produced from renewable resources, such as, solar, hydro, biomass, and so on, carbon oxide and sulfur oxide emissions would be greatly decreased. Sponsored by the JAIST COE program titled Technology Creation Based on Knowledge Science, a project was carried from 2003 which aimed to help several researchers in Japan who were working in the field of fuel cell technologies to develop their strategic research topics or interests.

4.1.1 Definition of fuel-cells

In principle a fuel-cells operates like a battery. Unlike a battery a fuel-cells does not run down or require recharging. It will produce energy in the form of electricity and heat as long as fuel is supplied. A fuel-cell consists of two electrodes sandwiched around an electrolyte. Oxygen passes over one electrode and hydrogen over the other, generating electricity, water and heat. Hydrogen fuel is fed into the "anode" of the fuel-cells. Oxygen (or air) enters the fuel-cells through the cathode. Encouraged by a catalyst, the hydrogen atom splits into a proton and an electron which take different paths to the cathode as shown in figure 4.1. The proton passes through the electrolyte. The electrons create a separate current that can be utilized before they return to the cathode, to be reunited with the hydrogen and oxygen in a molecule of water. A fuel-cells system which includes a “fuel reformer” can utilize the hydrogen from any hydrocarbon fuel – from natural gas to methanol, and even gasoline. Since the fuel-cells relies on chemistry and not combustion, emissions from this type of a system would still be much smaller than emissions from the cleanest fuel combustion processes (see Online fuel cell information resource, National Technology Energy Laboratory 2000, Graham 2002 and Michael)

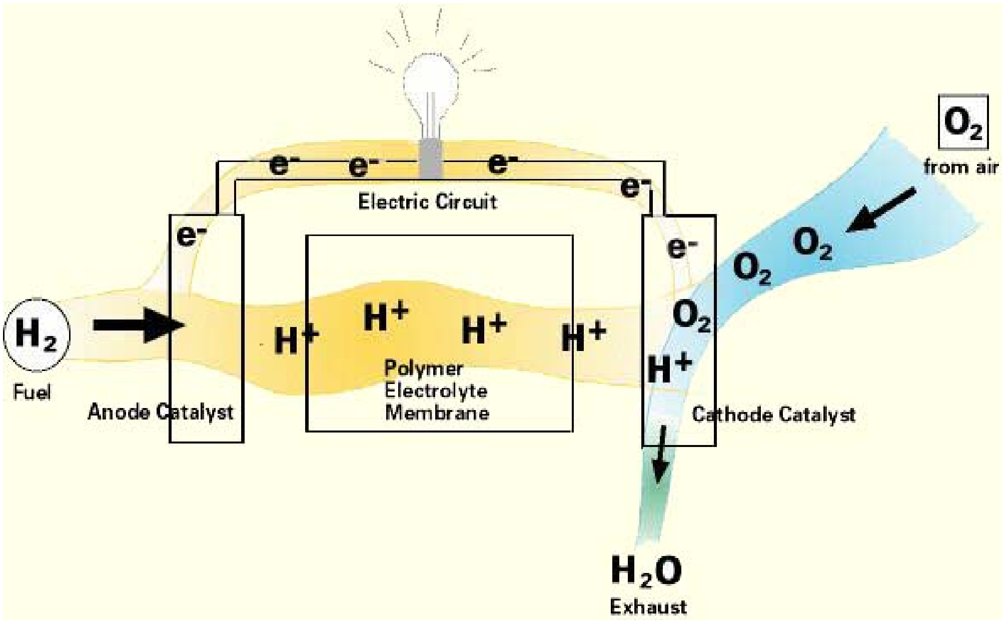


Fig 4.1 Fuel-cells Principle

4.1.2 Types of fuel-cells

- Phosphoric Acid (PAFC)

This type of fuel cell is commercially available today. More than 200 fuel cell systems have been installed all over the world - in hospitals, nursing homes, hotels, office buildings, schools, utility power plants, an airport terminal, landfills and waste water treatment plants. PAFCs generate electricity at more than 40% efficiency -- and nearly 85% of the steam this fuel cell produces is used for cogeneration -- this compares to about 35% for the utility power grid in the United States. Operating temperatures are in the range of 300 to 400 degrees F (150 - 200 degrees C). At lower temperatures, phosphoric acid is a poor ionic conductor, and carbon monoxide (CO) poisoning of the Platinum (Pt) electro-catalyst in the anode becomes severe. The electrolyte is liquid phosphoric acid soaked in a matrix. One of the main advantages to this type of fuel cell, besides the nearly 85% cogeneration efficiency, is that it can use impure hydrogen as fuel. PAFCs can tolerate a CO concentration of about 1.5 percent, which broadens the choice of fuels they can use. If gasoline is used, the sulfur must be removed. Disadvantages of PAFCs include: it uses expensive platinum as a catalyst, it generates low current and power comparably to other types of fuel cells, and it generally has a large size and weight. PAFCs, however, are the most mature fuel cell technology.

Anode: $H_2(g) \rightarrow 2H^+(aq) + 2e^-$

Cathode: $\frac{1}{2}O_2(g) + 2H^+(aq) + 2e^- \rightarrow H_2O(l)$

- Proton Exchange Membrane (PEM)

These cells operate at relatively low temperatures (about 175 degrees F or 80 degrees C), have high power density, can vary their output quickly to meet shifts in power demand, and are suited for applications, -- such as in automobiles – where quick startup is required. According to DOE, "they are the primary candidates for light-duty vehicles, for buildings, and potentially for much smaller applications such as replacements for rechargeable batteries." The proton exchange membrane is a thin plastic sheet that allows hydrogen ions to pass through it. The membrane is coated on both sides with highly dispersed metal alloy particles (mostly platinum) that are active catalysts. The electrolyte used is a solid organic polymer poly-perflourosulfonic acid. The solid electrolyte is an advantage because it reduces corrosion and management problems. Hydrogen is fed to the anode side of the fuel cell where the catalyst encourages the hydrogen atoms to release electrons and become hydrogen ions (protons). The electrons travel in the form of an electric current that can be utilized before it returns to the cathode side of the fuel cell where oxygen has been fed. At the same time, the protons diffuse through the membrane (electrolyte) to the cathode, where the hydrogen atom is recombined and reacted with oxygen to produce water, thus completing the overall process. This type of fuel cell is, however, sensitive to fuel impurities. Cell outputs generally range from 50 to 250 kW.

Anode: $H_2(g) \rightarrow 2H^+(aq) + 2e^-$

Cathode: $\frac{1}{2}O_2(g) + 2H^+(aq) + 2e^- \rightarrow H_2O(l)$

- Molten Carbonate (MCFC)

These fuel cells use a liquid solution of lithium, sodium and/or potassium carbonates, soaked in a matrix for an electrolyte. They promise high fuel-to-electricity efficiencies, about 60% normally or 85% with cogeneration, and operate at about 1,200 degrees F or 650 degrees C. The high operating temperature is needed to achieve sufficient conductivity of the electrolyte. Because of this high temperature, noble metal catalysts are not required for the cell's electrochemical oxidation and reduction processes. To date, MCFCs have been operated on hydrogen, carbon monoxide, natural gas, propane, landfill gas, marine diesel, and simulated coal gasification products. 10 kW to 2 MW MCFCs have been tested on a variety of fuels and are primarily targeted to electric utility applications. Carbonate fuel cells for stationary applications have been successfully demonstrated in Japan and Italy. The high operating temperature serves as a big advantage because this implies higher efficiency and the flexibility to use more types of fuels and inexpensive catalysts as the reactions involving breaking of carbon bonds in larger hydrocarbon fuels occur much faster as the temperature is increased. A disadvantage to this, however, is that high temperatures enhance corrosion and the breakdown of cell components.

Anode: $H_2(g) + CO_3^{2-} \rightarrow H_2O(g) + CO_2(g) + 2e^-$

Cathode: ½O_2(g) + CO_2(g) + $2e^-$ -> CO_3^{2-}

- Solid Oxide (SOFC)

Another highly promising fuel cell, this type could be used in big, high-power applications including industrial and large-scale central electricity generating stations. Some developers also see SOFC use in motor vehicles and are developing fuel cell auxiliary power units (APUs) with SOFCs. A solid oxide system usually uses a hard ceramic material of solid zirconium oxide and a small amount of ytrria, instead of a liquid electrolyte, allowing operating temperatures to reach 1,800 degrees F or 1000 degrees C. Power generating efficiencies could reach 60% and 85% with cogeneration and cell output is up to 100 kW. One type of SOFC uses an array of meter-long tubes, and other variations include a compressed disc that resembles the top of a soup can. Tubular SOFC designs are closer to commercialization and are being produced by several companies around the world. Demonstrations of tubular SOFC technology have produced as much as 220 kW. Japan has two 25 kW units online and a 100 kW plant being testing in Europe.

Anode: H_2(g) + O^{2-} -> H_2O(g) + $2e^-$

Cathode: ½O_2(g) + $2e^-$ -> O^{2-}

- Alkaline

Long used by NASA on space missions, these cells can achieve power generating efficiencies of up to 70 percent. They were used on the Apollo spacecraft to provide both electricity and drinking water. Their operating temperature is 150 to 200 degrees C (about 300 to 400 degrees F). They use an aqueous solution of alkaline potassium hydroxide soaked in a matrix as the electrolyte. This is advantageous because the cathode reaction is faster in the alkaline electrolyte, which means higher performance. Until recently they were too costly for commercial applications, but several companies are examining ways to reduce costs and improve operating flexibility. They typically have a cell output from 300 watts to 5 kW.

Anode: $H_2(g) + 2(OH)^-(aq) \rightarrow 2H_2O(l) + 2e^-$

Cathode: $\frac{1}{2}O_2(g) + H_2O(l) + 2e^- \rightarrow 2(OH)^-(aq)$

4.1.3 Market of fuel-cells

- New Markets

The current market for fuel cells is about $218 million and will rise to $2.4 billion by 2004, reaching $7 billion by 2009, according to studies by the Business Communications Company. The studies estimate the 2004 markets for fuel cells to break down as follows:

- $850 million - electric power generation
- $750 million - motor vehicles
- $200 million - portable electronic equipment
- $200 million - military/aerospace

- $400 million - other
- Energy Security

U.S. energy dependence is higher today than it was during the "oil shock" of the 1970s, and oil imports are projected to increase. Passenger vehicles alone consume 6 million barrels of oil every single day, equivalent to 85 percent of oil imports.

- If just 20 percent of cars used fuel cells, we could cut oil imports by 1.5 million barrels every day.
- If every new vehicle sold in the U.S. next year was equipped with a 60-kW fuel cell, we would double the amount of the country's available electricity supply.
- 10,000 fuel cell vehicles running on non-petroleum fuel would reduce oil consumption by 6.98 million gallons per year.

One study forecasts that there will be millions of fuel cell vehicles on the road by 2010. According to K. Atakan Ozbek, Allied Business Intelligence Senior Energy Analyst, "By the second decade of this century, mass production of automotive fuel cells will result first in a glut in the world oil supply and then in a total rejection of oil as a vehicle fuel".

Fuel cell power will reach tens of thousands of vehicles by 2003 to 2004. ABI estimates that, by 2010, automotive fuel cells will have a nearly 4 percent market share — 608,000 vehicles.

Market penetration in 2010 could rise as high as 1.2 million vehicles, representing 7.6 percent of the total U.S. new car market.

- Clean and Efficient

Fuel cells could dramatically reduce urban air pollution, decrease oil imports, reduce the trade deficit and produce American jobs.

The U.S. Department of Energy projects that if a mere 10% of automobiles nationwide were powered by fuel cells, regulated air pollutants would be cut by one million tons per year and 60 million tons of the greenhouse gas carbon dioxide would be eliminated. DOE projects that the same number of fuel cell cars would cut oil imports by 800,000 barrels a day — about 13 percent of total imports. On the stationary side, fuel cells are ideal for power generation, either connected to the electric grid to provide supplemental power and backup assurance for critical areas, or installed as a grid-independent generator for on-site service in areas that are inaccessible by power lines. Since fuel cells operate silently, they reduce noise pollution as well as air pollution and the waste heat from a fuel cell can be used to provide hot water or space heating. They are highly efficient and low maintenance.

4.1.4 Seeds-needs of fuel-cells

- Needs of fuel-cells

There are many uses for fuel cells — right now, all of the major automakers are working to commercialize a fuel cell car. Fuel cells are powering buses, boats, trains, planes, scooters, even bicycles. There are fuel cell-powered vending machines, vacuum cleaners and highway road signs. Miniature fuel cells for cellular phones, laptop computers and portable electronics are on their way to market. Hospitals, credit card centers, police stations, and banks are all using fuel cells to provide power to their facilities. Wastewater treatment plants and landfills are using fuel cells to convert the methane gas they produce into electricity. The possibilities are endless.

Based on diverse applications, fuel cells can be classified into five types (see Online fuel cell information resource, National Energy Laboratory 2005, Graham 2002 and Michael):

- Stationary

More than 2500 fuel cell systems have been installed all over the world — in hospitals, nursing homes, hotels, office buildings, schools, utility power plants, and an airport terminal, providing primary power or backup. In large-scale building systems, fuel cells can reduce facility energy service costs by 20% to 40% over conventional energy service.

- Residential

Fuel cells are ideal for power generation, either connected to the electric grid to provide supplemental power and backup assurance for critical areas, or installed as a grid-independent generator for on-site service in areas that are inaccessible by power lines. Since fuel cells operate silently, they reduce noise pollution as well as air pollution and the waste heat from a fuel cell can be used to provide hot water or space heating for a home. Many of the prototypes being tested and demonstrated for residential use extract hydrogen from propane or natural gas.

- Transportation

All the major automotive manufacturers have a fuel cell vehicle either in development or in testing right now, and Honda and Toyota have already begun leasing vehicles in California and Japan. Automakers and experts speculate that the fuel cell vehicle will not be commercialized until at least 2010. Fuel cells are also being incorporated into buses, locomotives, airplanes, scooters and golf carts.

- Portable Power

Miniature fuel cells, once available to the commercial market, will help consumers talk for up to a month on a cellular phone without recharging. Fuel cells will change the telecommuting world, powering laptops and palm pilots hours longer than batteries. Other applications for micro fuel cells include pagers, video recorders, portable power tools, and low power remote devices such as hearing aids, smoke detectors, burglar alarms, hotel locks and meter readers. These miniature fuel cells generally run on methanol, an inexpensive wood alcohol also used in windshield wiper fluid.

- Landfill/Wastewater Treatment

Fuel cells currently operate at landfills and wastewater treatment plants across the country, proving themselves as a valid technology for reducing emissions and generating power from the methane gas they produce.

However, for each application fuel-cells with longer span, cheaper price, smaller size, wider variety, more application etc. will be paid more and more attention to.

- Seeds of fuel-cells

After 291 records of data about fuel-cells products collected from all over the world analyzed, we found that

  - Fuel-cell products of transportation using are deficient as shown in Figure 4.2, which means that fuel-cell for transportation using still stopped at scientific research level.
  - Fuel-cell products using PEM are plentiful as shown in Figure 4.3.
  - More than half of products of transportation using fuel-cell use PEM as shown Figure 4.4.
  - Function of fuel-cell for transportation using is highest as shown in Figure 4.5.

4.1.5 Domain definition

Base on analysis of fuel-cells products, transportation oriented fuel-cell products constitute only 11.6%. It is well known that, if fuel-cells would become substitute of gasoline, the emissions of carbon oxides and sulfur oxides would be strongly decreased. Why vehicles using fuel-cell products are so slowly developed? How to support cooperation among academy, industry and government to promote research in this field?

How does technology creation proceed in this field? What data and information is needed to accelerate such technology creation? With these questions in mind, we decide domain as tow keywords: *fuel-cell* and *vehicle*.

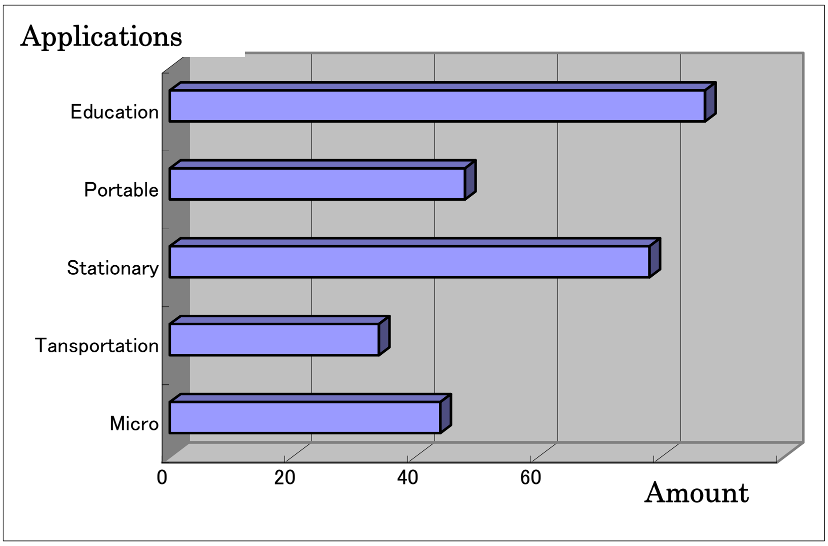


Fig 4.2 Applications of fuel-cells products

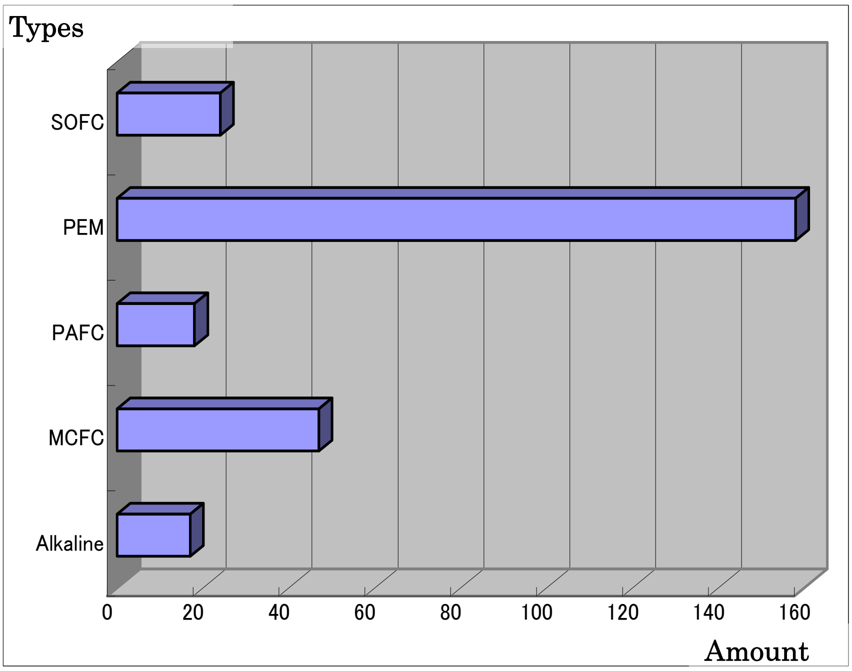


Fig4.3 Fuel-cells products classified by types

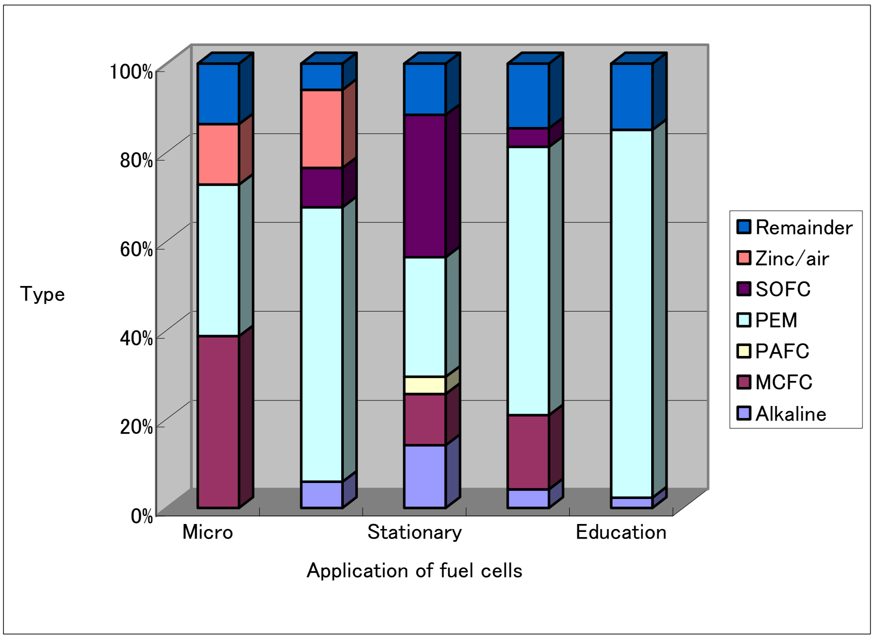


Fig4.4 Fuel-cells classified by different applications of products

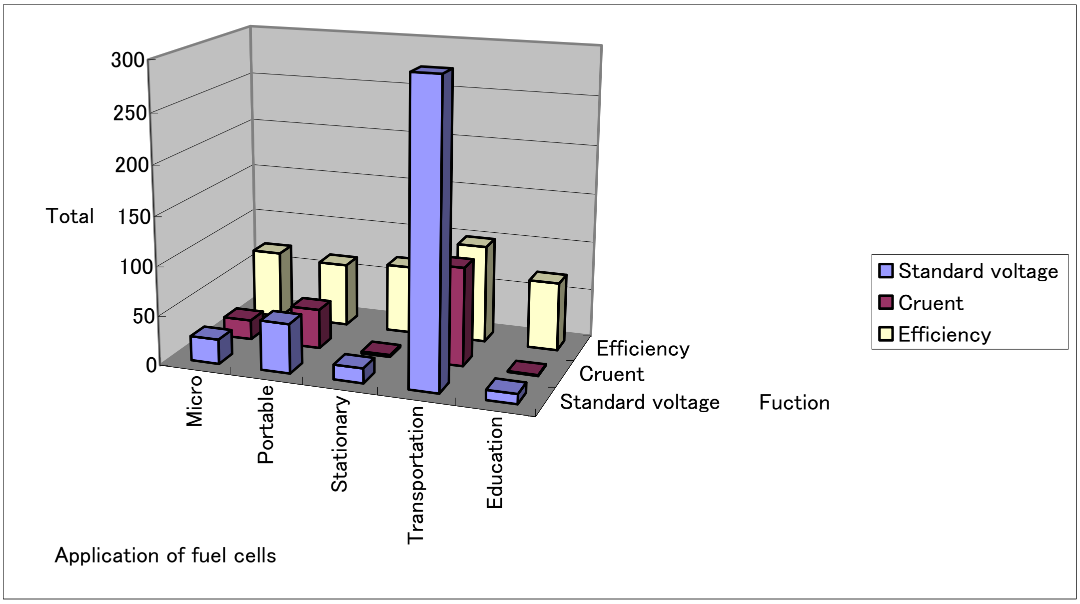


Fig4.5 Function based on different applications of fuel-cell products

4.2 Data collection

In a domain of transportation using fuel-cells, we collected data from industry, government and academia, got three data sets. How to evaluate accomplishment of scientific researches in academia, products in industry and trend of support from government? With such question in mind, we collected data from industry, government and academia.

4.2.1 Data collection in industry

Industry data set (51 records)

http://www.ryutu.ncipi.go.jp/PDDB/Service/PDDBService

Industry data set was obtained from the patent circulation database (2006), Japan. Because as mentioned in Chapter 2, after technology developer get valuable products, they try to grant patent, that means patent is a way to evaluate products developed by technology developers in industry.

Industry data set contains (shown in table 4.1)

- Patent owner's name
- Patent owner's affiliation
- Title of patent
- The date of applying or granting
- Content of patent (keywords)

Owner	Affliation	Title	Number	Application	Keywords	Adress
高橋　長一	三菱電機株式会社	固体高分子型燃料電池用	3351285,09－0757	実用性	3種類触媒重量比1:1:1,印刷法	神奈川県川崎市幸区大宮町1311番
山上　喜吉	独立行政法人産業技術総	燃料電池用水素ガス精製	2001－011219	実用性	COセンサー用触媒,結晶成長抑	茨城県つくば市梅園1－1－2,kyama
高橋　長一	東芝	固体高分子型燃料電池お	2793523,07－1830	小型化	PEM,白金－ルテニウム触媒,12C	神奈川県川崎市幸区大宮町1310番
高橋　長一	独立行政法人　新エネルギ	燃料電池の複合ガスセパ	3380805,2001－00	高効率	イオン伝導性,電子伝導性,複合ガ	神奈川県川崎市幸区大宮町1310番
高橋　長一	三菱電機株式会社	燃料改質装置	3129670,09－0458	高効率	各部平板形状,近接,積層,一体化	神奈川県川崎市幸区大宮町1312番
高橋　長一	三菱電機株式会社	一酸化炭素を含む水素ガ	3088320,09－0240	高効率	ガス拡散電極がイオン,触媒層,一	神奈川県川崎市幸区大宮町1313番
山上　喜吉	独立行政法人産業技術総	コリオリ流量計	2004－119950	性能向上	加速センサー,速度センサー,コリ	茨城県つくば市梅園1－1－1,kyama
高橋　長一	三菱電機株式会社	固体高分子型燃料電池発	3032461,08－0776	実用性	起動,改質器供給,容積増加	神奈川県川崎市幸区大宮町1314番
丈井　敏孝	テイクティ有限会社	組電池の電池管理方法と	2002－162356	シナリオ	キャパシタの残容量算出	神奈川県藤沢市本藤沢1－10－9,tt
産学連携推進部　業務	日本原子力研究所	ナノ構造制御高分子イオン	2003-305094	実用性	グラフト鎖,スルホン酸基,照射損	茨城県那珂郡東海村白方白根2－4,
高橋　長一	独立行政法人　新エネルギ	固体高分子型燃料電池	3429661,10－0315	小型化	固体高分子,PEM,複数積層体,ガ	神奈川県川崎市幸区大宮町1311番
高橋　長一	独立行政法人　新エネルギ	固体高分子型燃料電池お	3440843,10－2814	システム化	固体高分子,PEM,炭化水素改質,	神奈川県川崎市幸区大宮町1310番
笹月　俊郎	独立行政法人科学技術振	ポリイミド樹脂およびその	2004－088682	実用性	固体高分子,PEM,高いプロトン伝	東京都千代田区四番町5－3,jstore@
笹月　俊郎	独立行政法人科学技術振	複合電解質薄膜および電	2003－385866	小型化	固体酸化物,複合電解質薄膜,CV	東京都千代田区四番町5－3,jstore@
笹月　俊郎	独立行政法人科学技術振	12SrO･7Al2O3化合物	2002－045302	実用性	ストロンチューム(Sr),アルミニュ	東京都千代田区四番町5－3,jstore@
高橋　長一	三菱電機株式会社	車載燃料電池発電装置	3242547,07－0740	高効率	停車状態の給電,水循環回路,水	神奈川県川崎市幸区大宮町1314番
井出　光宏		質量バランスのとれた内燃	3080468,2000－00	高効率	ディスク型,蒸気タービンの集積,円	山梨県韮崎市旭町上条北割2083－
山上　喜吉	独立行政法人産業技術総	金属水素化物	2002－252480	金属材料	二元合金,水素と高温と加圧,高水	茨城県つくば市梅園1－1－2,kyama
齋藤　政敏	社団法人発明協会,特許流	表面改質方法及び表面改	第3555928,11－196	実用性	パルスパワー技術,プラズマイオン	東京都港区虎ノ門4－1－40　江戸
大江　通博	創造企画有限会社	風力発電装置	2003－101208	シナリオ	風力	茨城県土浦市右籾2700－18,oemic
齋藤　政敏	社団法人発明協会,特許流	磁気ブリッジ型電流センサ	PCT／JP2003／007	実用性	ブリッジのバランス,微小直流電流	東京都港区虎ノ門4－1－40　江戸
山上　喜吉	独立行政法人産業技術総	光学反射率変化を用いる	2003－314593	性能向上	マグネシウム･ニッケル合金薄膜,	茨城県つくば市梅園1－1－2,kyama
山上　喜吉	独立行政法人産業技術総	低温型燃料電池	2001－226762	小型化	永久磁石,キュリー温度以下	茨城県つくば市梅園1－1－1,kyama
駒村　利憲	株式会社デンソー	燃料電池利用型冷凍装置	2504006,61－2814	実用性	温度低下利用	愛知県刈谷市昭和町1－1,komamura
山上　喜吉	独立行政法人産業技術総	可視光感応性光触媒、そ	2002－143883	高効率	可視光感応性光触媒,水素発生	茨城県つくば市梅園1－1－1,kyama
今成　公美		回転体の特性を利用した	2001－030008	シナリオ	回転体の運動特性	新潟県長岡市川崎4－396
高橋　長一	株式会社日立製作所	燃料電池発電システム	3220438,11－1337	小型化	改質反応,緩衝タンク,圧力差,燃料	神奈川県川崎市幸区大宮町1310番
山上　喜吉	独立行政法人産業技術総	光触媒を用いた水素製造	2003－302157	実用性	金属硫化物光触媒,光照射,加熱	茨城県つくば市梅園1－1－2,kyama
小島　博助	株式会社日昭技研	無機質系軽量発泡体	2026874,03－2848	水素貯蔵	軽量発泡体	東京都江戸川区平井　4－29－16－
山上　喜吉	独立行政法人産業技術総	有機･無機複合材料を用い	3103888,10－2794	コスト低減	固体高分子電解質膜,PEM,エンド	茨城県つくば市梅園1－1－8,kyama
山上　喜吉	独立行政法人産業技術総	二温制御連結式固体酸化	11－074629	高効率	固体酸化物型燃料電池,部分酸	茨城県つくば市梅園1－1－5,kyama
山上　喜吉	独立行政法人産業技術総	白金－ルテニウム電極触	2000－266439	小型化	高分子電解質膜,白金錯体,ルテ	茨城県つくば市梅園1－1－3,kyama
角田　正吾		原動機の動力として永久	2001－039211	シナリオ	磁石回転	東京都東村山市栄町3－4－1マン
笹月　俊郎	独立行政法人科学技術振	貴金属ナノチューブ及びそ	2002－194693	実用性	親水部サイズの比較的小さい非	東京都千代田区四番町5－3,jstore@
山上　喜吉	独立行政法人産業技術総	水素貯蔵材料	2004-155393	実用性	水酸化ナトリウム,水素化ナトリウ	茨城県つくば市梅園1－1－1,kyama
山上　喜吉	独立行政法人産業技術総	新規な水素吸蔵合金及び	3015885,10－3275	性能向上	水素吸蔵合金,ニッケル－水素化	茨城県つくば市梅園1－1－6,kyama
山上　喜吉	独立行政法人産業技術総	三元系水素吸蔵合金およ	2955662,10－2930	性能向上	遷移金属元素添加,三元系水素	茨城県つくば市梅園1－1－7,kyama
奥野　隆夫		環境に優しい筒型式水中	10－213406	シナリオ	大量生産,防水効果,バケツ型	大阪府高槻市郡家新町　1－32
田崎　明	株式会社筑波リエゾン研究	カーボンナノチューブに担	2005－163348	コスト低減	脱白金触媒,カーボンナノチューブ	茨城県つくば市天王台1－1－1　筑
高橋　長一	日立製作所株式会社	積層型燃料電池	2125003,04－1693	実用性	単位電池複数個積層	神奈川県川崎市幸区大宮町1311番
山上　喜吉	独立行政法人産業技術総	水性ガスシフト反応及びメ	2002－129816	システム化	担体,アルミナ,シリカ,ジルコニア,水	茨城県つくば市梅園1－1－1,kyama
山上　喜吉	独立行政法人産業技術総	水素製造用予備改質触媒	2004－065359	高効率	炭化水素分解,改質触媒,分解触	茨城県つくば市梅園1－1－2,kyama
山上　喜吉	独立行政法人産業技術総	電極用複合粉末及びその	2003－369835	高効率	電極用複合粉末,毎分600回転,	茨城県つくば市梅園1－1－2,kyama

Tab 4.1 Industry data set

4.2.2 Data collection in government

Government dataset (56 records)

http://ge.nii.ac.jp/genii/jsp/index.jsp

Government dataset was obtained from NII (National Institute of Informatics) Scholarly and Academic Information Portal, Japan. Because projects information which was or are getting subsidy from government should be understood as a way to read trend of supporting from government.

Government data set contains (shown in table 4.2)

- Leader's name of project

- Leaders' affiliation
- Period of project
- Title of project
- Content of project (keywords)
- Budget from government (per year)

Leader	Belonging	Period	Technology	Keywords	Subsidy 1000円
安川 茂	金沢工業大学	1997-1999	エネルギ	co2再燃料化	3000
松瀬 貢規	明治大学	2001-2003	高効率	EV駆動,速度制御,並列接続ベクトル制御	14000
若山 修一	東京都立大学	2000-2002	水素貯蔵	圧力容器,リングバースト実験	13000
中田 俊彦	東北大学	2002-2003	シナリオ	エネシステム,コスト低減,環境影響	3700
森 俊介	東京理科大学	1997-1998	シナリオ	エネ需要,環境負荷	1400
三浦 浩之	関西大学	2000-2001	シナリオ	エネネットワーク	1500
丸山 茂夫	東京大学	2001-2003	水素貯蔵	カーボンナノチューブ,単層ナノチューブ,触媒CVD,分子動	12800
菅野 幹宏	東京大学	2004-2005	水素貯蔵	ガス容器,水素貯蔵	11900
架谷 昌信	名古屋大学	1999-2000	エネルギ	吸着ヒートポンプ,マイクロ波,シリカゲル	31500
邉 吾一	日本大学	2001-2002	水素貯蔵	形状記憶合金,有限要素法,圧力容器	3100
山田 太	国立鈴鹿工業高等専門学校	2004	システム化	高分子電解質,PEM	730
朝日 吉太郎	鹿児島県立短期大学	1999-2000	シナリオ	国際競争	4100
内本 喜晴	東京工業大学	2000-2002	小型化	固体高分子,PEM,イオン交換膜,プラズマ重合	4700
渡辺 政廣	山梨大学	1996	小型化	固体高分子,PEM,改質ガス,合金電極触媒,イオン交換	2000
陣内 亮典	東京工業大学	2000-2002	コスト低減	固体高分子,PEM,ガソード電極触媒	3000
内本 喜晴	京都大学	1996	高効率	固体高分子,PEM,傾斜機能,非平衡プラズマ,イオン伝導,	2300
江口 浩一	京都大学	1999-2001	実用性	固体高分子,PEM,固体酸化物,SOFC,水素製造,シフト触	14300
津島 将司	東京工業大学	2002-2003	性能向上	固体高分子,PEM,磁気共鳴,膜,水分布	3900
渡辺 政廣	山梨大学	2000-2001	高効率	固体高分子,PEM,自己加湿型電解質膜,白金触媒,酸化物	6500
永井 正幸	武蔵工業大学	1999-2000	実用性	固体高分子,PEM,室温,電解質,伝導性,成膜性	13300
工藤 徹一	東京大学	1997-2000	高効率	固体高分子,PEM,炭化タングステン,過酸化水素,プロトン	15700
内田 裕之	山梨大学	2001-2002	コスト低減	固体高分子,PEM,電極触媒,酸素還元,白金合金	3500
江尻 英治	千葉工業大学	2001-2002	高効率	固体高分子,PEM,流れ計測,レイノルズ数,アスペクト化	3100
小久見 善八	京都大学	1996-1998	高効率	固体高分子,PEM,プラズマ重合,イオン交換膜,ガス拡散電	14500
恩田 和夫	豊橋技術科学大学	1997-1998	エネルギ	固体高分子,PEM,分割極セル,電気浸透係数	3300
恩田 和夫	豊橋技術科学大学	1999-2000	高効率	固体高分子,PEM,膜の湿潤度	3500
中尾 真一	東京大学	1998-1999	実用性	固体高分子,PEM,メタノール,プラズマグラフと重合,電解質	14100
菱沼 孝夫	北海道大学	2001-2002	システム化	固体高分子,PEM,メタノール改質器	6600
菱沼 孝夫	北海道大学	1998-1999	エネルギ	固体高分子,PEM,メタノール改質器,多層セル,触媒反応,	3500
脇坂 知行	大阪市立大学	2003-2004	システム化	固体高分子,膜電極接合体製法,PEM,MEA	3200
内田 裕之	山梨大学	2003-2004	性能向上	固体酸化物,SOFC	7600
江口 浩一	九州大学	1988	高効率	固体酸化物,SOFC,酸素イオン導電体,安定化ジルコニア,	3400
内田 裕之	山梨大学	1994	高効率	固体酸化物,SOFC,ジルコニア電解質,混合導体,高分散	1700
川田 達也	東北大学	2000-2001	高効率	固体酸化物,SOFC,炭素析出,水蒸気改質,白金電極,ニッ	14400
内田 裕之	山梨大学	1999-2000	高効率	固体酸化物,SOFC,電極触媒,低温作動,混合導体	3500
山田 興一	東京大学	1995-1997	高効率	固体酸化物,SOFC,電極反応,作動温度	2200
伊原 学	東北大学	1998-2001	実用性	固体酸化物,SOFC,燃料極反応機構,ドライメタン燃料	10800
藤元 薫	北九州市立大学	2001-2002	高効率	ジメチルエータル,水蒸気改質,ロジウム触媒,パラジウム触	2500
佐々木 哲彦	宮城工業高等専門学校	1999-2000	エネルギ	水素エネ	3200
野口 博司	九州大学	2001-2004	水素貯蔵	ステンレス鋼	2500
堀 洋一	東京大学	2003-2004	金属材料	増粘着制御	47190
関口 秀俊	東京工業大学	2001-2003	水素貯蔵	大気マイクロ波水蒸気プラズマ,改質,炭化水素	10200
田村 卓也	産業技術総合研究所	2001-2002	水素貯蔵	体心立方構造,同位体効果	2000

Tab 4.2 Government data set

4.2.3 Data collection in academia

Academia data set (47 records)

http://www.aist.go.jp/RRPDB/system/Koukai.Top

Academia data set was obtained from the online database of publications of achievements, National Institute of Advanced Industrial Science and Technology, Japan. Because we also mentioned in Chapter 2 that there is only one way to evaluate research accomplishment in academia, that is publication.

Academia data set includes (shown in table 4.3)

- Author's name
- Author's affiliation
- Title of paper
- Abstract of paper (keywords)
- The date of publication
- The journal in which each paper was published

Author	Title	Technology	Keywords	Date	Affiliation	Journal
Abudaula,Abuliti	燃料電池電気自動車の現状及	性能向上	アルカリ助触媒	20010200	弘前大学理工学部環境調和エネルギー工	弘前大学理工学部研究報告3(2) / ページ103-110
市川 勝	燃料電池自動車に向けての水	水素貯蔵	アルカリ二次電池用水素電	20030101	北海道大学触媒化学研究センター	自動車技術57(1) / ページ 58-64
山根 公高	水素燃料利用システムの研究	システム化	ナノコンポジット 膜	20010501	武蔵工業大学工学部	自動車技術55(5) / ページ 80-87
石谷 久	燃料電池車の普及に向けて：	性能向上	ニッケル－水素化物電池	20040101	慶応義塾大学大学院政策・メディア研究科	自動車技術58(1) / ページ 6-13
高木 靖雄	自動車用燃料電池の燃料選択	高効率	燃料改質	20010926	武蔵工業大学	日本セラミックス協会秋季シンポジウム講演予稿集14() / ページ80
太田 健一郎	燃料電池開発の現状と課題	小型化	白金触媒	20060113	横浜国立大学大学院工学研究院	電子情報通信学会技術研究報告105(538) / ページ1-5
長谷川 貴彦	消費者の選好を考慮した燃料	実用性	パルスパワー技術	20060305	東京大学大学院新領域創成科学研究科環	エネルギー・資源(ISSN 02850494)27(2) / ページ 135-141
小川 知行	燃料電池ハイブリッド鉄道車両	システム化	複雑系同定手法	20050721	早稲田大学	電気学会研究会資料2005(28) / ページ 49-56
許斐 敏明	燃料電池運転状態診断方法の	シナリオ	マグネシウム・ニッケル合	20060225	フェロー.九州大学大学院工学研究院	日本機械学會論文集. B編(ISSN 03875016)72(714) / ページ455-462
雪田 和人	バッテリカー・燃料電池車の製	システム化	モデル駆動	20051201	愛知工業大学	電気学会研究会資料2005(32) / ページ 59-63
紙屋 雄史	実用化を待つ燃料電池自動車	実用性	温度低下利用	20000301	群馬大学	電気学会誌120(3) / ページ 165-168
鬼鞍 宏猷	燃料電池車用超高圧水素タン	水素貯蔵	改質	20051105	九州大学	日本機械学會誌108(1044) / ページ875
川田 達也	固体酸化物形燃料電池の自動	シナリオ	改質触媒と分解触媒	20010701	東北大学多元物質科学研究所	セラミックス36(7) / ページ 489-492
村山 博	燃料電池開発における企業間	シナリオ	環境負荷	20040700	桃山学院大学経営学部	桃山学院大学総合研究所紀要30(1) / ページ179-201
寺山 弘晃	水素供給ステーションの整備	シナリオ	環境負荷	20020228	早稲田大学理工学部建築学科	環境工学(72) / ページ573-576
吉川 大雄	自動車用固体高分子型燃料電	性能向上	合金電極触媒	20001225	北海道大学大学院	日本機械学會論文集66(652) / ページ3218-3225
引田 覚	デッドエンド系水素燃料電池の	高効率	磁気共鳴	20020115	武蔵工業大学工学部エネルギー基礎工学	自動車技術会論文集33(1) / ページ 43-48
引田 覚	固体高分子形燃料電池の性能	性能向上	触媒CVD	20041015	武蔵工業大学大学院	自動車技術会論文集35(4) / ページ 71-76
引田 覚	固体高分子形燃料電池におけ	性能向上	触媒CVD	20040415	武蔵工業大学エネルギー環境技術開発セン	自動車技術会論文集35(2) / ページ 95-100
濱口 和洋	スターリング機関および燃料電	システム化	水素供給装置用触媒	20010805	明星大学	日本機械学會誌104(993) / ページ530
今西 啓之	自立型固体高分子燃料電池と	性能向上	遷移金属元素添加と三元	20050225	大阪市立大学大学院工学研究科	日本機械学會論文集71(702) / ページ 674-681
山田 裕也	燃料電池車におけるLCA(エネ	エネルギ	多層セル触媒反応	20050220	法政大学工学部	日本金屬學會誌 69(2) / ページ 237-240
吉沢 四郎	最近の電池の動向	実用性	脱白金触媒とカーボンナノ	19670501	京都大学工学部	テレビジョン21(5) / ページ322-330
衣笠 良	燃料電池自動車導入に伴う運	シナリオ	地域経済統合	20030305	東北大学大学院工学研究科航空宇宙工学	エネルギー・資源24(2) / ページ 128-134
国松 昌幸	直接メタノール燃料電池の出力	性能向上	直接メタノール型	20011015	武蔵工業大学大学院	自動車技術会論文集32(4) / ページ 81-86
引田 覚	直接メタノール燃料電池におけ	性能向上	直接メタノール型	20010715	武蔵工業大学工学部エネルギー基礎工学	自動車技術会論文集32(3) / ページ 51-56
引田 覚	直接メタノール燃料電池のメタ	性能向上	直接メタノール型	20010415	武蔵工業大学工学部エネルギー基礎工学	自動車技術会論文集32(2) / ページ 49-54
小竹 智仁	直接メタノール形燃料電池の	高効率	直接メタノール型	20050315	武蔵工業大学大学院工学研究科	自動車技術会論文集36(2) / ページ 65-70
久保 則夫	固体高分子形燃料電池におけ	高効率	直接メタノール型	20041015	早稲田大学大学院理工学研究科	自動車技術会論文集35(4) / ページ 65-70
田中 優実	酸化タングステン水和物のプロ	性能向上	低温作動	20001100	東京大学生産技術研究所	生産研究52(11) / ページ523-527
加藤 康平	二酸化炭素排出削減に向けて	性能向上	電解質膜	20000601	金沢工業大学大学院工学研究科	Japan Society of Energy and Resources19 / ページ 7-10
朴 桂林	木質バイオマス高温ガス変換	高効率	電極触媒	20040720	名古屋大学大学院工学研究科30(4) / ページ 385-390	
石谷 久	各種燃料による燃料電池自動	高効率	電極触媒	20000905	東京大学工学系研究科地球システム工学	エネルギー・資源21(5) / ページ 417-425
高木 靖雄	自動車用燃料電池と水素燃料	性能向上	二元合金	20030420	武蔵工業大学工学部エネルギー基礎工学	日本エネルギー学会誌82(4) / ページ172-179
高木 靖雄	燃料中の一酸化炭素と硫化水	性能向上	熱媒式改質反応器と原料	20041015	武蔵工業大学	自動車技術会論文集35(4) / ページ 77-81
石谷 久	水素社会における燃料電池自	高効率	燃料極反応機構	20060505	慶應義塾大学大学院政策・メディア研究科	エネルギー・資源(ISSN 02850494)27(3) / ページ 168-172
渡辺 政廣	ゼロエミッション電気自動車用	性能向上	白金－ルテニウム触媒	19990000	山梨大学工学部	山梨大学地域共同開発研究センター研究成果報告書7 / ページ32-35
新井 宏	純水素/空気燃料電池車に利	性能向上	白金合金	20010100	東京理科大学工学部	エネルギーシステム・経済・環境コンファレンス17 / ページ 377-382
吉川 大雄	自動車用固体分子型燃料電池	性能向上	白金触媒	20010125	北海道大学大学院	日本機械学會論文集67(653) / ページ197-202
清水 浩	電気自動車, 燃料電池車, ハイ	性能向上	白金触媒	20000701	慶應義塾大学環境情報学部	自動車技術 54(7) / ページ 4-6
内田 裕之	電気自動車駆動用 固体高分	高効率	白金電極	19980305	山梨大学工学部	日本機械学會誌101(952) / ページ216-217
山根 公高	内燃機関方式および燃料電池	性能向上	反応層シート 折り畳むと電	20020401	武蔵工業大学工学部エネルギー基礎工学	Petrotech25(4) / ページ 288-293
加藤 康平	二酸化炭素回収技術を併用し	システム化	複合触媒	20010601	金沢工業大学大学院工学研究科	Japan Society of Energy and Resources20 / ページ 43-48

Tab 4.3 Academia data set

4.3 Data analysis

4.3.1 First-cut roadmap

After basic analysis of the data we got an overlook roadmap as shown in Figure 4.6 in which provides an overview of transportation-oriented fuel-cell technology development in the past, present, and future, including technological, social, and marketing aspects.

- Technologies were reclassified into 10 types
  - hydrogen storage technology
  - practicability of fuel-cells
  - technology for capability mounting up
  - energy development
  - technology of metallic materials for fuel cells
  - cost reduction of fuel-cell technology
  - efficiency increase of fuel-cell technology
  - fuel-cell systems technology
  - small-scale and miniature fuel-cell technology
  - scenarios (supply chain facilities for fuel-cells…)
- Numerical data was based on averaging diverse data sets
- The estimates of carbon dioxide emission decrease were calculated by the method used by the Ministry of Environment of Japan.

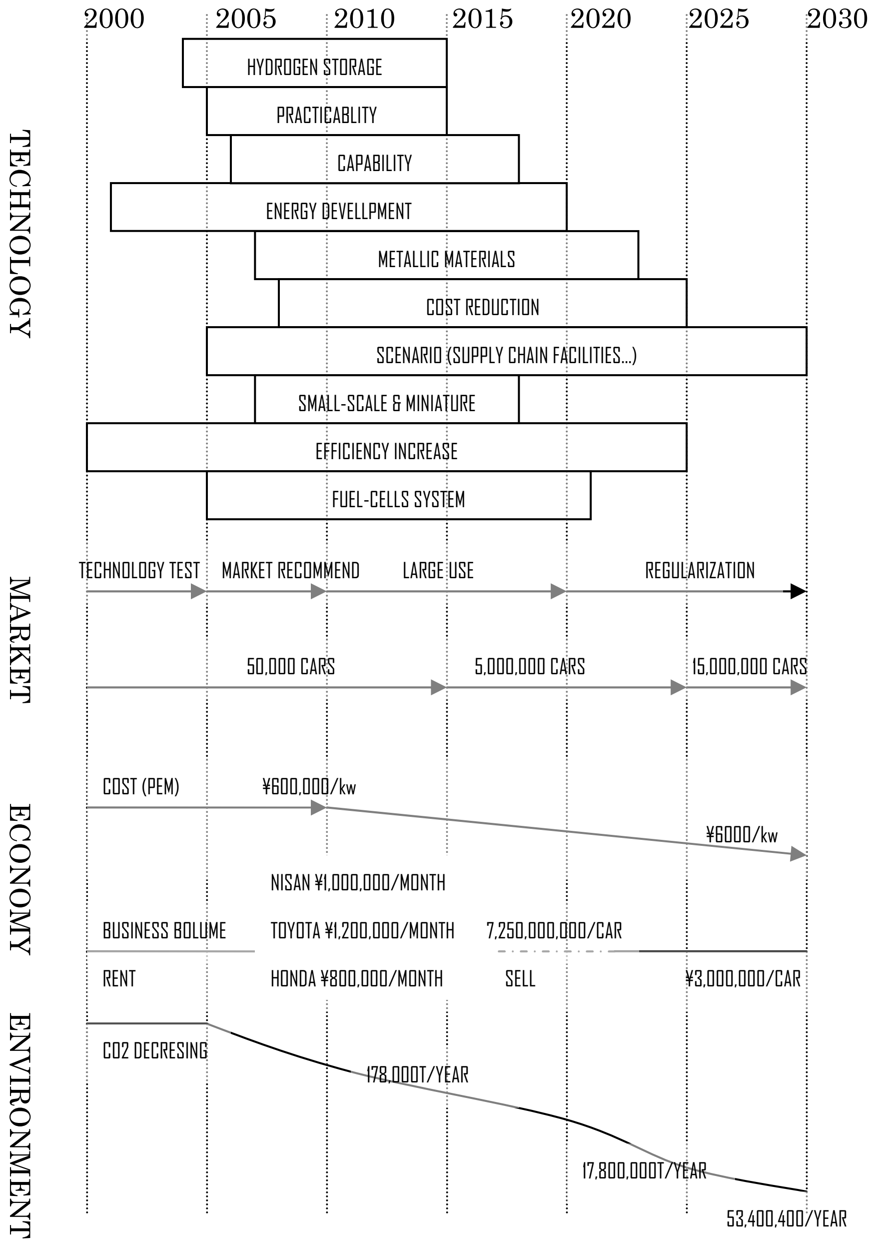


Fig 4.6 First-cut roadmap

The first-cut roadmap is a general roadmap to give an overview of transportation-oriented fuel-cells technology, marketing and society influences. For researchers in this research field, what are their requests of data, information and RMA, the first-cut roadmap was presented to researchers who are doing scientific research on transportation oriented fuel-cell technology at three universities: Osaka University (Osaka), Toyama University (Toyama), and JAIST (Ishikawa). These researchers were interviewed (questions in Appendix 1) and expressed the following opinions about transportation oriented fuel-cell technology development (similar for all three universities):

- They would be interested most in advanced technology information
- Related information on social and marketing aspects is not crucial for them
- The development of transportation-oriented fuel-cell technology takes such long time because costs are high and related safety problems are difficult.
- The time from technology to actual product development will also be long if useful implementation scenarios are not formulated.
- Most helpful would be more detailed information on plans and actions of other researchers in academia, industry, and government who are developing transportation-oriented fuel-cell technology.

Some examples of individual researchers' opinions are as follows:

- Researcher A said: It is necessary to help researchers make research plans, but it is hard to say what future research topics will be; it would be useful, however, to develop some support that would help researchers find the most valuable research topics

- Researcher B said: The first-cut roadmap can give researchers a different perspective and review of the whole research field including technology, marketing, and social influences. However, for researchers who are doing scientific research, the overview is not enough. More detailed information is needed about technologies, research topics, patents, etc., including other information such as the availability of subsidies from government.
- Researcher C said: Forecasting is a useful way to support researchers in generating new ideas and new research topics, but more useful would be more detailed information about what researchers in academia, industry, and government are doing now, what the relationships are among research topics, researchers, and technologies.

4.3.2 Ontology extraction

Based on opinions about detailed information of technology, research topics etc., we should process data in data sets to different levels. "Ontology" is used for this purpose (see Quine 1969, Kriple 1963 1980, and Guarino 1995,1998):

- In both computer science and information science, an ontology is a data model that represents a set of concepts within a domain, and the relationships between those concepts. It is used to reason about the objects within that domain.

- In philosophy, ontology is the study of being or existence. It seeks to describe or posit the basic categories and relationships of being or existence to define entities and types of entities within its framework. Ontology can be said to study conceptions of reality.
- Difference and similarity with respect between computer science ontology and philosophy ontology

The term ontology has its origin in philosophy, where it is the name of one fundamental branch of metaphysics, concerned with analyzing various types or modes of existence, often with special attention to the relations between particulars and universals, between intrinsic and extrinsic properties, and between essence and existence. According to Tom Gruber at Stanford University, the meaning of ontology in the context of computer science is "a description of the concepts and relationships that can exist for an agent or a community of agents." He goes on to specify that an ontology is generally written, "as a set of definitions of formal vocabulary." What ontology has in common in both computer science and philosophy is the representation of entities, ideas, and events, along with their properties and relations, according to a system of categories. In both fields, one finds considerable work on problems of ontological relativity, and debates concerning whether a normative ontology is viable. Differences between the two are largely matters of focus. Philosophers are less concerned with establishing fixed, controlled vocabularies than are researchers in computer science, while computer scientists are less involved in discussions of first principles (such as debating whether there are such things as fixed essences, or whether entities must be ontologically more primary than processes).

During the second half of the 20th century, philosophers extensively debated the possible methods or approaches to building ontologies, without actually building any very elaborate ontologies themselves. By contrast, computer scientists were building some large and robust ontologies with comparatively little debate over how they were built. In the early years of the 21st century, the interdisciplinary project of cognitive science has been bringing the two circles of scholars closer together. For example, there is talk of a "computational turn in philosophy" which includes philosophers analyzing the formal ontologies of computer science (sometimes even working directly with the software), while researchers in computer science have been making more references to those philosophers who work on ontology (sometimes with direct consequences for their methods). Still, many scholars in both fields are uninvolved in this trend of cognitive science, and continue to work independently of one another, pursuing separately their different concerns.

- Elements of ontology

- Individuals (instances): the basic, "ground level" components of an ontology. The individuals in an ontology may include concrete objects such as people, animals, tables, automobiles, molecules, and planets, as well as abstract individuals such as numbers and words. Strictly speaking, an ontology need not include any individuals, but one of the general purposes of an ontology is to provide a means of classifying individuals, even if those individuals are not explicitly part of the ontology.
- Classes (concepts): abstract groups, sets, or collections of objects. They may contain individuals, other classes, or a combination of both.
- Attributes: objects in the ontology can be described by assigning attributes to them. Each attribute has at least a name and a value, and is used to store information that is specific to the object it is attached to
- Relationships: an important use of attributes is to describe the relationships (also known as relations) between objects in the ontology. Typically a relation is an attribute whose value is another object in the ontology.

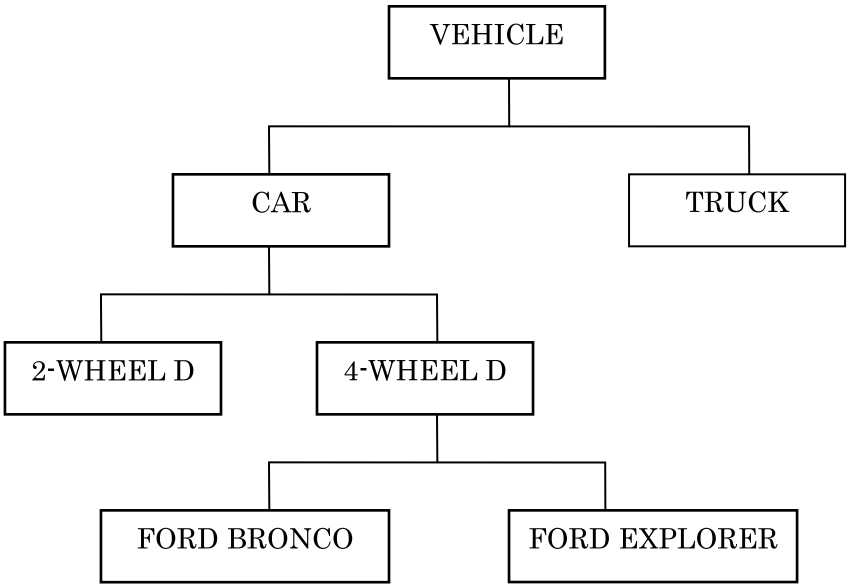


Fig 4.7 Example of ontology

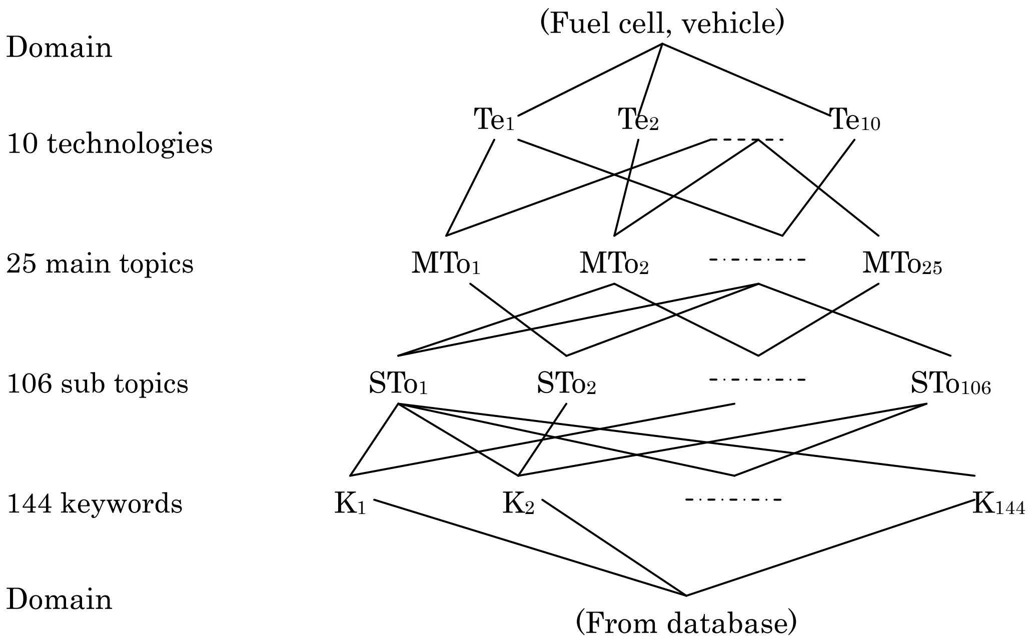


Fig 4.8 Four-level ontology

Figure 4.7 gives an example of an ontology. “Ford Bronco” and “Ford Explorer” are individuals; “CAR” and “Truck” are classes; “2-wheel drive” and “4-wheel” are one of attributes of car class; relationship of this ontology is a tree.

In this case, we construct a four-level ontology shown as figure 4.8 by top-down and bottom-up approaches (see Wolfe JM 2003). Top-down is a method of organization in which a general statement is presented first, and details presented last. Bottom-up is an approach which builds simple low-level objects into more complex higher-level objects. For different purpose top-down and bottom-up approaches have different contents. Fore example, as a systemic approach, top-down and bottom-up are strategies of information processing and knowledge ordering, mostly involving software, and by extension other humanistic and scientific system theories. In a top-down approach an overview of the system is first formulated, specifying but not detailing any first-level subsystems. Each subsystem is then refined in yet greater detail, sometimes in many additional subsystem levels, until the entire specification is reduced to base elements. A top-down model is often specified with the assistance of "black boxes" that make it easier to manipulate. However, black boxes may fail to elucidate elementary mechanisms or be detailed enough to realistically validate the model. In a bottom-up approach the individual base elements of the system are first specified in great detail. These elements are then linked together to form larger subsystems, which then in turn are linked, sometimes in many levels, until a complete top-level system is formed. This strategy often resembles a "seed" model, whereby the beginnings are small, but eventually grow in complexity and completeness. However, "organic strategies", may result in a tangle of elements and subsystems, developed in isolation, and subject to local optimization as opposed to meeting a global purpose. In this case, we use these two approaches as a similar definition with it for system design (see Wolfe JM 2003):

- Individuals (top-down)

The bottom-level in ontology will be 144 keywords (see appendix 6) which are distilled from abstract of paper in academia dataset, content of project subsidized by government in government dataset and introduction of patent in industry dataset with our knowledge.

- Classes (bottom-up)

We defined three classes which are other three levels in ontology: 106 sub-topics, 25 main-topics and 10 technologies (see appendix5,4,3). Subtopics are more general than keywords, so the number of subtopics will be smaller than the number of keywords. Main topics are more general than subtopics, and technologies are more general than main topics.

- Attributes

Each element in four-level ontology has 5 attributes:

Name: Author's name (academia)

Project leader's name (government)

Patent owner's name (industry)

Time: Publication time (academia)

Subsidized project period (government)

Patent application or granted time (industry)

Subsidy: what was, is or will be the budget provided by the government

Patent number: number of patent applied or patent granted

Journal name: name of journal which researchers' papers published in

- Relations

The structure of the ontology is not a tree, it is a network, which means a keyword can be related to several subtopics, a subtopic can be related to several main topics, a main topic can be related to several technologies, and vice versa as shown in Figure 9,10,11.

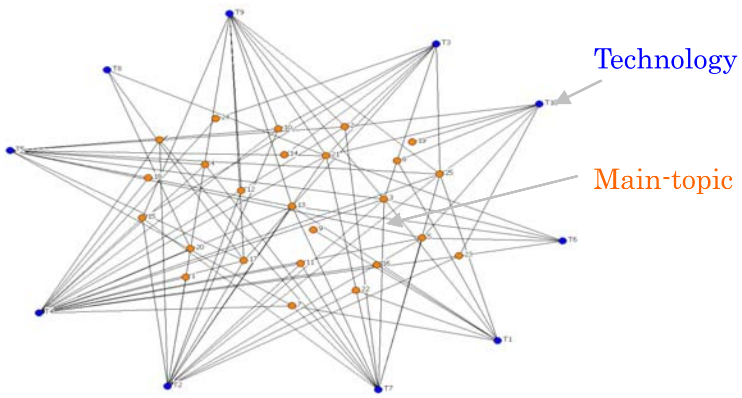


Fig 4.9 Relation between Technology and Main-topic

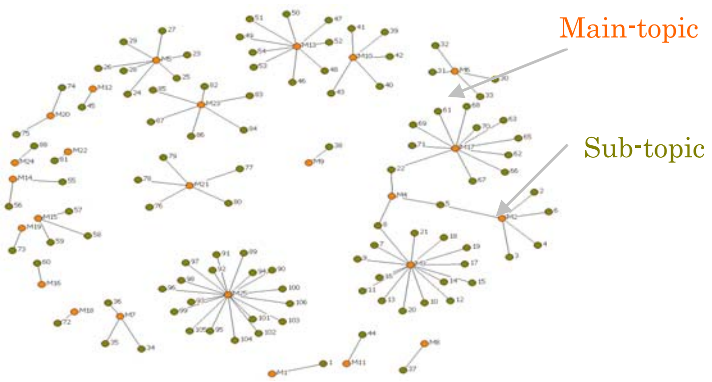


Fig 4.10 Relation between Main-topic and Sub-topic

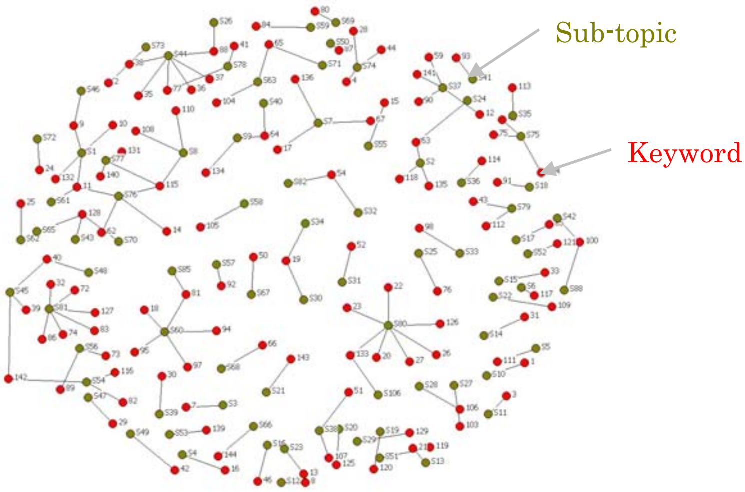


Fig 4.11 Relation between Keyword and Sub-topic

4.3.3 Triple helix cooperation

As mentioned in Chapter 3, triple helix of in this study means relations of research for technology development among academia, industry and government. The purpose is to help researchers make a clear picture of their position in whole research field, find potential cooperators for a new research or new interest, also can push cooperation among academia, industry and government for technology development.

Based on four-level ontology, triple helix will be two levels:

- Level 1: Triple helix of each level in ontology
    - Triple helix on technology level

    As shown in Figure 4.12, triple helix of technology 1, technology 2, technology 3, technology 4, technology 5, technology 7 and technology9 are the same. There is no paper about technology 6 and technology 8 from academia, and there is not patent about technology 10 from industry.

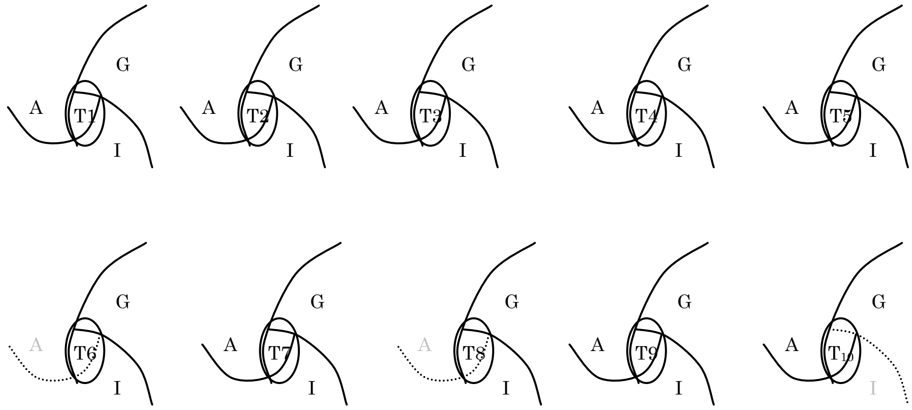


Fig 4.12 Triple helix on technology level

- Triple helix on main-topic level

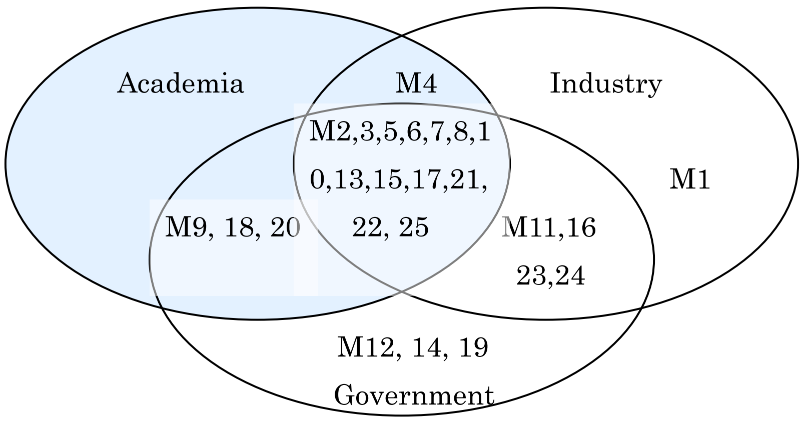


Fig 4.13 Triple helix on main-topic level

As shown in Figure 4.13, there are 13 main-topics in which papers published by researchers in academia, patents applied or granted by technology developers in industry and projects subsidized by government; 4 main-topics have no related paper published by researchers in academia; 3 main-topics have no related patent from industry; 1 main-topic has no related projected subsidized by government; 4 main-topics are being researched only in industry or government, there is no main-topics only related papers published in academia.

- Triple helix on sub-topic level

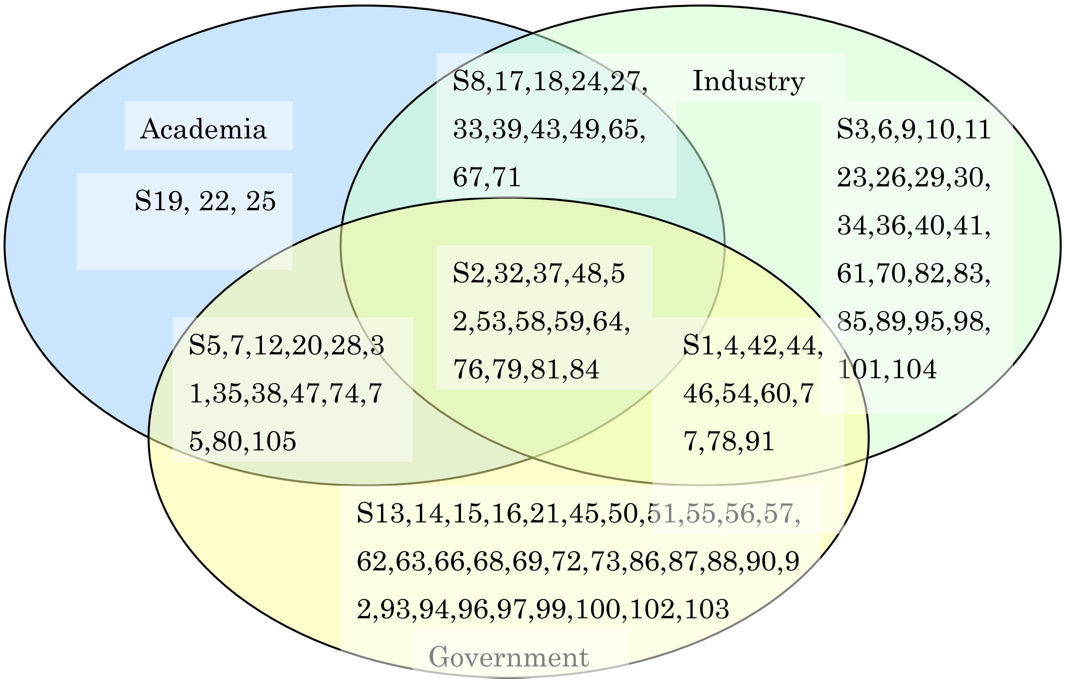


Fig 4.14 Triple helix on sub-topic level

As shown in Figure 4.14, 23 sub-topics are only related to patents in industry; 31 sub-topics are related to projects subsidized by government; 3 sub-topics are only related to papers published by researchers in academia; 10 main-topics have no related paper published by researchers in academia; 10 main-topics have no project subsidized by government; 13 main-topics have no related patent from industry and 14 main-topics are related to papers published by researchers in academia, patents applied or granted by technology developers in industry and projects subsidized by government.

- Triple helix on keyword level

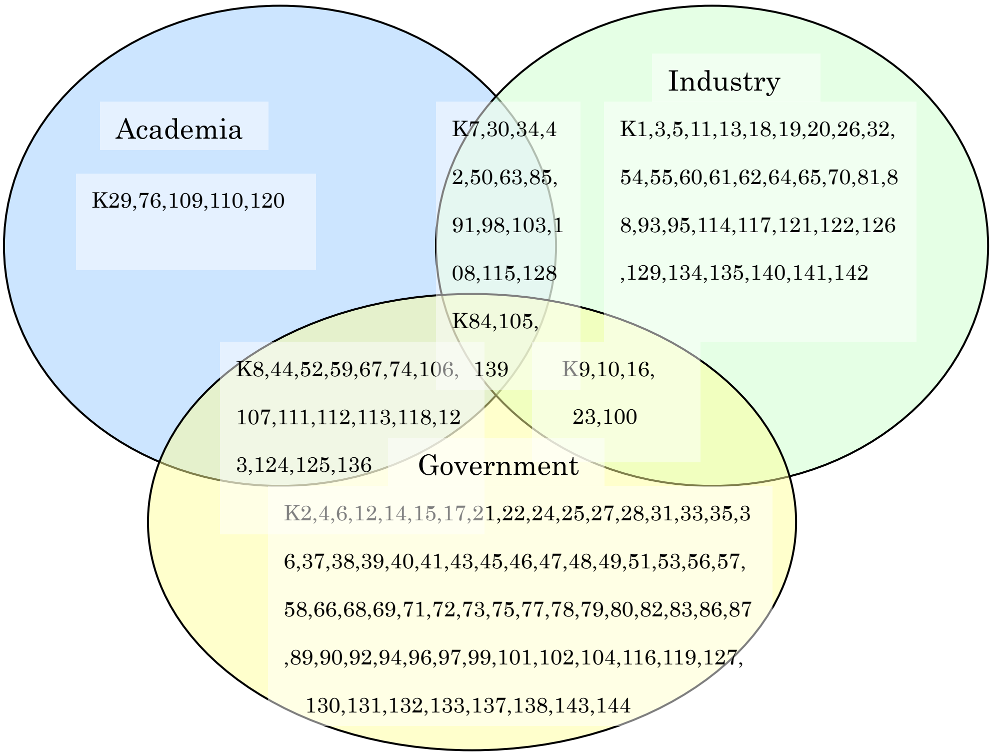


Fig 4.15Triple helix on keyword level

As shown in Figure 4.15 there are 3 keywords related to papers published by researchers in academia, patents from industry and projects subsidized by government; 13 keywords related to both of papers and patents; 16 keywords related to both of projects and papers; 5 keywords related to both of projects and patents; 69 keywords only related to subjects subsidized by government; 33 keywords only related to patents from industry; 5 keywords only related to papers published by researchers in academia.

- Level 2: Triple helix from the top level to the bottom level

As shown in Figure 4.16, nodes which are in blue are technologies, others are keywords. The different colors mean the keyword is related to papers published by researcher from academia (in purple) or patents from industry (in green) or projects subsidized by government (in brown).

These tow levels triple helix will help researchers find potential cooperative research project by answering follow questions:

- How many technologies, research topics and keywords are related to papers published by researchers in academia
- How many technologies, research topics and keywords are related to patents from industry
- How many technologies, research topics and keywords are related projects subsidized by government

- How many technologies, research topics and keywords are cooperated by all of or two of government, industry and academia.

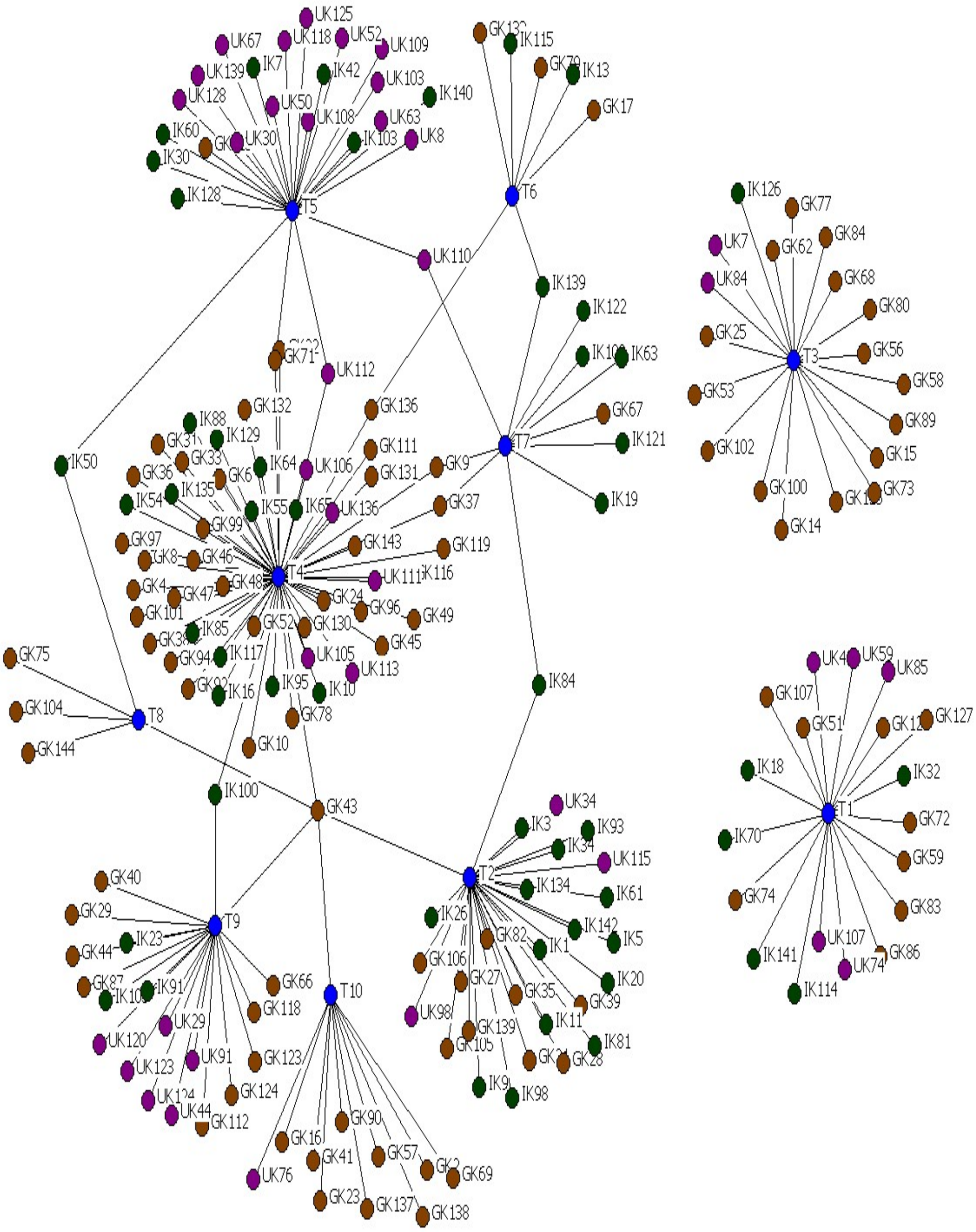


Fig 4.16 Triple helix between technology and keyword levels

4.3.4 Dissimilarity calculation

Triple helix gives an analysis of relation in four-level ontology. For a real roadmap, distance information which can give an idea about one place is near or far from another also should be provided to users.

Triple helix can provide rough distances between each two nodes as shown in Figure 4.16. For example, if two keywords are related to the same technology, we could say the distance between them is small. Simply speaking, the distance between two nodes could be roughly calculated as the smallest number of connections between them. In this study, we also calculate the distance of research situation between two keywords, because keyword is the most detailed information in four-level ontology with a method proposed by SiQuang Le and TuBao Ho (see SiQuang and TuBao 2005). The basic idea of this method is to consider the dissimilarity Dm(i,j) (distance) of a given attribute(m)-value pare(i,j) as the probability: there are how many pairs (p,q)- $\delta\{p,q\}$ in all probabilities- *k(k-1)*, of picking randomly a value pair(p,q) that is less similar than or equally similar in terms of order relations defined appropriately for data types (1). Disimilarities of attribute value pairs D(i,j) are then integrated into similarities between data objects using a statistical method (2).

$$\mathrm{Sm}\{i,j\}=\frac{\delta m\{p,q\}}{k(k-1)} \qquad (1)$$

$$\mathrm{D}\{i,j\}=-2\sum_{m=1}^{n}\ln Sm\{i,j\} \qquad (2)$$

- Attributes of keyword and their data types

There are 8 attributes for each keyword as shown in Table 4.4:

- Technologies (A1)

A class of technology identifying the research topics and keywords

- Number of researchers (A2)

The total number of unique researchers in subsidized projects, patents and papers related to a given keyword.

- Current subsidy (A3)

Whether there is at least one subsidized project related to a given keyword running in current year (S-still running F-finished N-no subsidized project).

- Subsidy amount (A4)

The total subsidy amount of all subsidized projects related to a given keyword.

- Number of patents (A5)

The total number of patents related to a given keyword.

- Current patent (A6)

Whether the patent related given keywords has been granted or is pending (P-pending G-granted N-no patent).

- Number of publications (A7)

The total number of papers related to a given keyword.

- Year of publication (A8)

The year in which paper related to a given keyword was published.

Attribute	Data type	Range
Technologies (A1)	categorical	T1…T10
Number of researchers (A2)	discrete	
Number of patents (A5)	discrete	
Number of publications (A7)	discrete	
Subsidy amount (A4)	continuous	
Year of publication (A8)	continuous	
Current subsidy (A3)	ordinal	S,F,N
Current patent (A6)	ordinal	P,G,N

Tab 4.4 Attributes and data types

There are 4 data types as shown in Table 4.4:

- Continuous data

Attribute values are continuous. (i.e. the height and the blood pressure for a person).

- Discrete data

Attribute values are discrete. (i.e. the number of cities in a country and the number of students in a class)

- Ordinal data

Attribute values are ordinal. (i.e. junior high school, high school, college or university, graduate school).

- Categorical data

Attribute values are categorical (i.e. the distinction of sex *male female,* blood types *A,B,O,AB*)

The main difference between ordinal data and categorical data is that there is an order relation between ordinal values while none of categorical values.

- Similarity measure for data of different types

Basic idea is to pick up randomly a value pair that is less similar than or equally similar to a chosen pair in terms of order relations defined appropriately for data types. Therefore, similarity measure will answer how to pick appropriate pair up for different data types:

Pair (i, j) is a chosen pair, pair (p, q) will be pick up if pair (p, q) is less similar than or equally similar to pair (i, j) in mth attribute (Vmp, Vmq, Vmi, Vmj are the values of pth , qth, ith, jth data of mth attribute)

  - Continuous data

$$P(p,q) \le P(i,j) \Leftrightarrow |Vmp - Vmq| \ge |Vmi - Vmj| \qquad (1)$$

  Pair (p, q) is less similar or equally similar to pair (i, j) if and only if the absolute difference of the pair (p, q) is greater than or equal to the pair (i, j).

  - Discrete data

$$P(p,q) \le P(i,j) \Leftrightarrow \frac{|Vmp \cap Vmq|}{|Vmp \cup Vmp|} \le \frac{|Vmi \cap Vmj|}{|Vmi \cup Vmj|} \qquad (2)$$

  Pair (p, q) is less similar than or equally similar to pair (i, j) if and only if the proportion between the intersection interval and the union interval of pair (p, q) is smaller than or equal to that of pair (i, j).

- Ordinal data

$$P(p,q) \le P(i,j) \Leftrightarrow |Vmp..Vmq| \supseteq |Vmi..Vmj| \qquad (3)$$

Pair (p, q) is less similar than or equally similar to pair (i, j) if and only if the interval between two values of the pair (p, q) contains that of the pair (i, j).

- Categorical data

$$P(p,q) \le P(i,j) \Leftrightarrow \{ \begin{matrix} Vmp = Vmi, Vmq = Vmj \\ Vmp \ne Vmq, Vmi = Vmj \end{matrix} \qquad (4)$$

Pair (p, q) is less similar than or equally similar to the pair (i, j) if and only if either they are identical or values of the pair (p, q) are not identical meanwhile those of the pair (i, j).

- Dissimilarity calculation

We give an example to calculate dissimilarity of K1 and K2, data as shown in Table 4.5

	A1	A2	A3	A4	A5	A6	A7	A8
K1	2	2	S	5000	1	P	0	0
K2	1	1	S	3000	0	N	0	0
K3	3	2	F	5000	0	N	1	2002
K4	2	2	F	2000	0	N	2	1998
K5	4	1	N	0	1	G	0	2005

Tab 4.5 Example of data for dissimilarity calculation

$$S(k1,k2)_{A1} = \frac{9 \times 2}{5(5-1)} = 0.9$$

$$S(k1,k2)_{A2} = \frac{6 \times 2}{5(5-1)} = 0.6$$

$$S(k1,k2)_{A3} = \frac{9 \times 2}{5(5-1)} = 0.9$$

$$S(k1,k2)_{A4} = \frac{8 \times 2}{5(5-1)} = 0.8$$

$$S(k1,k2)_{A5} = \frac{6 \times 2}{5(5-1)} = 0.6$$

$$S(k1,k2)_{A6} = \frac{5 \times 2}{5(5-1)} = 0.5$$

$$S(k1,k2)_{A7} = \frac{10 \times 2}{5(5-1)} = 1$$

$$S(k1,k2)_{A8} = \frac{10 \times 2}{5(5-1)} = 1$$

$$D(k1,k2) = -2\sum_{m=1}^{8} \ln Sm$$
$$= -2(\ln 0.9 + \ln 0.6 + \ln 0.9 + \ln 0.8 + \ln 0.6 + \ln 0.5 + \ln 1 + \ln 1)$$
$$= 4.2973$$

Then, we can calculate situation distance between keywords based on this method as shown in Table 4.6 (programmed by VB)

	A	B	C	D	E	F	G	H	I	J	K
1		1	2	3	4	5	6	7	8	9	10
2	1	FALSE	24.251051720	11.383166610	20.092168630	26.188170040	20.092168630	13.856097130	20.092168630	11.383166610	19.239999840
3	2	24.251051720	FALSE	26.207307590	8.044458466	16.849320700	8.229587524	28.791274960	7.971076497	26.207307590	8.586083679
4	3	11.383166610	26.207307590	FALSE	16.804208970	22.900210370	16.804208970	17.144194830	16.804208970	2.796066169	15.952040180
5	4	20.092168630	8.044458466	16.804208970	FALSE	10.923509520	1.549431886	19.388176330	0.882578648	16.804208970	2.457797770
6	5	26.188170040	16.849320700	22.900210370	10.923509520	FALSE	10.212700520	25.484177740	10.996891490	22.900210370	11.131320600
7	6	20.092168630	8.229587524	16.804208970	1.549431886	10.212700520	FALSE	19.388176330	1.608346308	16.804208970	1.738295822
8	7	13.856097130	28.791274960	17.144194830	19.388176330	25.484177740	19.388176330	FALSE	19.388176330	17.144194830	18.536007540
9	8	20.092168630	7.971076497	16.804208970	0.882578648	10.996891490	1.608346308	19.388176330	FALSE	16.804208970	2.491383782
10	9	11.383166610	26.207307590	2.796066169	16.804208970	22.900210370	16.804208970	17.144194830	16.804208970	FALSE	15.952040180
11	10	19.239999840	8.586083679	15.952040180	2.457797770	11.131320600	1.738295822	18.536007540	2.491383782	15.952040180	FALSE
12	11	11.383166610	26.207307590	2.796066169	16.804208970	22.900210370	16.804208970	17.144194830	16.804208970	2.796066169	15.952040180
13	12	22.258384840	15.085518690	18.970425170	8.544417290	13.488544690	7.910652012	21.554392540	8.611787376	18.970425170	8.017033840
14	13	15.688678590	30.623856420	18.976776290	21.220757790	13.440432730	21.220757790	14.984686290	21.220757790	18.976776290	20.368589000
15	14	11.383166610	26.207307590	2.796066169	16.804208970	22.900210370	16.804208970	17.144194830	16.804208970	2.796066169	15.952040180
16	15	26.683842370	7.328353905	28.640098240	14.047281190	19.243212810	14.413048710	31.224065610	14.011804190	28.640098240	14.770142800
17	16	25.637346080	2.020056182	27.593601960	8.467537828	17.364994950	8.613165820	30.177569320	8.461754343	27.593601960	8.792811531
18	17	20.092168630	8.231394372	16.804208970	1.563024172	10.236647550	0.768069262	19.388176330	1.613668114	16.804208970	1.726708304
19	18	22.107657010	16.436714940	18.750586960	15.274156590	20.278938420	14.612835390	26.633695090	15.298059900	18.750586960	14.516660730
20	19	22.978085850	31.337206310	14.390985410	21.934107680	28.030109090	21.934107680	22.274093550	21.934107680	14.390985410	21.081938890
21	20	11.383166610	26.207307590	2.796066169	16.804208970	22.900210370	16.804208970	17.144194830	16.804208970	2.796066169	15.952040180
22	21	15.088923130	13.262778320	11.800963460	6.052741305	12.417280100	6.827406094	20.848951350	6.076688326	11.800963460	7.718284668
23	22	19.410315460	8.467537828	16.122355790	2.020056182	10.737099250	1.278243674	18.706323160	2.052126353	16.122355790	1.203279782
24	23	23.804764620	16.150909670	20.516804950	10.313063660	16.080447690	10.463115800	23.100772310	10.302914010	20.516804950	10.479064240
25	24	19.239999840	8.589711469	15.952040180	2.484621307	11.200978780	1.812400292	18.536007540	2.513863583	15.952040180	0.861888808
26	25	23.415581320	14.085761340	20.127621650	8.237185790	12.325760250	7.495373282	22.711589010	8.269255961	20.127621650	8.213479156
27	26	11.383166610	26.207307590	2.796066169	16.804208970	22.900210370	16.804208970	17.144194830	16.804208970	2.796066169	15.952040180
28	27	15.979545160	13.002139010	12.691585490	6.652809672	11.863821260	7.092948449	21.740573380	6.713720544	12.691585490	7.944610132
29	28	17.517811340	12.598807250	14.229851670	7.192936928	12.213537850	7.449964311	23.278839560	7.252369274	14.229851670	8.079315097
30	29	43.711646060	21.005309560	45.653716780	21.724585160	26.832367330	21.747848900	48.237684140	21.721968500	45.653716780	21.838383080
31	30	13.856097130	28.791274960	17.144194830	19.388176330	25.484177740	19.388176330	2.931505593	19.388176330	17.144194830	18.536007540
32	31	22.521056840	2.156149106	24.477312720	7.992575094	16.607199470	8.049610209	27.061280080	7.976464535	24.477312720	8.653277271
33	32	13.331368600	28.266546430	16.619466300	18.863447800	24.959449210	18.863447800	12.627376300	18.863447800	16.619466300	18.011279010
34	33	20.982790670	7.868631729	17.694831000	2.020056182	9.892969597	1.278243674	20.278798360	2.052126353	17.694831000	1.996349548
35	34	5.480053715	26.880252070	8.768151415	17.477153440	23.573154850	17.477153440	11.241081940	17.477153440	8.768151415	16.624984650
36	35	14.902796140	9.358114511	16.844866860	10.393575130	15.289384600	10.521707420	25.893854750	10.387017180	16.844866860	11.126519770
37	36	19.239999840	8.574518775	15.952040180	2.361565980	10.734485050	1.650756985	18.536007540	2.434947948	15.952040180	0.932177634
38	37	20.982790670	7.842379442	17.694831000	1.846834472	9.948124285	1.406695695	20.278798360	1.901362301	17.694831000	2.263443803
39	38	19.239999840	8.586083679	15.952040180	2.457797770	11.131320600	1.738295822	18.536007540	2.491383782	15.952040180	0.535342084
40	39	15.088923130	13.367433990	11.800963460	6.236454805	12.280176130	6.676593583	20.848951350	6.297365678	11.800963460	7.579315157
41	40	22.521056840	7.116434559	19.233097180	1.845965473	11.046564850	2.499189001	21.817064540	1.761203974	19.233097180	3.122383434
42	41	25.377239820	15.552003570	22.089280160	10.313063660	15.236318030	10.463115800	24.673247520	10.302914010	22.089280160	11.272134010
43	42	17.590481930	25.935417240	14.233411880	21.776534150	27.872535560	21.776534150	22.116520020	21.776534150	14.233411880	20.924365360
44	43	24.615694830	17.442828680	21.327735160	10.901727280	15.845854690	10.267962000	23.911702530	10.969097370	21.327735160	10.374343830

Sheet1 / Sheet2 / Sheet3

Tab 4.6 Research situation distance between keywords

4.4 Applications of RMA support

4.4.1 Network

A computer network consist of multiple computers connected together using a telecommunication system for the purpose of communicating and sharing resources. A social network is a social structure made of nodes (which are generally individuals or organizations) that are tied by one or more specific types of relations, such as financial exchange, friendship, hate, trade, web links, or airline routes.

We use a free soft-ware named net-draw to make the map of network. Net-draw is a program for drawing networks. It uses several different algorithms for laying out nodes in 2-dimensional space. Net-draw reads UCINET system files, UCINET DL text files, and Pajek text files (.net, .clu and .vec). It can save data to Pajek and to Mage. It can save diagrams as EMF, WMF, BMP and JPG files. It can also print directly from the program at high resolution (much better than printing document containing embedded graphics). The program has a number of useful features, including:

- *Multiple Relations*. You can read in multiple relations on the same nodes, and switch between them (or combine them) easily.
- *Valued Relations*. If you read in valued data, you can sequentially "step" through different levels of dichotomization, effectively selecting only strong ties, only weak ties, etc. In addition, you have the option of letting the thickness of lines correspond to strength of

ties.

- *Node Attributes.* The program makes it convenient to read in multiple node attributes for use in setting colors and sizes of nodes (as well as rims, labels, etc.). In addition, the program makes it easy to turn on and off groups of nodes defined by a variable, such as males or members of a given organization. [In addition, there are buttons for deleting isolates and pendants.
- *Analysis.* A limited set of analytical procedures are included, such as the identification of isolates, components, k-cores, cut-points and bi-components (blocks).
- *2-mode Data.* Net-draw can read 2-mode data, such as the Davis, Gardner and Gardner data and automatically create a bipartite representation of it.
- *Saving Pictures.* Network diagrams can be saved as bitmaps (.bmp), jpegs (.jpg), windows metafiles (.wmf) and enhanced metafiles (.emf). In addition, the program exports to Pajek and Mage.
- *Printing.* There is a Print button. This is very good for creating publication-quality diagrams because the results utilize the full resolution of the printer. (When you save an image like a bitmap to disk and insert into a document and then print that, the image resolution is no better than your screen's.)
- *Appearance Options.* A full range of options is implemented, including the ability to change sizes and colors of nodes, node-rims, labels, lines and background. Different node shapes are not yet

implemented. You can also rotate, flip, shift, resize and zoom configurations.

- *Layout*. Two basic kinds of layouts are implemented at present: a circle and an MDS/ spring embedding based on geodesic distance. The MDS includes options for exaggerating clustering, biasing toward equal-length edges, and turning on/off node-repulsion.

dl n= 20 format = edgelist1
labels embedded
data:

②

T1	T10	1
T1	T4	1
T10	T2	2
T10	T3	1
T10	T4	2
T10	T6	1
T10	T8	1
T10	T9	1
T2	T3	1
T2	T4	5
T2	T5	1
T2	T6	2
T2	T7	3
T2	T8	1
T2	T9	4
T3	T4	1
T3	T9	1
T4	T5	3
T4	T6	2
T4	T7	4
T4	T8	2
T4	T9	3
T5	T6	1
T5	T7	1

Technology.txt

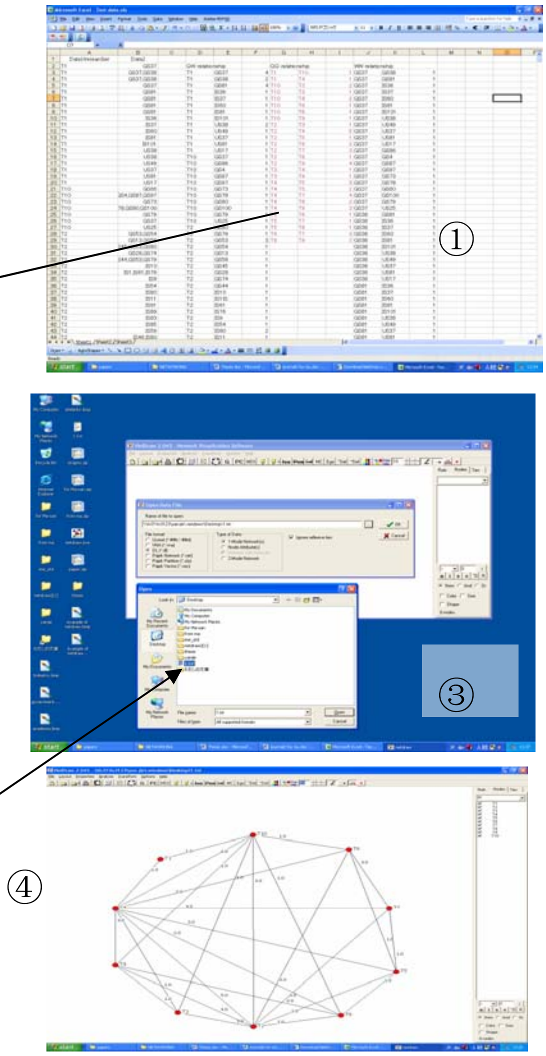


Fig 4.17 Net-draw software

How to use net-draw software is shown in Figure 4.17:

Step 1: Calculate number of relations (programmed by VB)

Step 2: Save the result of step1 as a text file

Step 3: Run net-draw software, select text file saved in step2

Step 4: Map of network drawing

Therefore, the basic idea of net-draw is that if A and B have relation, there will be a line between nodes A and B on the map. The basic nodes in the network are researchers that are tied by technology (as shown in Figure 4.18), research topics (as shown in figure 4.19 and 4.20) and keywords (as shown in Figure 4.21) in patents, projects and papers, also by affiliation (as shown in Figure 4.22). If we say one researcher is related to another, that means that they are doing related work with the same technology, topic and keyword or in the same academic area, industry or government. Network will help researchers find potential cooperator for a specific project.

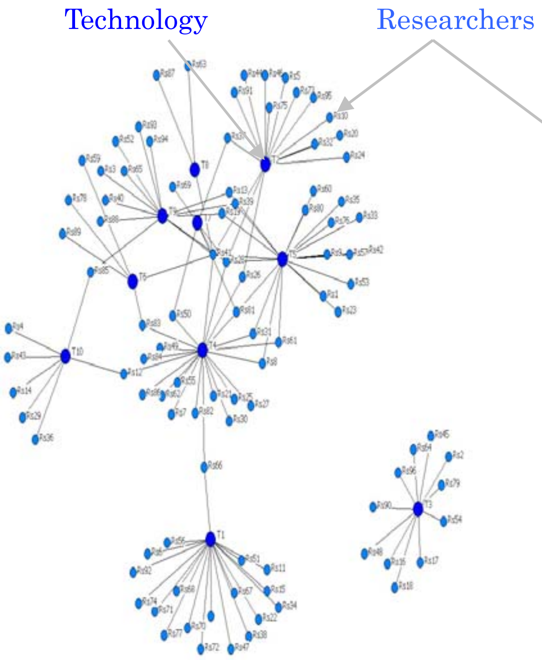


Fig 4.18 Network of researcher-technology

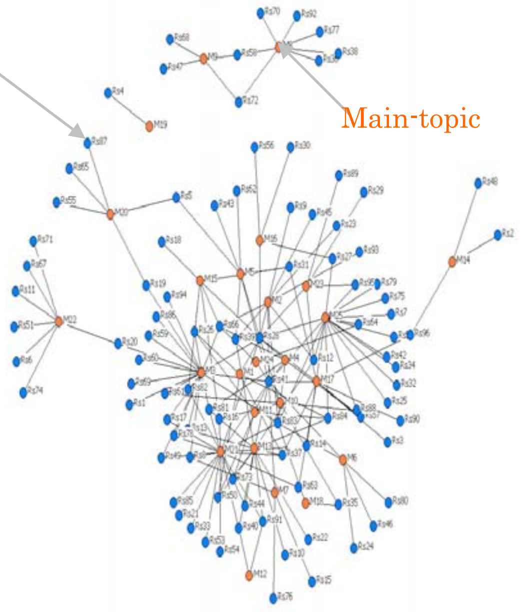


Fig 4.19 Network of researcher-maintopic

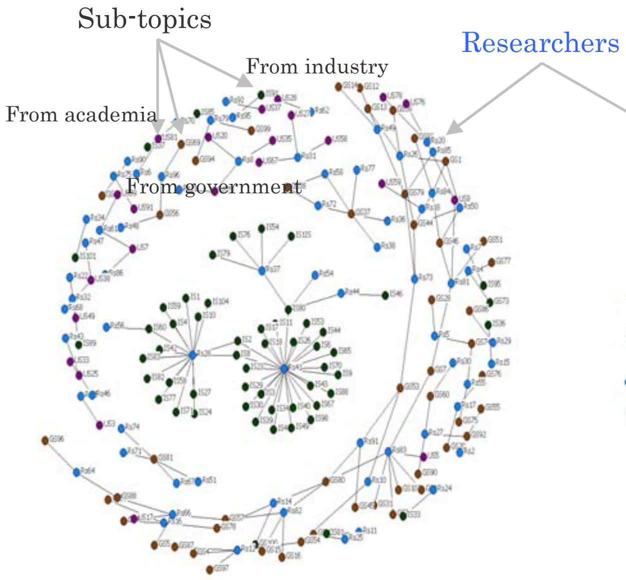


Fig 4.20 Network of research-subtopic

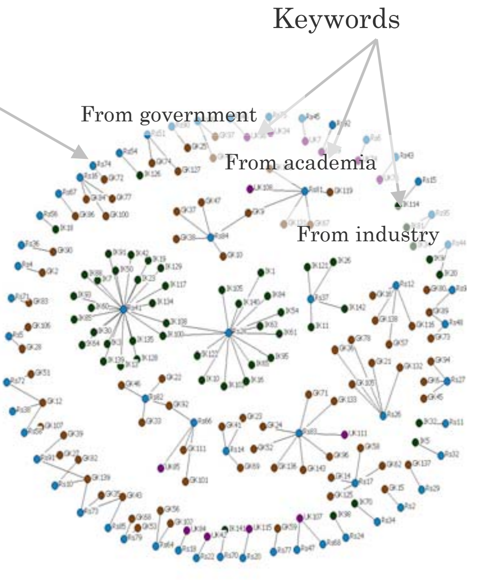


Fig 4.21 Network of research-keyword

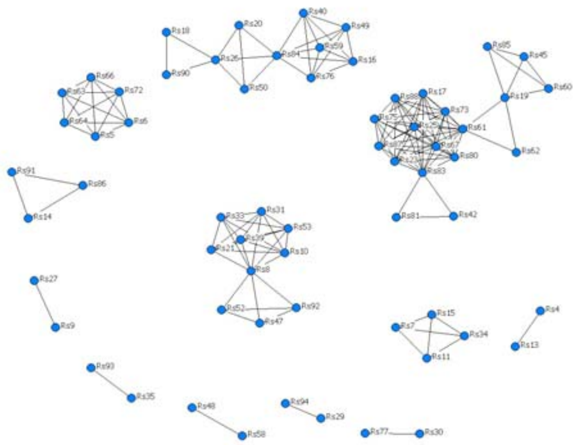


Fig 4.22 Network of researchers by affiliation

4.4.2 Map

Network is to help researchers find potential cooperators by mapping relation among researchers. We also use the software to make map of relations among topics and keywords as shown in Chapter 4.3.2. (Figure 4.9, 4.10, 4.11 and 4.16) Such maps will help researchers find potential cooperative projects, and also make a clear picture about where they are and where they want to go. As a result of RMA for supporting scientific researchers in academia, we also need map to help answer how to get there which is designed as shown in Table 4.7.

Because keywords are the most detailed data on four-level ontology, as a result of RMA in academia, we help researchers find how to get keyword 2 from keyword1, including marketing information in a time dimension.

Where are you	Where do you want to go
K1	K2
From year	End year
Marketing information	Marketing information
Researcher name	Researcher name
Affiliation	Affiliation
Academia Industry Government	Academia Industry Government
How to get there	
K1 → K5 → T3 → T6 → K7 → K2	

Tab 4.7 Roadmap from K1 to K2

4.4.3 Search

Ontology extraction, triple helix cooperation, network and map,such analysis will help researchers answer following questions:

- What projects were, are, or will be supported by governments based on the technology, topics and keywords?
- Who (persons and academia) was, is or will be in charge of the projects?
- What was, is or will be the budget provided by the government?
- How many patents have been issued or are under application based on the technology, topics and keywords?
- Who holds or is applying for patents?
- Who from academia is doing research related to the technologies, topics and keywords?
- What are publications of researchers in academia?

- Which technologies/research topics are often addressed by academia-industry-government, and which are not?
- What are the relationships among technologies, research topics and researchers?
- Who will be potential cooperators or competitors on which technology, topic and keyword in which project?
- How to get a technology, topic and keyword from another?

and so on. To answer more and more such questions we need to design a searching tool. Users can search data and information in datasets or results of analysis by inputting keywords which they are interested in. Chapter 5 will introduce a RMA support system designed for these purposes.

Chapter 5

RMA Support System

This Chapter will introduce a support system with searching, networking and mapping functions. First three functions and their interfaces will be introduced, then how to use the system will be explained. As evaluation of the system, users' opinions will be introduced at the end of this Chapter.

5.1 RMA support system introduction

As mentioned in Chapter 3, in the framework of computer based RMA support, there are 3 modules:

- Domain-defining module- input (select) from users
- Data collecting module- related Ren's work (the same lab)
- Data analyzing module
    - Ontology extraction- related Ren's work
    - Triple helix cooperation analysis- related Nie's work (the same lab)
    - Searching, networking and mapping- RMA support system

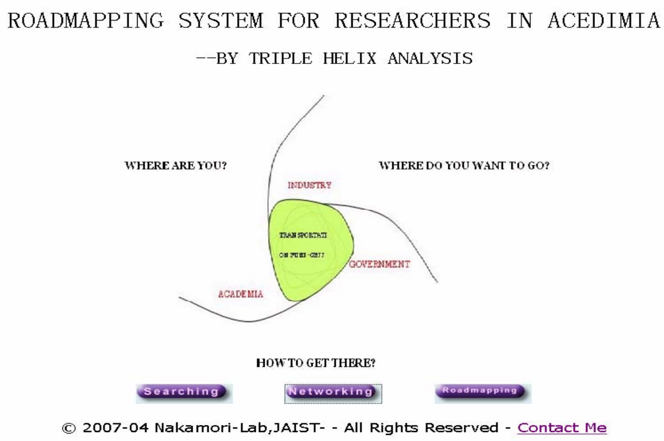


Fig 5.1 Interface of support system

Therefore, support system designed in this study based on case-study as introduced in Chapter 4 is one part of framework mentioned in Chapter 3, to integrate all analysis results. Users can search data and information by inputting keyword (because keywords are most detailed data on four-level ontology). System can help users answer where are you? and where do you want to go? by searching and networking, and answer how to get there? by mapping also can help researchers find potential cooperators or competitors in a specific project related a given keyword, research topic and technology (programmed by JAVA). Fig 5.1 gives an interface of support system designed in this study. There are three buttons (in purple) which link to three interfaces of searching, networking and mapping functions. If click "contact me", a email will be sent to yan-jie@jaist.ac.jp

5.2 RMA support system functions

- Function 1 Searching

Figures 5.2 and 5.3 are the main interfaces for searching, and Figure 5.4 shows the results. With the window shown in Figure 5, we provide 8 links explaining ontology, including *144 keywords*, *106 sub-topics*, *25 main-topics*, *10 technologies* and their relations also including relations between *keywords and subtopics*, *sub and main topics*, *main topics and technologies,* and *technology and keywords*. User can search the database with the keywords, because keywords are the most detailed data on four-level ontology. User can select one keyword from the list, and then push the "Search" button. 20 keywords similar (based on results of dissimilarity calculation mentioned in Chapter 4) to the keyword selected are shown in Figure 5.3. The most similar keyword is itself, and the distance is 0. As shown in Figure 5.3, if user wants to know more about a keyword, by pressing the blue button detailed information will be shown, and pressing the map button network map will be shown, as shown in Figure 7. And user can perform more detailed analysis on the result, for example, analysis of the distribution of funding from government along the time-dimension.

Searching function will give an overview to researchers about triple helix of Academia-Industry-Government using each keyword in the transportation fuel-cell research field: for each keyword, there is data on how may researchers are doing the same work in academia, industry and government, how many research projects are related to each other in academia, industry and government, etc., and this will help them get ideas about where they are and where they want to go, also help them find potential cooperative research projects.

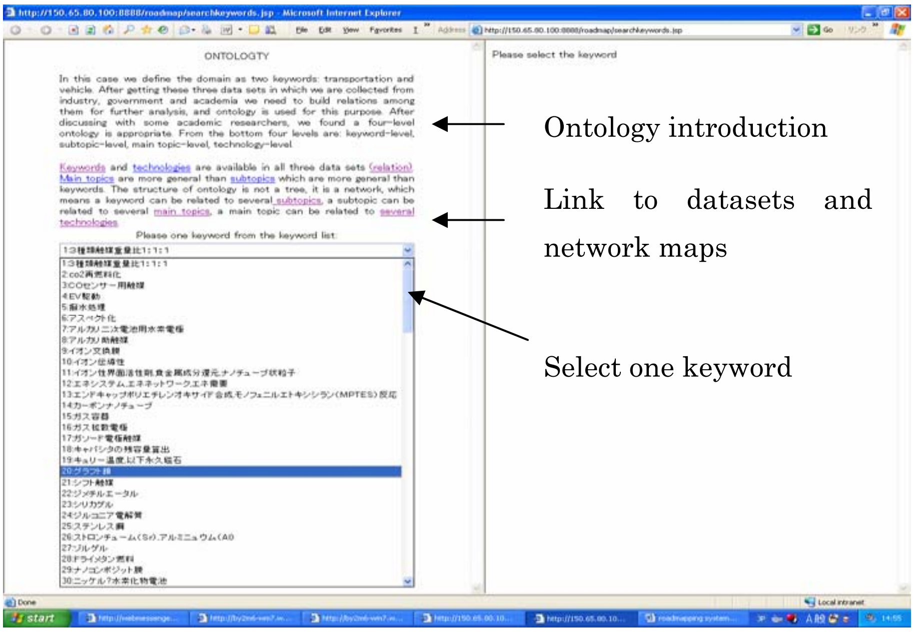


Fig 5.2 Interface for setting search criteria

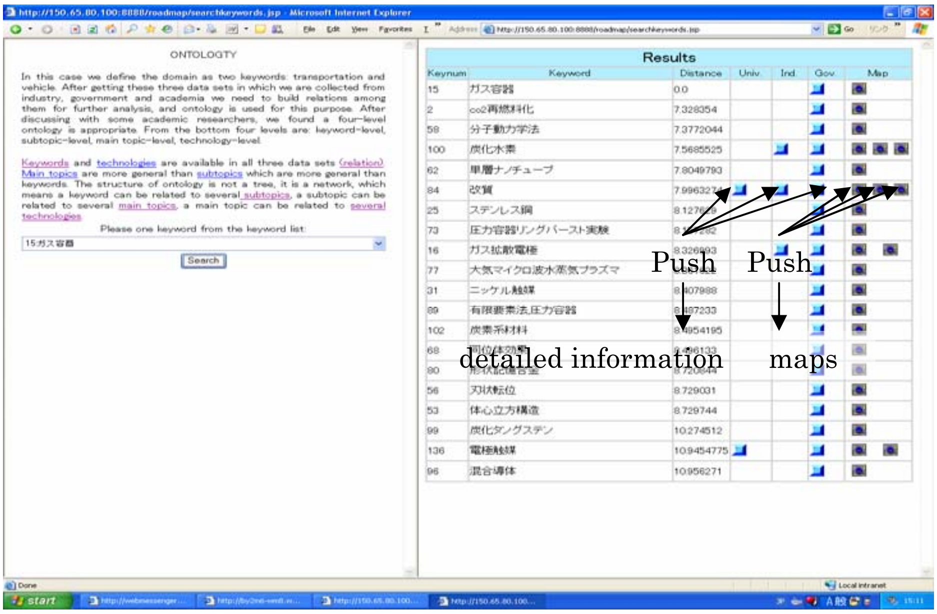


Fig 5.3 Interface for the search results

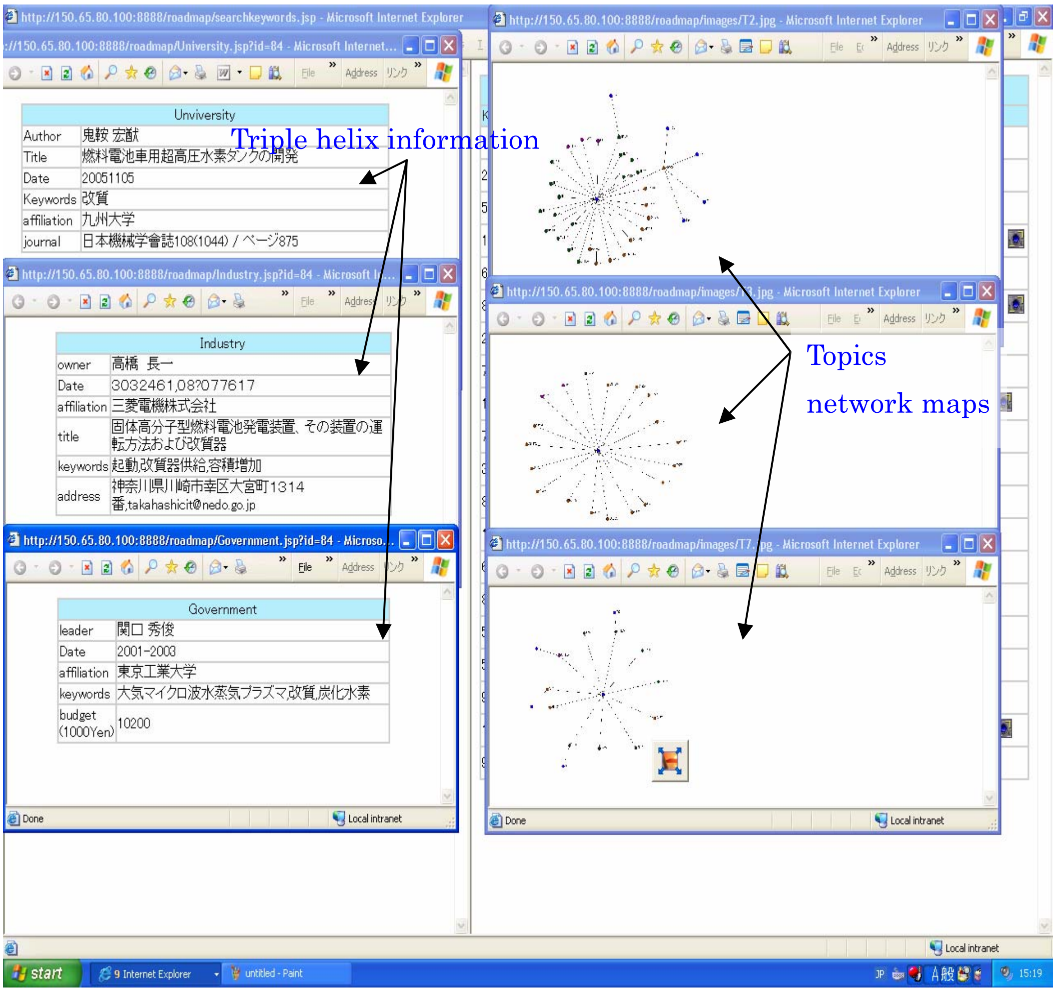


Fig.5.4 Detailed information searching

- Function 2 Networking

As mentioned in Chapter 4, the basic nodes in the network are researchers that are tied by technology, research topics and keywords in patents, projects and papers. The network can also provide rough distances between each two nodes, and also those elements linked to the basic nodes, such as publications, patents, projects, researchers, and so on by calculating the connections between them. For example, if two topics are related to the same technology, we could say the distance between them is small. Simply speaking, the distance between two nodes could be roughly calculated as the smallest number of connections between them.

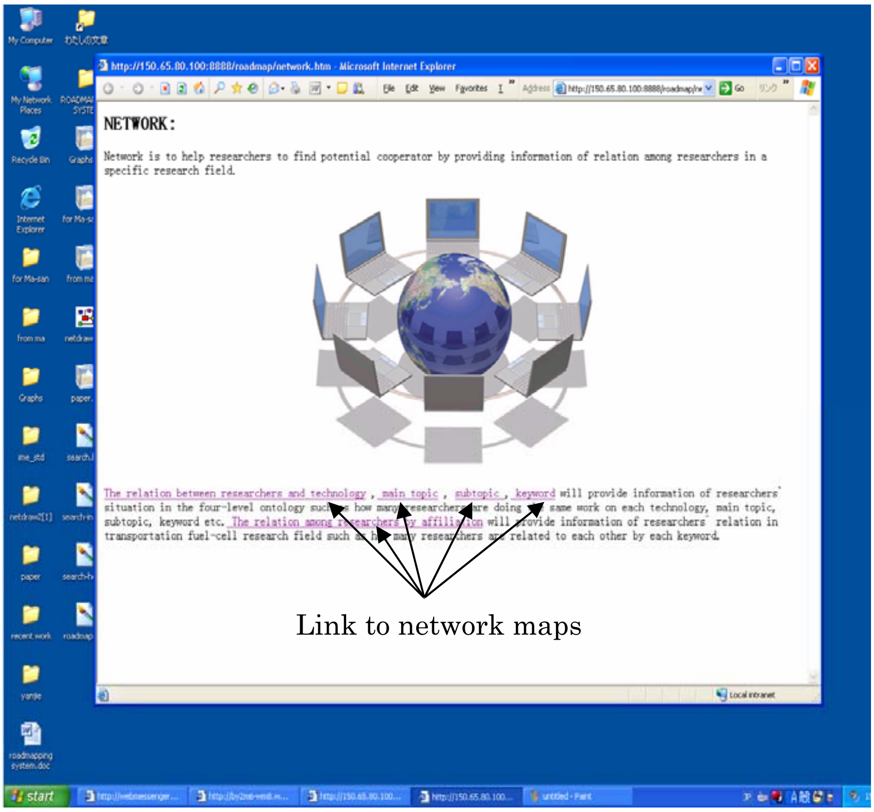


Fig.5.5 Network interface

Networking interface as shown in Figure 5.5, gives 5 links for network maps of *researchers and technologies, sub topics, main topics, keywords* and network of *researchers by affiliation*. The basic idea is, if we say one researcher is related to another, that means that they are doing related work with the same technology, topic and keyword or in the same academic area, industry or government. Networking function will help researchers to answer where they are and where they want to go, also help them find potential cooperators and competitors for a specific research project related to a given keyword, topic or technology.

- Function 3 Mapping

Mapping function integrates search function and networking function to help researchers to answer the question of how to get there. After searching and networking, researchers will have a clear picture of where they are and where they want to go. They can select the keyword in the list and push the “how to get there” button. Result is shown in Figure 5.6. The results also give some information of market by time dimension, and roots common to keywords.

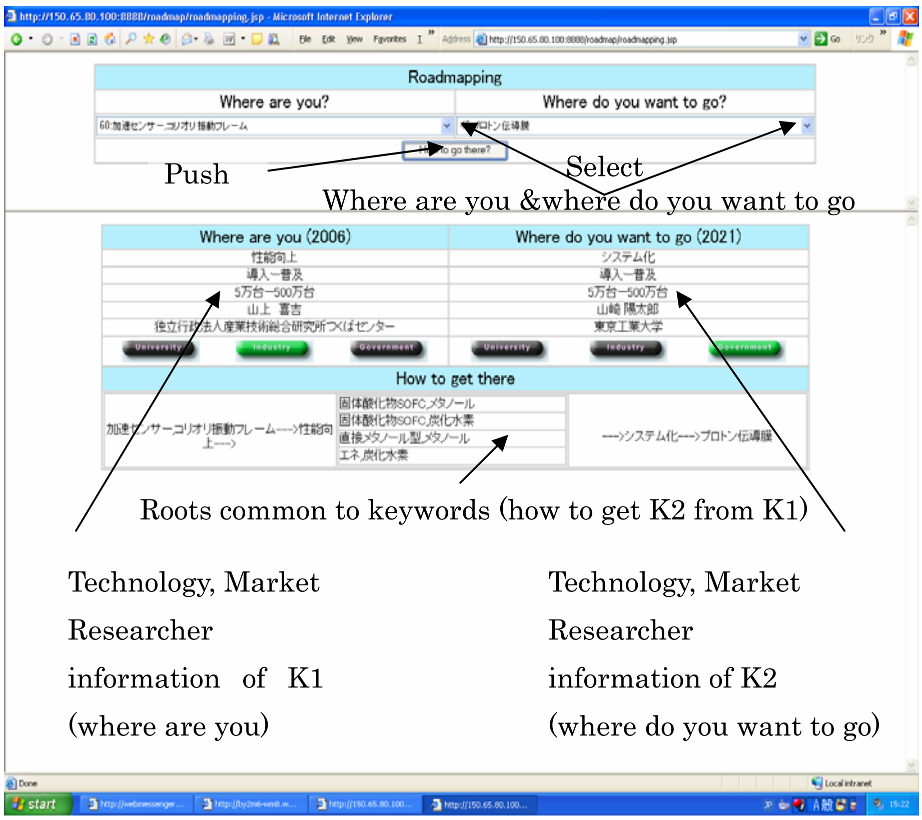


Fig.5.6 Interface of mapping and result

The support system can give users supports as following.

- Finding potential collaborators

Those researchers in academia, industry or government who are a relatively small distance or have strong relation to a user could be potential collaborators with the user.

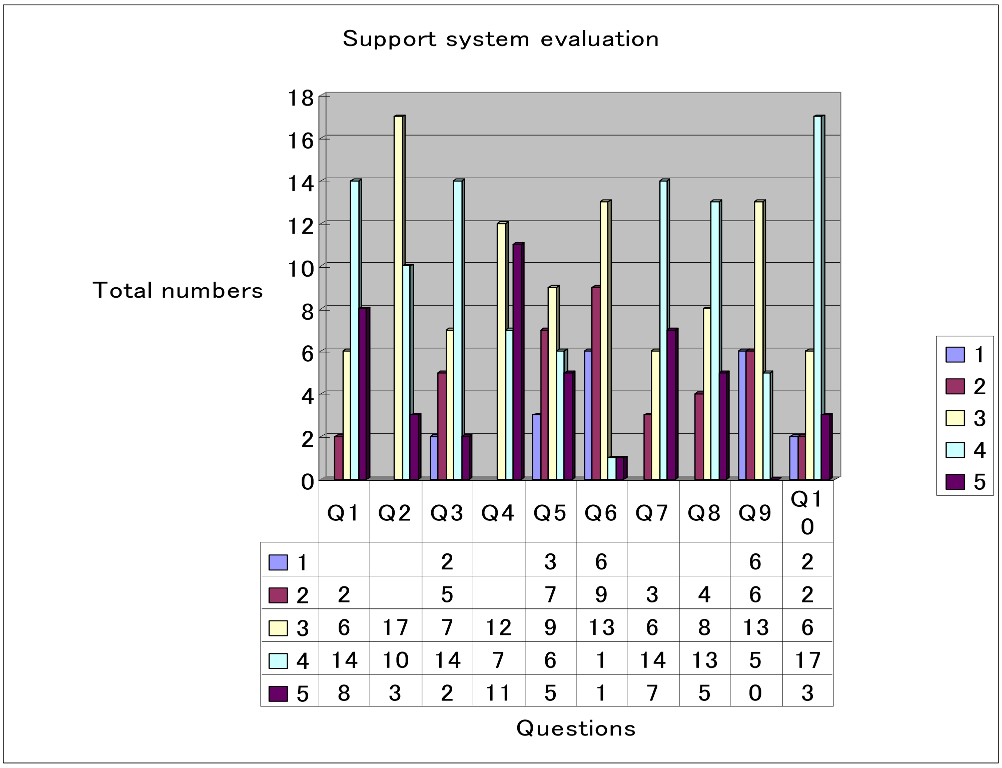
- Deciding new research topics

Researchers commonly want to do some different topics after doing a topic for several years. Doing a totally different topic from the former one usually is not a good idea, since it will need completely different expertise. In this sense, providing the distance between keywords of research topics is helpful when researchers want to start a different topic. Although the network could not provide new topics, because all topics in the datasets are existing ones, it can somehow inspire researchers to put forward new topics. From the viewpoint of complex systems, any new technologies can be looked upon as the combination of previous existing technologies, and a new technology will serve as a component/block for further new combinations. Although it is almost impossible to model the genotype-phenotype structure of every combination of technology or topics, providing distance between topics aids researchers' intuition in putting forward new topics.

Support system online address: http://150.65.80.100:8888/roadmap/

5.3 RMA support system and the idea evaluation

We provided the system to 3 labs in JAIST. We made a survey of the uses of system (questionnaire in appendix 2) and interview with 30 users as shown in Figure 5.1:



	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
1			2		3	6			6	2
2	2		5		7	9	3	4	6	2
3	6	17	7	12	9	13	6	8	13	6
4	14	10	14	7	6	1	14	13	5	17
5	8	3	2	11	5	1	7	5	0	3

Fig 5.1 Evaluation of system uses

- 85% of users give "4" for question 10 " Would you like to use such system when you want to find new interests or new research topics"
- 100% of users give higher than "3" for question 2 "Is it useful for find new idea" and question 4 "Is searching function useful "
- 30% of users give "1" for question 6 "Is mapping function useful"

and question 9 “Can you answer “how to get there” by using system” The reasons are explained as following:

Support system is very useful for understanding “where are you” and “where do you want to go”, but for “how to get there” it is not easy to get conclusion only by this system.

They have the same opinions as following:

- Almost users in those labs said that what we provided to them was very helpful in making answer to those three questions:
    - Where are you?
    - Where do you want to go?
    - How to get there?
- System is very functional to use
- Searching and networking will let users have a clear picture for the position of their research
- Maps are very easy for understanding the positions and relations
- It is a good idea that introduce RMA for supporting researchers’ new interests and new research topics finding
- Different from general technology road mapping used in industry and government as a planning tool, RMA in this study is more likely to making a real roadmap, because it also calculates distances between two points on the map.
- If there are 3D or dynamic maps, system will be more interesting and results also will be easier to understand
- If datasets can be changed to research information of lab members,

it will be very useful for lab management.

For the idea evaluation, we did interview with researchers (professors and students) from three universities (mentioned as Chapter 4).

They have the same opinions:

The idea is very new that support researchers when they want to find new research topics. There are so many works have been done for supporting researchers to make research plan but only it is not enough, researchers also need support before making research plan, to understand:

where are you?

where do you want to go?

how to get there?

(not only in a time dimension).

- Professors

The idea will help to make sure our research positions and understand relations among research topics and researchers in a specific research field. Information of cooperative projects and cooperators, competitors are useful.

- Students

System and the idea will help to understand what researchers (university, industry, government) are doing now in a specific research field. It is useful to help make decision for choosing a research topic.

Chapter 6

Conclusion

Chapter 6, as a final chapter, reviews RMA support in academia we designed, summarizes the results and discusses their implications.

6.1 Summary and limitation

6.1.1 Summary

In this study, we addressed a problem that how to support RMA in academia for scientific researchers when they want to find new interests or new research topics. After compare applications of RMA in academia with them in industry and government, we designed a framework of a computer-based RMA support. The approach uses a four-level ontology and triple helix analysis to analyze the data in three datasets, namely academia dataset, industry dataset, and government dataset in which data collected from academia, industry and government within a specified domain. Then, we did a case-study, to make clear real applications of RMA support for scientific researchers in the field of transportation using fuel-cells. Based on the lessons on case-study a RMA support system was proposed.

6.1.2 Limitation

The computer-based approach itself does not generate research roadmaps. Its purpose is to give support to researchers in academia. It can be looked at as a starting point of road mapping process. It can be integrated with other computer-based approaches, and also most likely with expert-based approaches and workshop-based approaches, for generating research roadmaps. During application, the approach should be customized according to different objectives and other contexts. For example, in the case study introduced in this study, data were from Japanese databases, since in the project the researchers cared most about were the triple helix of academia-industry-government in Japan. When applying the approach in a different country or in a different field, the data sources will be different. When defining the four-level ontology, different methods can be applied according to real situations. Also researchers are not limited to use the four-level ontology, if they have found a two or three-level ontology is more appropriate in their field.

6.2 Further study

Many problems and lessens have been revealed after this dissertation. RMA support defined in academia for scientific researchers find new interests or new research topics is quite different from its definition in industry and government. RMA support in academia is not a planning support tool, it will support researchers find targets of their scientific research. Therefore RMA support in academia will help researchers answer the same three question, where are you? where do you want to go? how to get there? but different to it in industry and government to answer "where do you want to go", it is not plan but relation, a physical position like a real map. In this study, we did a case-study, a case of supporting researchers in transportation using fuel-cells technology research field. As further study, we will do other cases in different research field not only in Japan. Also, we introduced an idea of triple helix , a method for calculating dissimilarity (distance) and a support system, as further study we will try to integrated more methods and soft wares to improve RMA support in academia both for supporting find new research topics or new interests and for planning.

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Appendix

Appendix 1

Interview with fuel-cells researchers for first-cut roadmap (questions)

輸送用燃料電池ロードマップについて

ロードマップ

一般的なロードマップについて

１．ロードマップという概念をご存知ですか

・聞いたことがある・詳しく調べたことがある・実際に使用している・聞いたことがない

２．ロードマップ用途としてどんな使い方のイメージをもっていますか

・企業での用途　・プランニングツール　・予測ツール　・多目的ツール

・研究現状の把握と研究スケジュールの作成　・産官学連携促進ツール

・興味がない　　　その他＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿

作られた輸送用燃料電池ロードマップについて

１．ロードマップの予測の有用性について

・研究内容に役立つ　・研究方向を決定するのに役立つ　・役に立たない　・わからない

第一問「役立つ」と答えた方

２．ロードマップのどの点が有用であると思いますか

・自分の研究を俯瞰できる　・技術の将来予測ができる　・ほかの要素技術と比べられる

・市場、経済影響情報を把握できる　・経済影響予測ができる　その他＿＿

第一問「役に立たない」「分からない」と答えた方

３．ロードマップにプラスαの要素を付加するとしたらどのようなものを考えますか

・もっと広い範囲での予測　　・もっと深く掘るデータで予測

・シナリオを作る　・提言をする　・プロセスシステムを構築　・その他

データ

１．下記の予測項目で予測した結果について

・要素技術　　　A 研究内容の位置づけ（内容・時間）　B 類似・関連研究の把握

C必要ではない　　D<u>その他　　　　　　　　　　　　</u>

・市場情報　　　A 市場情報の俯瞰　B 研究結果の市場効果の把握　C 必要ではない

D<u>その他　　　　　　　</u>

・経済影響　　　A研究の経済効果の把握　B　必要ではないC<u>その他　　　</u>

・環境影響　　　A研究の環境効果の把握　B　必要ではないC<u>その他　　　</u>

２．それ以外興味があるデータ・項目

・個別の技術予測<u>（どんな技術）　　　　　　　　　　　　　　　</u>・技術の難易度

・政府の補助金　　　　・産学官連携研究情報　　　　・<u>その他　　　</u>

<u>意思決定</u>

１．研究の際の重要度について

a.政府の方針　b.ほかの研究者の動向　c.学会や協会の動向　d.海外動向　e.ほか

答え例：　燃料電池技術　　a＞ c＞ b＞ d＞ e（自分の興味）＞研究内容決定

重要度　　　　＞　＞　＞　＞　＞　研究内容決定

プロセス　　→ →　→　→ →　　研究内容決定

２．ロードマッピングプロセス(ロードマップ作成プロセス）は意思決定に役に立つと思いますか

・はい　・いいえ(「いいえ」と答えた方は次の問題に)

３．ロードマッピングとは自身の研究においてどのように使用しますか

・ 情報・データの収集ツール　・形式の変換　・予測＋アルファ（シナリオ、提言・・・）

<u>その他　　　　　　　　　　　</u>

４．ロードマッピングとは自身の研究においてどのような位置づけですか

（仮にロードマッピングを自身研究に用いるとしたら）

ご協力を誠にありがとうございます

Appendix 2

Questionnaire for evaluation of RMA support system

RMA support system evaluation questionnaire

Please answer following 10 questions by giving a number from 1 to 5,
5: perfect　4 very good　3 good 4 bad 5 very bad
If choose 1, please give reasons

Q1 Is it very easy to understand about how to use it
5
4
3
2
1______________________________

Q2 Is it functional to use
5
4
3
2
1_____________________________

Q3 Is it useful for find new idea
5
4
3
2
1_______________________________

Q4 Is searching function useful
5
4
3
2

1________________________________

Q5 Is networking function useful

5

4

3

2

1__________________________________

Q6 Is mapping function useful

5

4

3

2

1________________________________

Q7 I can answer "where are you" by using system

5

4

3

2

1_______________________________

Q8 Can you answer "where do you want to go" by using system

5

4

3

2

1_______________________________

Q9 Can you answer "how to get there" by using system

5

4

3

2

1________________________________

Q10 Would you like to use system when want to find new interests or new research topics

5

4

3

2

1

Appendix 3

10 Technologies

T1	scenario (supply chain facilities for fuel-cells)	シナリオ
T2	practicability of fuel-cells	実用性
T3	hydrogen storage technology	水素貯蔵
T4	efficiency increase	高効率
T5	capability of fuel-cells	性能向上
T6	cost reduction	コスト低減
T7	small-scale and miniature	小型化
T8	metallic materials	金属材料
T9	fuel-cell system	システム化
T10	energy of fuel-cells	エネルギ

Appendix 4

25 Main-topics

M1	イオン
M2	電極
M3	触媒
M4	白金
M5	反応
M6	温度
M7	磁気
M8	エネ
M9	環境
M10	水素
M11	プラズマ
M12	プロトン
M13	膜
M14	容器
M15	改質
M16	測定
M17	金属
M18	電解質
M19	燃料
M20	駆動・制御
M21	材料
M22	政策
M23	電気
M24	炭素
M25	電池製造法

Appendix 5

106 Sub-topics

S1	イオン
S2	水素電極
S3	ガス電極
S4	白金電極
S5	光電極
S6	電極製法
S7	電極触媒
S8	白金触媒
S9	光触媒
S10	３種類触媒
S11	COセンサー用触媒
S12	アルカリ助触媒
S13	シフト触媒
S14	ニッケル触媒
S15	パラジウム触媒
S16	ロジウム触媒
S17	改質触媒・分解触媒
S18	水素供給装置用触媒
S19	複合触媒
S20	触媒CVD
S21	高分散触媒
S22	白金合金
S23	モノフェニルエトキシシラン（MPTES）反応
S24	電極部反応
S25	多層セル触媒反応
S26	原子プラズマ重合反応
S27	熱媒式改質反応
S28	燃料極反応
S29	部分酸化反応
S30	キュリー温度
S31	低温作動
S32	水温度調整

S33	温度低下利用
S34	永久磁石
S35	磁気共鳴
S36	磁石回転
S37	エネ
S38	環境影響・環境負荷
S39	ニッケルー水素化物
S40	水素発生
S41	水酸化ナトリウム・水素化ナトリウム
S42	炭化水素
S43	三元系水素
S44	プラズマ
S45	プロトン
S46	イオン交換膜
S47	ナノコンポジット膜
S48	プロトン伝導膜
S49	マグネシウム・ニッケル合金薄膜・マグネシウム薄膜
S50	有機・無機複合膜
S51	自己加湿型電解質膜
S52	複合電解質薄膜
S53	電解質膜
S54	膜製法
S55	ガス容器
S56	圧力容器
S57	水蒸気改質
S58	燃料改質
S59	ほか改質
S60	測定
S61	貴金属成分還元
S62	ステンレス鋼
S63	各部平板
S64	燃料タンク
S65	遷移金属元素添加
S66	高耐食性表面処理鋼板
S67	二元合金

S68	合金応用
S69	形状記憶合金
S70	吸蔵合金
S71	各部平板
S72	ジルコニア電解質
S73	燃料
S74	駆動
S75	制御
S76	カーボンナノチューブ
S77	粒子
S78	マイクロ波
S79	メタノール
S80	ほか材料
S81	政策
S82	停車状態の給電
S83	単位電池
S84	導電性高分子
S85	微小直流電流高感度
S86	電気二重層キャパシタ
S87	電気浸透係数
S88	炭素
S89	撥水処理
S90	アスペクト化
S91	パルスパワー技術
S92	レイノルズ数
S93	三相界面
S94	体心立方構造
S95	円錐ローラー,ボールベアリング
S96	刃状転位
S97	分割極セル
S98	加速センサー,コリオリ振動フレーム
S99	同位体効果
S100	吸着ヒートポンプ
S101	回転体の運動特性
S102	固体酸化物 SOFC
S103	炭化タングステン

S104	複数積層体,ガス流路
S105	複雑系同定手法
S106	酸素還元

Appendix 6

144 keywords

K1	3種類触媒重量比1：1：1
K2	co2 再燃料化
K3	COセンサー用触媒
K4	EV駆動
K5	撥水処理
K6	アスペクト化
K7	アルカリ二次電池用水素電極
K8	アルカリ助触媒
K9	イオン交換膜
K10	イオン伝導性
K11	イオン性界面活性剤,貴金属成分還元,ナノチューブ状粒子
K12	エネシステム,エネネットワーク,エネ需要
K13	エンドキャップポリエチレンオキサイド合成,モノフェニルエトキシシラン（MPTES）反応
K14	カーボンナノチューブ
K15	ガス容器
K16	ガス拡散電極
K17	ガソード電極触媒
K18	キャパシタの残容量算出
K19	キュリー温度,以下永久磁石
K20	グラフト鎖
K21	シフト触媒
K22	ジメチルエータル
K23	シリカゲル
K24	ジルコニア電解質
K25	ステンレス鋼
K26	ストロンチューム（Sr）,アルミニュウム（Al）
K27	ゾルゲル
K28	ドライメタン燃料
K29	ナノコンポジット膜
K30	ニッケルー水素化物電池

K31	ニッケル触媒
K32	バケツ型,大量生産
K33	パラジウム触媒
K34	パルスパワー技術
K35	プラズマグラフと重合
K36	プラズマ溶射
K37	プラズマ重合
K38	非平衡プラズマ
K39	プロトン
K40	プロトン伝導膜
K41	マイクロ波
K42	マグネシウム・ニッケル合金薄膜とマグネシウム薄膜
K43	メタノール
K44	モデル駆動
K45	レイノルズ数
K46	ロジウム触媒
K47	三相界面
K48	並列接続ベクトル制御
K49	乱流拡散火炎
K50	二元合金
K51	低減,環境影響
K52	低温作動
K53	体心立方構造
K54	停車状態の給電,水循環回路,水温度調整
K55	円錐ローラー,ボールベアリング
K56	刃状転位
K57	分割極セル
K58	分子動力学法
K59	分散型エネ利用システム
K60	加速センサー,コリオリ振動フレーム
K61	単位電池複数個積層
K62	単層ナノチューブ
K63	反応層シート折り畳む,電極部反応層形成
K64	可視光感応性光触媒,水素発生方法
K65	各部平板形状

K66	合金応用
K67	合金電極触媒
K68	同位体効果
K69	吸着ヒートポンプ
K70	回転体の運動特性
K71	固体酸化物 SOFC
K72	国際競争
K73	圧力容器リングバースト実験
K74	地域経済統合
K75	増粘着制御
K76	多層セル触媒反応
K77	大気マイクロ波水蒸気プラズマ
K78	安定化ジルコニア
K79	導電性高分子,自己ドーピング
K80	形状記憶合金
K81	微小直流電流高感度,非接触測定,センサー
K82	成膜性
K83	技術情報のオープン化
K84	改質
K85	改質触媒,分解触媒
K86	日米欧比較
K87	有機・無機複合膜
K88	有機溶媒,解離したガス,原子プラズマ重合反応
K89	有限要素法,圧力容器
K90	水素エネ
K91	水素供給装置用触媒
K92	水蒸気改質
K93	水酸化ナトリウム,水素化ナトリウム
K94	流れ計測
K95	流体流路,湿度,ガスセパレータ
K96	混合導体
K97	混合気の燃焼速度測定
K98	温度低下利用
K99	炭化タングステン
K100	炭化水素
K101	炭素析出

K102	炭素系材料
K103	熱媒式改質反応器,原料量推算
K104	燃料タンク
K105	燃料改質
K106	燃料極反応機構
K107	環境負荷,環境影響
K108	白金ールテニウム触媒
K109	白金合金
K110	白金触媒
K111	白金電極
K112	直接メタノール型
K113	磁気共鳴
K114	磁石回転
K115	脱白金触媒,カーボンナノチューブの内部に金属微粒子
K116	膜の湿潤度
K117	膜状半導体光電極,多孔質構造,
K118	膜電極接合体製法
K119	自己加湿型電解質膜
K120	複合触媒
K121	複合電解質薄膜,CVI法,管状ワイヤー状
K122	複数積層体,ガス流路
K123	複雑系同定手法
K124	複雑非線形系制御
K125	触媒CVD
K126	軽量発泡体
K127	輸出自主規制
K128	遷移金属元素添加,三元系水素吸蔵合金
K129	部分酸化反応工程
K130	酸化チタン
K131	酸化物超微粒子
K132	酸素イオン導電体
K133	酸素還元
K134	金属硫化物光触媒,光照射,加熱
K135	電極用複合粉末
K136	電極触媒

K137	電気二重層キャパシタ 適用
K138	電気浸透係数
K139	電解質膜
K140	面内細孔分布均一と粒子解砕
K141	風力
K142	高いプロトン伝導度,膜内水保持合成
K143	高分散触媒
K144	高耐食性表面処理鋼板

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Publications and conference papers

Journal

Jie YAN, Tieju MA and Yoshiteru NAKAMORI

Constructing Ontology for Exploring the Triple Helix of Academia-Industry-Government -- for road mapping in academia

Journal of Information and Decision science (accepted)

Jie YAN, Tieju MA and Yoshiteru NAKAMORI

Exploring the Triple Helix of Academia-Industry-Government for Supporting Road Mapping in Academia

IJMDM (International Journal of Management and Decision Making) (in review)

Tieju MA, Jie YAN, Yoshiteru NAKAMORI, Andrzej P. WIERZBICKI

Creative Environments

Chapter 7 Creativity Support for Road Mapping

(in press)

Conference and workshop

閻潔，三宅幹夫，小林俊哉，中森義輝

技術開発支援手法ロードマッピングプロセスに関する研究 ―燃料電池技術開発支援 in JAIST

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