A Road Mapping Approach for Research Cooperation among Academia Industry and Government

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Abstract

In this paper, we focus on the cooperation and relations of research topics and researchers who are doing technology creation in academia, technology development in industry and policy making in government. We address Road Mapping Approach (RMA), which is used successfully in industry for technology development, as data collection and analysis methods to support scientific research of technology development in research fields such as materials science, information science, etc., for helping researchers find new interests, new research topics, and also promoting cooperation among industry, university and government.

Keywords: Road mapping approach (RMA), research situation analysis, research cooperation analysis, technology development

1 Introduction

RMA as a process method for technology forecasting, planning and marketing strategy development is widely used in industry and government for supporting technology development. Can RMA also be used as data collection and data analysis methods for supporting scientific researchers finding new interests, and new research topics which are related with what they are doing now in academia? The main idea of this paper relates to issues of how to use RMA to support researchers finding new interests new topics of technology development. The functions of RMA focused on in this paper will be searching, networking, and mapping.

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After interviewing researchers from 20 companies and 3 universities to make clear possible differences and similarities among technology development in industry, in government and technology creation in university, we designed a framework of RMA based on approaches which have been used successfully in industry and government for supporting finding new interests and new topics for technology development. After the analysis of 291 records of information of fuel-cell products, a case study concerning supporting transportation fuel-cell technology development was carried out in order to test how to support researcher. The lessons we learned from the case study will be presented in the last part of this paper.

2 Road Mapping Approach (RMA)

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*1. 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 [1]. 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*2. The roadmap document, resulting from a technology road Mapping process, is the first step toward consensus on a number of topics [2][3]:

- 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 have been representation, communication, planning, coordination, forecasting and selection [4][5]. The roadmap document addresses [6]:

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

A road Mapping process has three general steps [7][8]:

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

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 [9]. 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 perform forecasting and planning to support technology development in industry [10] and [11]. We collected data and information from 20 companies, and we found that they use RMA with the purpose of creating more benefits and services from technology development. Four aspects of road mapping can be distinguished [6]:

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

Technology development in industry is a group activity. Usually, there are several groups per-topic of technology development. First, each group will decide their sub-topic of technology development. Then every member will recount their opinions and reasons, member will change his or her own opinion. At last a consensus conclusion (with which every member agrees) will be reached. They also invite specialists from different fields to provide discussions and workshops regarding their opinions.

2.2 RMA in Government

RMA is also used in government, with slightly different goals than in industry: deciding which topics should receive governmental support of research, and how to coordinate government-supported scientific research and technology creation. Industry and academia provide government with a report of what has been done, what the next plan is, and what the problems are every year. Then the government will decide which kind of technology they will support, in which kinds of ways [12].

- To present and keep the balance between new needs and seeds
- To get and analyze data and information of technology development and creation
- To decide how to support technology development and creation

2.3 RMA in Academia

RMA is not as broadly used in academia as in industry and government, but there are some cases of using RMA to support scientific research in academia.

A new approach for making personal academic research roadmaps by applying ideas of Interactive Planning (IP) was suggested by Ma [13]. The approach suggests the use of a process composed of six phases: forming groups; explanations from knowledge coordinators; descriptions of the 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

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*1 Robert Galvin, CEO of Motorola, 1998

*2 Bennett R. Idaho National Engineering and Environmental Laboratory, INEEL

[14], based upon the idea that students from science and engineering laboratories should be asked to manage their research, since they will have to do so in the future, whether in 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 of these ideas aim to support students from scientific and engineering laboratories, to develop their research proposals and research plans.

2.4 RMA for Relation and Cooperation Analysis

In this paper, however, we use RMA in a slightly different way, because we concentrate all researchers in academia, industry and government. We would like to support researchers in finding new interests and research topics of technology development, as well as to push or promote cooperation among university, industry and government.

From the different motivations of academia, industry and government, it is interesting to note the novel point of the substantial difference of the expectations of researchers' research of technology development. The reason for this difference is probably not so much due to diverse motivations, but due to different levels of expertise. Dreyfus and Dreyfus [15] have shown that the way of decision making changes essentially at some point when achieving better expertise: Thus, the conclusion is that we should develop a new RMA, if we want to support all researchers from Academia, industry, and government. In order to do so, we must first interview them to find what they expect from road mapping.

A good roadmap addresses three main questions in a correct way, based on users' requests:

Where we are?
Where do we want to go?
How to get there?

In this paper, we re-present RMA as a way to support researchers in finding answers to such questions: how are their research topics of technology creation related to other activities in the field (where we are), what goals of research should they postulate (where we want to go), how to support their research of technology development using the diverse tools of information sharing, networking and cooperation that give researchers a chance to identify, evaluate and select among research topics of technology development in a specific research field.

Researchers naturally want to concentrate on timely, advantageous and original research topics [16]. For this purpose, they need advanced technology information, including such topics as who is doing related research in academia; who is developing related technology in industry; who is making related policy in government, what are results of technology forecasting activities, what might be societal influences on technology creation in a specific research field; and all such information should be presented in a roadmap document in this case.

3 Framework of RMA for Relation and Cooperation analysis

3.1 Interview

We did interviews with researchers from Academia-Industry-Government to make sure that situation of researchers in Academia-Industry-Government for technology development. 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. However in academia, there are no such organizations to support researchers' scientific research for technology creation.

Because of such characteristics of technology development in academia industry, and government when we design RMA we should pay attention to: Road Mapping as relation and cooperation analysis methods should be oriented towards supporting researchers to answer where we are, where we want to go, and how to get there as a computer-based approach.

3.2 Framework Design

If we want to support researchers in finding new interests and research topics of technology creation, the classical RMA as a planning tool, such as in industry, is not suitable. Therefore, we designed a framework of a computer-based RMA as an analyzing, cooperating and mapping tools, shown in Figure 1:

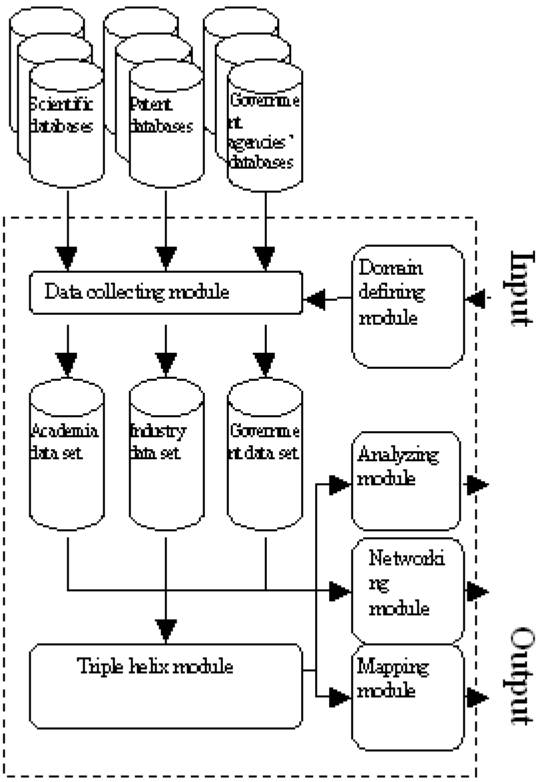

Fig.1 Framework of RMA in Academia

Domain defining module:
For researchers, when they develop their research roadmaps, 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. 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 collecting module:
After a domain is specified, three kinds of data sets corresponding to each dimension of the triple helix in the domain are 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.

- 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 for 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, and is commonly available on some government agencies' websites.
The above data could be collected manually, but that would be very time consuming. So we developed several software agents/modules which will cooperate with each other to automatically gather data in a specified domain from specified data sources which include websites of government agencies, scientific databases, and patent databases.

Triple helix module:
The triple helix analysis module is thus named because data is collected from academia, industry and government, and we will analyze data from these three dimensions. The module includes three functions:

- Analytic module

We want to give some support to scientific researchers, to answer the following questions.
What projects were, are, or will be supported by governments based on the technology? Who (persons and institutes) was, is or will be in charge of the projects? How much funding was, is or will be invested from government in those projects? How many patents have been issued or are under application based on the technology?

Who holds or is applying for those patents? Who from academia is doing research related to the technologies, and what are their publications?

- Networking module

Networking can help scientific researchers to answer the following questions.

Which technologies or research topics are often addressed by academia-industry-government, and which are not? What are the relationships among technologies, research topics, researchers, applications and products?

- Mapping module

Mapping can help scientific researchers to integrate results of the above two modules to get a research map.

4 Case Study

Is RMA design useful or not? How can we use RMA to support researchers finding more valuable research topics of technology development? In order to find a useful way to apply RMA to support scientific research in academia, industry and government, we carried out a case study for supporting researchers of transportation using fuel-cell technology in finding valuable research topics of technology development based on the framework we have designed.

Step1: Domain

The fuel-cell can trace its roots back to the 1800s. A Welsh born, Oxford educated barrister named Sir William Robert Grove, who practiced patent law and also studied chemistry or "natural science" as it was then known, realized that if electrolysis, using electricity, could split water into hydrogen and oxygen, then the opposite would also be true. Combining hydrogen and oxygen, with the correct method would 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 [17]. Because of its characteristics such as long durability, high efficiency and no pollution, the fuel-cell has been widely accepted as useful way to solve environmental problems related to car traffic and transportation.

After collecting 291 records of data and information on fuel-cell products from all over the world, it was found that transportation-oriented fuel-cell products constitute only 11.6%. It is well known that, if fuel-cell would become a substitute for gasoline, the emissions of carbon oxides and sulfur oxides would be sharply decreased. Why are vehicles using fuel-cell products so slow to be 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 decided domain as two keywords: fuel-cell and vehicle.

Step2: Data collection

We collected data from academia, industry and government, and got three data sets.

- The academia data set was obtained from the database of publications of achievements, National Institute of Advanced Industrial Science and Technology, Japan (http://www.aist.go.jp/RRPDB/system/Koukai.Top). This data set includes: (authors, author's affiliation, titles of papers, Keywords, the date of publication, the journal in which the paper was published). It includes 47 records.
- The industry data set was obtained from the patent circulation database, Japan (http://www.ryutu.ncipi.go.jp/PDDB/Service/PDDBService). This data set contains: (owner, owner's affiliation, title of patents, the date of application, keywords), and it includes 51 records.
- The government dataset was obtained from NII (National Institute of Informatics) Scholarly and Academic Information Portal, Japan (http://ge.nii.ac.jp/genii/jsp/index.jsp). This data set contains (leaders of projects, leaders' affiliation, period of projects, title of projects, contents of projects, funding from government), and it has 56 records.

Step3: Analyzing, networking and mapping

- Analyzing

Qualitative analysis

We classified data from the three data sets into four levels: 10 technologies, 25 main-topics, 106 sub-topics and 144 keywords. The structure is not a tree, it is a network, which means a keyword can be related to several sub-topics, a sub-topic can be related to several main-topics, a main-topic can be related to several technologies, and vice versa.

Quantitative analysis

Then we calculated the research situation similarity between two keywords, because keyword is the most detailed information in our four levels of data, using a method proposed by Si Quang Le and Tu Bao Ho [18]. The basic idea of this method is to consider the similarity Sm(i,j) of a given attribute(m)-value pair (i,j) as the probability 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). Similarities of attribute value pairs D(i,j) are then integrated into dissimilarities between data objects using a statistical method (2). Of course, users are not limited to this method.

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

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

- Networking

Figure 2 gives an example of researchers-144 keywords network. The basic nodes in the network are researchers which in blue and keywords in purple (ac.), brown (gov.) and green (ind.).

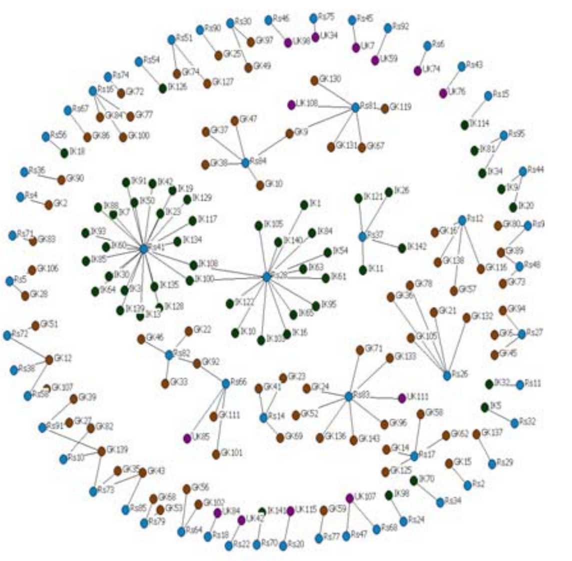

Fig.2 Researchers-keywords network

For each node, academic publications, patents, and projects supported by government linked to it will be demonstrated by using the search function. That is to say, users can analyze the triple helix of academia-industry-government based on each node. 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.

Networking will help researchers to find potential cooperators, and the competition.

- Mapping

Networking is to understand the relations between researchers and research topics. Mapping is to understand relations among research topics.

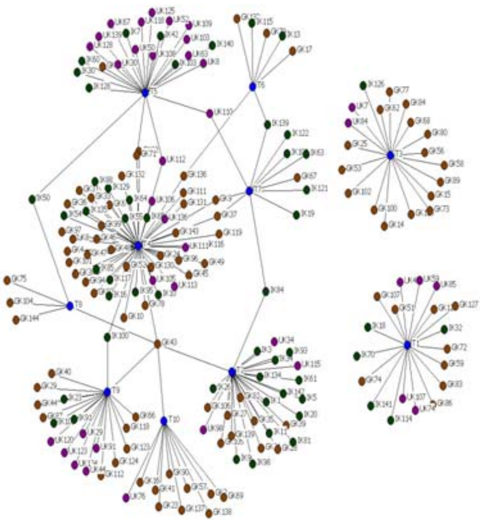

Fig.3 Technology-keyword map

Figure 3 gives an example of 10 technologies-144 keywords relation map.

Nodes which are in blue are technologies, others are keywords. The different colors mean the related keyword is from academia (in purple), industry (in green) or government (in brown). Such a map will help researchers to answer:

- For each technology there are how many research keywords in academia, industry and government are studying.
- Which two technologies or two keywords have the strongest relation.
- Which is the hottest technology and keyword.
- Which is the most important node

connecting technologies and keywords.

We also can get a network map between technologies and research topics, research topics and keywords etc. The Mapping function will help researchers to find potential cooperative projects in a specific research field.

Based on analysis, network and map, researchers can analyze data by themselves such as:

- Around ¼ of the research topics which are getting or have gotten subsidy from the government are about developing high efficiency technology.
- Research topic which is the newest, getting highest subsidy, is about organic and inorganic composite membrane.
- Around 50% of researchers are doing scientific research about catalysts in the transportation fuel-cell field.

We provided the ideas and results to 3 labs in three different universities which are doing research related to the (fuel cell, vehicle) domain. All the directors of those labs expressed that what we provided to them were very helpful for answering the questions where we are, where we want to go, and how to get there.

5 Conclusion

In this paper, we aim to find a useful way to support researchers who are doing research on technology development in academia, industry and government in fields such as materials science, physics and chemistry, etc. We also aim to push the cooperation among academia, industry and government with RMA, which is used successfully in industry and government. After interviewing scientific researchers we concluded that RMA should be different from that in industry and government, which are used for forecasting and planning. Then, after a framework of RMA was designed, a case-study for supporting researchers in the research field of transportation fuel-cell technology development was carried out. The purpose of RMA in academia is supporting scientific researchers by giving an overview of the whole research field and making sure of their positions in the research field, and also helping researchers to find potential cooperators and cooperative projects with industry and government.

RMA 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 paper, data were from Japanese databases, since in the project what the researchers cared about were research topics of transportation using fuel-cells from academia, industry and government in Japan. When applying the approach in a different country or in a different field, the data sources will be different. So, we are making a computer-based system for collecting and analyzing data so that we can use the idea also in other research fields.

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