Roadmapping and *i*-Systems for Supporting Scientific Research

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ABSTRACT

Roadmapping, as a strategic planning tool, is attracting increasing applications in industries. This paper argues that roadmapping can also be a useful way to manage knowledge in the academe and to support scientific research. By applying the principles of Interactive Planning (IP), this paper puts forward a new solution for making personal academic research roadmaps. Then this paper introduces an ongoing project that is to develop a roadmapping support system based on the solution, and gives some considerations about applying the *i*-System Methodology for enhancing the knowledge creation in a roadmapping process.

Keywords: roadmapping, interactive planning, *i*-systems

1. INTRODUCTION

Motorola Inc. firstly introduced the concept of "roadmap" as a strategic planning tool in the 1970s. Perhaps the most widely accepted definition of a roadmap was given by Bob Galvin, CEO of Motorola: "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". "Roadmaps" can mean different things to different people. What all those different roadmaps have in common, however, is their goal, to help their owners clarify the following three problems:

- Where are we now?
- Where do we want to go?
- How can we get there?

There are many existing solutions for roadmapping, developed for the purpose of industry, with strong commercial background. Roadmapping for supporting scientific research should be different from those solutions for industry, since academic labs have different features from commercial organizations. The main target of academic labs should be "emerging technology" and "creative invention", and academic labs should also have the function for the accumulation and expansion of scientific knowledge and function for inspiring researchers. Based on the Interactive Planning (IP) Methodology, we developed a solution for the roadmapping for supporting scientific research.

Roadmapping is independent of information technology. However, the appropriate information technology, applied judiciously to the proper phase of roadmapping, can significantly improve the efficiency and effectiveness of the road-mapping process. It was based on this understanding that we developed a web-based roadmapping support system.

The purpose of making personal academic research roadmaps is not only to make plans, it should also be a knowledge creation process. The *i*-Systems methodology is a systems methodology that uses approaches in social and natural sciences complementarily [14-16], which is very useful for enhancing the knowledge creation in a roadmapping process.

The rest of this paper is organized as the following. Section 2 introduces the Interactive Planning Methodology and explains why we applied it for roadmapping. Section 3 gives the new solution for making personal academic research roadmap. Section 4 introduces the roadmapping support system. Section 5 gives some considerations about applying the *i*-system methodology for enhancing the knowledge creation in the roadmapping process.

2. INTERACTIVE PLANNING

IP was put forward by Ackoff R.L [1-4]. It is regarded as a basic methodology for solving creative problems by researchers in both the field of management science and the field of systems science. It has demonstrated great power in dealing with a wide range of possible organizational issues with very insightful systems metaphors, while these systems metaphors are also very applicable to an individual's research. A scientist's research could be looked as a purposeful system inside the brain. First of all, this system is composed of the knowledge and skills the researcher already holds, of course, with a complex relationship among them. To generate invention and innovation, this system should always keep learning and adapting. A researcher's general research purpose can be divided into several sublevel purposes, and at the same time, that research is included in a more general research goal, for example, the goal of the research group to which the individual belongs. This accords with the systems metaphor that a "purposeful system" contains other "purposeful systems" and is part of a "wider purposeful system" [6].

IP has the following three important principles, which we think are also very important in the roadmapping process.

- Participative principle. Ackoff believed that the process of planning is more important than the actual plan produced. "It is by being involved in the planning process that members of the organization come to understand the organization and the role they can play in it. It follows, of course, that no one can plan for anyone else-because this would take away the main benefit of planning [6]".

- Continuity principle. This principle points out that planning is a never-ending process, since the values of the organization's stakeholders will change over time and unexpected events will occur. "No plan can predict everything in advance, so plans, under the principle of continuity, should be constantly revised [6] ".
- Holistic principle. This principle insists that people should make plans both simultaneously and interdependently. Not only should units at the same level plan together and at the same time – because it is the interactions between units rather than their independent actions that give rise to most difficulties – but also, units at different levels should plan simultaneously and together, because decisions taken at one level will usually have effects at other levels as well.

IP is composed five interrelated phases, namely, formulating the issue, ends planning, means planning, resource planning, and design of the implementation and controls. Sometimes the final phase is divided into two, design of the implementation and design of the controls [4]. These phases should be "regarded as constituting a systemic process, so the phases may be started in any order and none of the phases, let alone the whole process, should ever be regarded as completed [4]". In the following, we will briefly introduce those phases. The introduction is mainly based on the chapter titled "Interactive Planning" in the book Creative Problem Solving [4].

1. **Formulating the Issue**. In this phase, problems, prospects, threats and opportunities facing the organization are highlighted.
2. **Ends Planning**. Ends planning concerns specifying the ends to be pursued in terms of ideals, objectives, and goals. The process begins with "idealized design", which is both the most unique and most essential feature of Ackoff's approach.
3. **Means Planning**. During this phase policies and proposals are generated and examined with a view to deciding whether they can help fill the gap between the desired future and the way the future appears at the moment. Alternative means to reach the specified ends must be carefully evaluated and a selection made.
4. **Resource Planning**. During this stage of planning, Ackoff recommends that four types of resources should be taken into account:
   - Inputs - materials, supplies, energy and services
   - Facilities and equipment - capital investments
   - Personnel
   - Money
5. **Design of Implementation and Control**. This "final" phase of interactive planning concerns itself with seeing that all the decisions made hitherto are carried out. "Who is to do what, when, where, and how?" is decided. Implementation is achieved and continually monitored to ensure that plans are being realized and that desired results are being achieved. The outcome is feedback into the planning process so that learning is possible and improvements can be devised.

In the description of IP, the objects are organizations, or systems from the viewpoint of systems science. A personal academic research plan can also been seen as a system inside human brain. In this sense, the five phases of IP can be clearly mapped to the three important questions that roadmapping aims to answer. The first phase of IP, namely "formulating the issue", in fact tries to answer the question "where are we now"; the second phase of IP, "ends planning", corresponds to the problem "where do we want to go"; and the remaining three phases of IP, "means planning", "Resource Planning" and "Design of Implementation and Control" -- are for answering the question "how can we get there". Fig. 1 shows the relationship between IP and the three important problems which roadmapping aims to solve.

Fig. Relationship between IP and Roadmapping

3. A NEW SOLUTION FOR MAKING PERSONAL ACADEMIC RESEARCH ROADMAPS

Applying the ideas of IP to the process of making personal academic research roadmaps can enhance communication among researchers from different fields, since IP pays much attention to the participation of stakeholders. In addition, an atmosphere can be created in which research on "emerging technology" and "creative invention" are encouraged by what R.L. Ackoff has called "idealized design" [1-4].

Idealized design is a very important feature of IP. It is meant to generate maximum creativity among all the stakeholders involved. "To ensure this, only two types of constraint upon the design are admissible. First, it must be technologically feasible, not a work of science fiction; it must be possible with known technology or likely technological developments; but it should not for example, assume telepathy. Second, it must be operationally viable; it should be capable of working and surviving if it is implemented. Financial, political, or similar constraints are not allowed to restrict the creativity of the design [1-4, 6]."

Our solution is composed of six interrelated phases, as shown in Fig 2.

Phase 1: Forming groups. We believe that roadmapping should be a group activity and a consensus building process. A group should contain two kinds of members in addition to the regular members. The first is experienced researchers, for example, professors, associate professors and so on. The second is knowledge coordinators. Knowledge coordinators are those people who can manage creative research activities based on the theory of knowledge creation [14].

Phase 2: Explanation from knowledge coordinators. In this phase, knowledge coordinators explain the following things (mainly) to all group members.

- Concept of roadmaps and the benefits of making roadmaps
- The role of every member
- The schedule of the group

Phase 3: Description of present situation. In this phase, the experienced researchers give a description of the present situation that mainly includes:

- Background knowledge in this research field
- The leading groups/labs, famous papers, journals and conferences over the world in the research field
- The common equipments and skills needed in this field

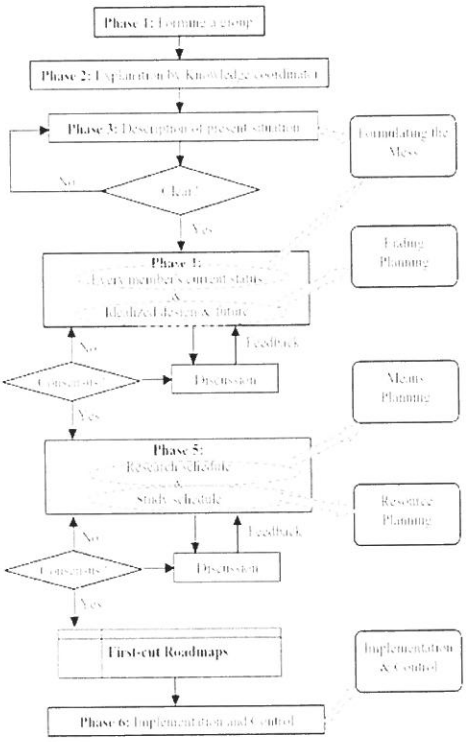

Fig. 2 Solution for making personal academic research roadmaps

- Hot topics at current time in this research field

Phase 4: Members' current status and idealized design. In this phase, every member firstly describes the experience (the skills and knowledge) he/she already has. Then, by using IP's idealized design, every member describes his/her research goals. The ideas generated by idealized design are discussed by the whole group, and each individual can refine, modify his/her idealized design with the benefit of the whole group's knowledge.

Phase 5: Research schedule and study schedule. In this phase, members not only make their own research schedules, but also make their own study schedules for reaching the goals. Those schedules should also be subjected to group discussion, and members need to modify those schedules according to the result of group discussion. After consensus is reached, group members can start to make their first-cut roadmaps. Road-mapping is a never ending process, people need to go back to some previous phases again and again, modify and improve their research roadmaps continuously.

Phase 6: Implementation and Control. This is mainly done by regular seminars, workshops and reports. By Phase 5, each researcher's personal research roadmap is ready. Although much effort has gone into making a reasonable research roadmap, it is still a first cut. The roadmap should be continuously refined in practice, which accords with the continuity principle of IP. The knowledge coordinator(s) should arrange regular seminars and workshops to monitor and control the implementation of the personal research roadmaps.

4. A ROADMAPPING SUPPORT SYSTEM

As a project supported by the JAIST COE Program titled "technology creation based on knowledge science", a roadmapping support system is under developing. The benefits of using the system include:

- Helping researchers to managing their personal roadmaps
- Helping the supervisor to managing his/her group/lab's research
- Promoting the knowledge sharing among researchers, especially promoting the dispute among researchers
- Building roadmap archives that can be used as the source of data mining (knowledge discovery)

The system is a web-based system. Basically, users only need a web browser, such as Internet Explorer or Netscape, and an Internet connection to access it. The following is the main techniques used for developing the system:

- **Java [8] and Java Applet [9].** Java is a programming language developed at Sun Microsystems in 1990. Applets are little programs written in Java language. They are designed to run inside a web browser and to perform some tasks such as animated graphics and interactive tools. For running the system, client users need to download some Java plug-in. But users do not have to worry about this, the system will atomically check if there is the right plug-in in client computers, if there is

Fig. 3 The entrance of the system

no, then it will automatically download it. What users need to do is to allow their computer to download and install the plug-in.

- **JSP (JavaServer Pages) [10]**. JSP technology enables Web developers and designers to rapidly develop and easily maintain, information-rich, dynamic Web pages that leverage existing business systems. As part of the Java technology family, JSP technology enables rapid development of Web-based applications that are platform independent. JSP technology separates the user interface from content generation, enabling designers to change the overall page layout without altering the underlying dynamic content.
- **Java Servlet [11].** Java Servlet technology provides Web developers with a simple, consistent mechanism for extending the functionality of a Web server and for accessing existing business systems. A servlet can almost be thought of as an applet that runs on the server side--without a face. Java servlets make many Web applications possible.
- **Tomcat** [7]. We use Tomcat 5.1 as the web server. Tomcat is the servlet container that is used in the official Reference Implementation for the Java Servlet and Java Server Pages technologies. Tomcat is developed in an open and participatory environment and released under the Apache Software License.
- SQL Server 2000 [12]. We use SQL Server 2000 as the background database server. SQL Server 2000 is a popular DBMS (data base management system) developed by Microsoft.

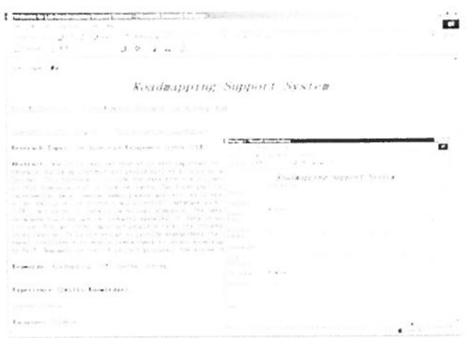

Fig. 4 Interface after logging in

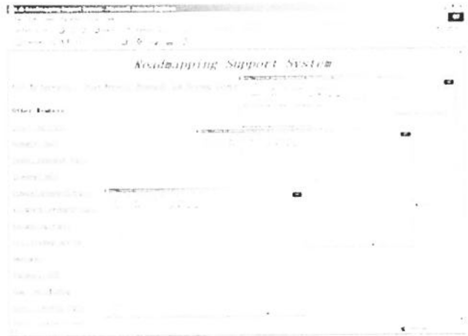

Fig. 5 Viewing and making comments on other members' research roadmap

Fig. 3 shows the interface of the entrance of the system. We provide both English version and Japanese version. Fig. 4 shows the interface after a user logging in. The user can see his research roadmap which has been storged in the system. The user can modify his research roadmap, as shown in the small window in the right downside of Fig. 4. Besides the function of viewing and editing his/her own research roadmap, there are several functions that users can use.

In Fig. 5, the biggest windows gives a list of all other group members's names and their research topics. Users can view other group members' research roadmap by clicking their names or research topics. The system provides two formats of a research roadmap, like a article (the first small window from right in Fig. 5) , or like a table (ATRM model [17], the second small window from right in Fig. 5). Users can make comments on other members' research roadmaps. The system allow users to make comments anonymously. As mentioned by Wierzbicki: Far Eastern societies are better than Western at Socialization and achieving consensus but (perhaps therefore) worse in Dispute [18]. Allowing making comments anonymously will promote the dispute among researchers, which is very important for knowledge creation.

Fig. 6 The general view of the group's research

Sometimes users, especially the leader or supervisor of the group would like to have a genertal structure or a gerenal view of his/her group's research. The system provides a chart to visualize the whole group's research, as shwon in Fig. 6. In this chart, each line denotes one member's research roadmap, and each ellipse denotes a time stamp, which means the points in the same ellipse means the same time. It will be easy to see what the group is doing now, what it plans to do and when it will do them. Of course it is also important to visulaize what the group have done, which will be considered in our future work. Each member's detailed research plan can be seen by clicking the names listed in the left side in Fig. 6.

Fig. 7 Viewing comments from other members

Users can also see comments from other members, and they can reply those comments online, as shown in Fig 7. The system can help the user to find potential cooperators. Now the system finds potential cooperators only based on keywords. In the future, the system should have the function that more complex conditions can be set by users to find their potential cooperators. Fig. 8 shows that three potential cooperators are found, and those potential cooperators' detailed research roadmaps (like the small window in Fig. 8) can be seen by clicking their names.

Fig. 8 Finding potential cooperators

5. THE *I*-SYSTEMS METHODOLOGY FOR ENHANCING KNOWLEDGE CREATION IN ROADMAPPING PROCESS

Developed by Nakamori, the i-systems methodology uses approaches in social and natural sciences complementarily [14-16]. According to Nakamori in [14], *i*-systems are composed of five subsystems/dimensions, at the subsystem Intervention, knowledge is a problem; at the subsystem Intelligence, knowledge is a model; at the subsystem Imagination, knowledge is scenarios; at the subsystem Involvement, knowledge is opinions; and at the subsystem Integration, knowledge is solutions.

Although the *i*-systems methodology does not give a sequential process or interrelated phases for practice, it identified the important dimensions and gave a clear descriptions of the relationship among the five dimensions. The understandings of the knowledge creation process, which we can learn from the i-systems methodology, can help us to design a better knowledge creation spaces [18].

Interactive Planning Methodology is developed in industry, it does not pay much attention to the "emerging technology" and "creative invention", which are the main targets of ademic labs. So it is necessary to apply some methodologies, such as the i-systems methodology, which addresses much the knowledge creation process, to enhance the knowledge creation in the solution introduced in Section 3. Instead of giving some concrete examples of applying i-systems methodology in roadmapping process, this paper only gives some considerations of applying it for making personal research roadmaps.

AS shown in Fig. 9, we start from the intervention dimension. In this dimension, one researcher should answer questions such as "what do you want to achieve" or "what's your purpose and motivation".

When the researcher finds the answer to those questions, he/she would refer to the social dimension, the scientific dimension and creative dimension (referred to as the three dimensions in the following). In the scientific dimension, the researcher gathers knowledge of the existing research models related to his/her research purpose. This is mainly done by reading literatures. In the social dimension, the researcher gathers the opinions from industry and government, and of course also from other researhers, especially those experienced researchers who work in the same fields. Sometimes, communications with researchers from different field can bring surprising wonderful ideas. And in the creative dimension, the researcher generates his individual ideas, makes his purpose clearer and writes rough research proposals. We would not like to make a sequential process for the actions in the three dimensions because a researcher maybe refers to these three dimensions at the same time, or the researcher will frequently refer to one or more than one dimensions for many times. For example, we could not say clearly that the work of gathering existing research models should be finished in one or two monthes, and in this one or two monthes, a researcher does not refer to other dimensions. Researchers should consider the work refering to the three dimensions according

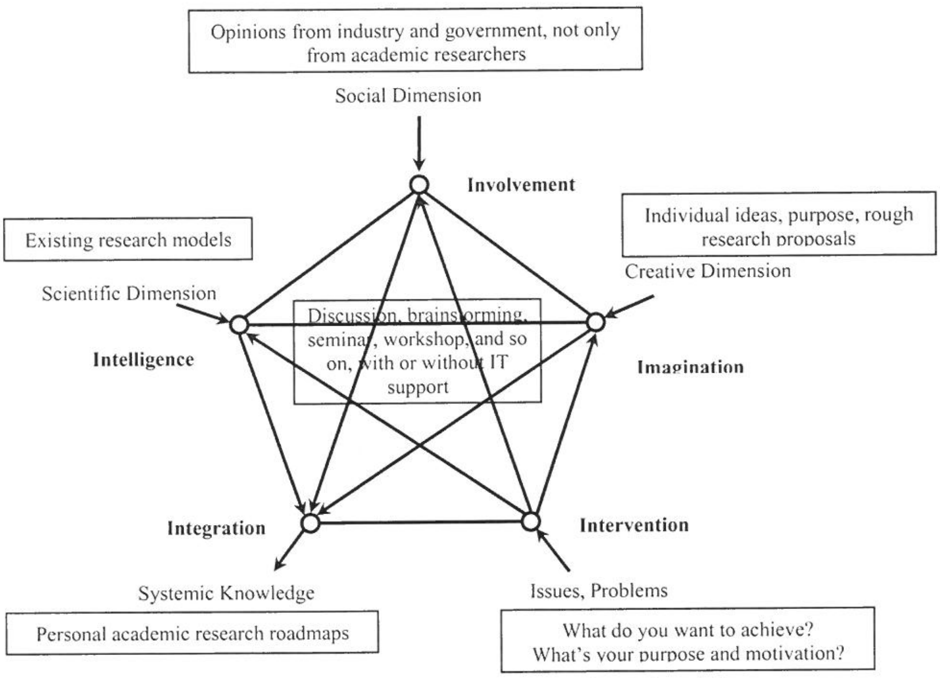

Fig. 9 The *i*-systems methodology for enhancing the knowledge creation in roadmapping process

to their own schedules. It is obviously that before a researcher answers the quesitions asked in the intervention process, he/she already refered to the three dimensions, and his/her answer in fact is based on the three dimensions. After answering the questions in intervention dimension, a researcher need deliberately refer to the three dimensions for improving his/her answers. After the answer is determinated, the researcher need refer to the three dimensions again for making his/her research roadmap. During those process, discussions, brainstorming, seminars, workshops, and other methods of communication, with or without IT support, should be used for the knowledge sharing (learning from each other), and thus to enhance the knowledge creation.

In the integration dimension, researchers work out their personal academic research roadmaps, which can be viewed as the solutions for those questions asked in the intervention dimension. Since roadmapping is a never ending process, a researcher should continuously refer to all the five dimensions again and again for improving his/her research roadmap.

6. CONCLUDING REMARKS

This paper put forward a solution for making personal academic research roadmaps based on the Interactive Planning Methodology, introduced a web-based roadmapping support system, and gave some considerations of applying the *i*-systems methodology for exhancing the knowledge creation in roadmapping process.

In the practice of roadmapping [13], we found that roadmapping can be an unwieldy and time consuming process, which can discourage participation, while competent knowledge coordinators and proper IT (information technology) support can reduce this negative factor.

In practice, we also found that roadmapping is more welcomed by junior researchers than senior researchers. It seems the benefits of roadmapping for junior researchers are obvious than those for senior researchers. Senior researchers are more likely to believe that they can arrange their research by themselves, and will be reluctant to spend time on roadmapping, but most of them would like to help making juniors researchers' roadmaps. The junior researchers are more likely to find that they can get useful information, knowledge, and good suggestions and ideas through the roadmapping process.

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