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Researcher Column 1:

Intuition and the Emergence of new Concepts in Science

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The new civilization era (global knowledge civilization) can be described as the period where the temporal distance between scientific and technological macro-changes is reduced and the connections between them are more direct. It is not because straightforward common sense possibilities have been exhausted – there still remain many others – but rather as is pointed out in the Creative Space theory, due to the connection between creative processes with the many-level structure of the environment for knowledge. It seems, however, that the intuitive level is also sub-structured, being hierarchical environment in the hermeneutical horizon.

It is not true that *macro-changes* in science consist *only* in the *conceptual changes* of the basic scientific terms or in the emergence of new concepts – many other factors are involved here. Furthermore, the description of the emergence of new concepts in science depends on the employed theory of scientific change. There are many different theories of scientific change and not in every one of them are concepts the most important factor.

The differentiation between the *higher level* (or *new*) concepts and implicit *basic level* (or *old*) concepts, connected with the *emergence principle* suggests a kind of hierarchical structure of scientific theories, incommensurable and non-reducible to each other. Obviously, there are many possible theories explaining the emergence of new scientific concepts, but without some kind of test these theories would be useless.

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Researcher Column 2:

Constructing Ontology for Exploring the Triple Helix of Academia-Industry-Government

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Introduction

When academic researchers developing their research roadmaps (or strategic research plans) (see Ma et al. 2006), it is necessary to have a wide view also on industry and government since future technology systems are more and more shaped by the evolutionary interactions among industry, government and academia, or what is called, the triple helix of academic-industry-government (see Etzkowitz 2002). But researchers sometimes find they are very much constrained by budget, time and opportunities to communicate with people from industry and government, or even from academia. A supplement (and maybe a main) way for many researchers is to get knowledge about the triple helix from publications, Internet, and other public medias.

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Institution and the Emergence of New… (con't)

The best known and widely accepted test is a historical case study. At first, we need information on what science really is, and without historical considerations we can speak only of what science should be. Scientific change is not a point-like event in space-time, but rather a temporal, historical process - it is simply impossible to see the changes in science without seeing this science in its historical time-interval – if the interval is short we can detect only *micro-changes*.

What does mathematical intuition consist in? Every act of mathematical intuition e.g. the guess of a proof, informal reasoning, the use of a non-formal meta-environment, the intuitive analysis of concepts etc., relies on the implicit recognition of the existence of something as given and ready-to-use, and equally implicit recognition of intuitive content of that "something". One can observe that the intuitive environment is previously *given*, *present* and has some implicit i.e. presupposed content and qualities *preceding* any kind of possible construction or decision.

It is possible to reconstruct such actively felt and grasped qualities because they manifest themselves as hidden assumptions, tacit knowledge, prejudices etc. It is because of their implicit character that they are *intuitive*. They absolutely determine every informal step in the intuitive mathematical reasoning which means they are *active*. In the moments when they "disclose themselves" during the creation of mathematical knowledge, the working mathematician feels that something is *evident*, and sometimes, *apodictically evident* i.e. "it can not be any other way".

So, it is possible and reasonable to reconstruct *what* is assumed intuitively i.e. as a tacit or a hidden assumption in the informal holes always present during creation of "all mathematics", be it formal or not. Let us call this reconstruction the *reconstruction of the hermeneutical horizon*.

The reconstruction of the hermeneutical horizon is possible for different mathematical theories in the same historical epoch and in different epochs, for example, the reconstruction of the horizon of ancient mathematics needs purely historical apparatus i.e. should be based on historical sources. Sometimes the reconstruction needs some new mathematical methods and theories.

It is very important to note that the historical changeability of the concepts does not support any kind of a social or historical variabilism or relativism. The possibility of the creation and understanding of mathematics is based on the possibility of thinking exactly *the same* sense by different subjects of cognition and *the same* sense by the same subject of cognition in different times. The historical changeability of concepts means only that the grasp of the same content is not automatic and sometimes one needs to resort to reconstruction. For mathematicians living in almost the same historical epoch, the possibility to think in the same way is almost automatic. But the possibility of understanding ancient mathematics is not so straightforward and needs the reconstruction of the hermeneutical horizon.

The received view on mathematical platonism define it as a conviction of the existence of some ideal, timeless, eternal and unchangeable mathematical entities. This kind of platonism is external to mathematics because it is not necessary for the creation of mathematical knowledge.

In contrast to this platonism, we connect mathematical intuition with the *internal* mathematical platonism which manifests itself in the strict methods of mathematical inquiry such as the use of classical negation, the use of the law of the excluded middle or the use of informal mathematical meta-level. Mathematical intuition is the fundamental mode of the *platonism as the method of mathematical enquiry*.

Theories of scientific development and mathematics ignoring platonism in *micro-* and *macro change* of science are unrealistic.

Hemeneutics makes it possible to determine and to find out such unconscious but fundamental conditions which are quite independent from the "formal" viewpoint sustained by a philosopher. The *platonism as the method of mathematical inquiry* is such a hermeneutical condition for the creation of mathematical knowledge. The reconstruction of the hermeneutical horizon is the effect of the detection and description of such hermeneutical conditions. New and revolutionary concepts in science can emerge *after* the change of hermeneutical conditions is done. As mostly unconscious and not explicit, the hermeneutical conditions are the base for intuition and tacit knowledge.

To avoid long discussions, we can demonstrate the existence of the hermeneutical horizon and its distinctness in antiquity by showing the results of a long historical case study. We can even make a "thought experiment" showing the aforementioned *active* character of the horizon.

The so called *Euclidean* (*elementary*) *geometry* with some basic constructions e.g. translations, drawings of circles, triangles, straight lines, sections etc., and the theorems such as the Pythagoras' theorem, are known from elementary school. It is also possible to read *Elements* from where geometry began.

The experiment relies on the possibility of reading the text of the translation of *Elements* with enough understanding. We can do it ourselves or observe the understanding of the text by a pupil or even a child. It sometimes happens that pupil can state many properties (e.g. "the diameter divides a circle into two equal parts"[1]) without any proof, or can even formulate some simple proofs.

We can reconstruct the hermeneutical conditions determining our understanding of Euclidean geometry and we will see that we create and understand the geometry in the determined *intuitive model*, which is a "part" of the hermeneutical horizon. In our example, the basis is the infinite, rigid, unchangeable or in the Newtonian sense, *absolute* "Euclidean space", treated as a container or an arena for geometry to play itself out, "the same" in every place and moment of time. When in *Elements* one reads the word "line", "surface" etc., it is understood as "infinite straight line", "infinite surface" injected in presupposed infinite space.

What are the main differences between intuitive ancient and modern models for Euclidean geometry?

The main difference is the absence of the concept of absolute space and general lack of any *infinite* notions: infinite surface, infinite straight line, infinite line, asymptote etc. The concept of absolute space does not appear in *Elements* nor the other infinite notions. Other differences are non-continuity and the non-metrical character of geometrical figures, sections etc. We have to ask once more: how is it possible?

At the starting point we have no infinite space, but only so much "place" as to perform permitted operations. So, "the space" extends with the constructions performed.

There is some historical evidence also outside *Elements* explaining the absence of the notion of Euclidean space there. For example, Heron from Alexandria (1st century B. C.), a commentator, tried to improve some of the proofs so when Euclid put a point on the other side of a construed figure, Heron changed the place of that point so that the figure contained it. It is because "there is no place [outspread] out of the figure".

Our infinite Euclidean space is "ready-to-use": all places are already present. This space is considered from the point of view of eternity. On the other hand, ancient mathematicians had to choose only some "parts" of the continuum: they considered only those parts which they could grasp by strictly determined methods of construction. Their continuum was viewed from the point of a human being and was temporal.

The classification of the book X forms a non-Euclidean model of geometry. In this model it is possible to construct an infinite number of lines (i.e. sections) parallel to a given one and different from it. We can describe a connection with the model A used in the proof of independence of the axiom of continuity in Hilbert's version of Euclidean geometry; cf. Z. Król *Plato and the Foundations of Contemporary Mathematics. Plato's Concept of Number*, Wydawnictwo Rolewski, Toruń 2005 (Król 2005).

We see the possibility of different "intuitive models" of understanding Euclid's geometry which are not uniquely determined. For more than 2000 years, Euclid's *Elements* were understood in a non-genuine way within variable intuitive frames. It does not mean, of course, that the Greeks did not have the notion of infinite, "vacuous" space or infinite straight line, cf. historical evidence from Aristotle's *De generatione et corruptione* or Democritus in (Król 2005). It only means that such notions were left out from *Elements* as unclear, not evident and not constructive. The infinite concepts were present in antiquity but outside the scientific

[1] We know that this is the theorem discovered by Thales of Miletus (VI B.C.).

frames and as the significant part of scientific theory they emerge much later.[2]

Now we are ready to see the horizontal conditions for the emergence of concrete scientific concepts. First of all, we detect by the reconstruction of the hermeneutical horizon, the two different intuitive models for Euclidean geometry. It means that there was a time during which the absolute and infinite notions such as absolute space were absent from mathematics and science. However, we know that absolute space was the fundamental concept of Newtonian physics and all modern science till the emergence of the special Theory of Relativity.

The emergence of the concept of absolute space was not the discovery of a single man, Newton or Descartes. This concept emerged as a result of a long historical process. It was connected with the gradual enrichment of geometrical methods, coming from constructions using a ruler and compasses (e.g. translations), studies of new types of curves where infinite lines (e.g. asymptotes) appeared and theories of proportion.

The accumulation of new results (Galileo Galilei, Giordano Bruno etc.) led to the revolutionary emergence of a new concept of absolute space in the Descartes' *Geometry*. However, Descartes did not see that he was using a new concept. All he was trying to do was to free geometry from the constraints of construction confined to the use of a ruler and compasses. But new Cartesian concepts were created *within* the new *horizon*: infinite "Euclidean" space. Descartes did not know this was a new conceptual frame because he understood Euclid's *Elements* in the new horizon, convinced (it was *obvious* to him) that this frame was the same as Euclid's. Descartes' convictions were *intuitive* i.e. *horizontal*. Descartes was working with a new horizon *before* any definition of absolute space appeared.

The first explicit use of absolute space together with the corresponding definition is by Newton and his *absolute space* is the *interpretation* of the earlier and implicit *horizontal change.* Newton studied *Elements* in depth and wrote many works concerning some basic geometrical problems in Euclidean geometry. However, also he explicitly works within the infinite space and explicitly (as well as implicitly) assumes that this space creates the base of *Elements* not only for him, but also for Euclid; cf. Newton's works such as *Analysis Geometrica*, *Inventio Porismatum*, *Geometrie Libri Tres* etc. The horizontal change at first can appear only as an *intuitive change*, it is a kind of *Gestalt*.

We can see that the rise of modern science based on mathematics was connected with the horizontal transition from the ancient constructive models for Euclidean geometry to the model of absolute space. It is necessary to change the received views on development schemes of geometry. The received view describes geometry at the starting point as almost the same till the 19th century when non-Euclidean geometry was discovered. Of course, the received view allows description of many *micro-changes* in Euclidean geometry, but in general they all appear in almost the same *intuitive frames*. Without the reconstruction (even partial) of the hermeneutical horizon, it is impossible to notice the change of the intuitive model for Euclidean geometry.

New concepts emerge in the hermeneutical horizon and its content is initially determined by the fundamental properties of the horizon. So, to explain why and which concepts can emerge it is necessary to reconstruct the hermeneutical horizon. The reconstruction reveals new internal mathematical possibilities and makes it possible to stimulate not only the creation and emergence of the concepts that are new, but also really useful.

[2] Cf. E. Grant *Much ado about nothing. Theories of space and vacuum from the Middle Ages to the Scientific Revolution*, Cambridge University Press, Cambridge, London, New York, New Rochelle, Melbourne, Sydney 1981. Grant's presentation avoids the problem of the introduction of infinite space into geometry and mathematics.

Constructing Ontology for Exploring… (con't)

We put forward a computer-based approach which aims to help academic researchers to explore the triple helix of academia-industry-government based on three kinds of databases, namely, scientific databases, patent databases, and project databases. These databases can be used as knowledge source for exploring the triple helix of academia-industry-government. But they are built and maintained by different agencies and for different purposes, in other words, they are distributed and not linked with each other. Thus it is not convenient and easy for researchers to get knowledge about the triple helix from them. Constructing ontology based on these three kinds of databases for a specific domain links those databases in the domain, and thus it offers an optional way for scientific researchers to explore the triple helix of academia-industry-government, which is budget and time-saving and can provide a lot of useful information for them to make their strategic research plans, or what we called research roadmaps.

A Hybrid Method of Constructing Ontology

For academic 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, 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*. After a domain is specified, three kinds of data sets corresponding to each dimension of the triple helix in the domain are collected.

1. Data set in academia dimension. This data set contains mainly the information about academic publications in the domain. Such data can be obtained from scientific databases.
2. Data set in industry dimension. This data set contains the information about the patents in the domain. This data set can be obtained from patent databases.
3. Data set in government dimension. This data set contains the information about the projects supported by government in the domain, and it can be obtained from project databases which is commonly available in some government agencies' websites.

After getting these three data sets, we need to build relations among them for further analysis, and ontology is used for this purpose. We put forward a hybrid method for constructing ontology from the three data sets. In terms of *hybrid*, we mean the method is composed of both a bottom-up process and a top-down process. 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 (see Wolfe 2003). After discussion with some academic researchers, we found a four-level ontology for a domain is appropriate for linking and analyzing the three datasets.

- Keyword level: keywords are gathered from the three data sets (bottom-up).
- Sub-topic level: subtopics are mainly summarized from keywords (bottom-up), and a sub-topic can also be added into this level with expertise from a more general level – topic level (top-down).
- Topic level: topics are more general than subtopics. They can be mainly summarized from sub-topics (bottom-up), and also could be generated with expertise (top-down).
- Sub-domain level: Sub-domains are mainly generated with expertise or from authorized agencies (top-down), and of courses, a sub-domain can be summarized from sub-topics (bottom-up).

As shown in Fig. 1, when identifying elements in each level, from keyword level to sub-domain level, less and less bottom-up, and more and more top-down is involved. Most of relations among elements can be identified during the hybrid process. For example, one subtopic was summarized from several keywords, and then it is naturally that those keywords are affiliated with this subtopic. New affiliation can also be added according to expertise. The structure of the ontology is a network, instead of a tree, 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.

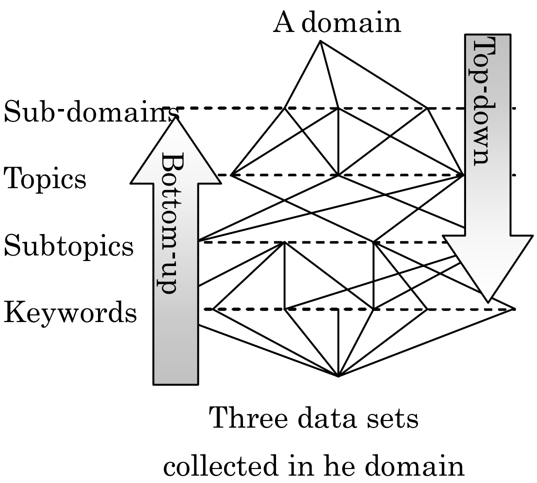

Fig. 1 A hybrid method of constructing ontology

With the ontology, the triple helix of academia-industry-government can be analyzed with each element from different level of the ontology. Information extracted from the three data sets is helpful for answering questions such as

- What projects were, are, or will be supported by governments in this sub-domain/topic/subtopic/keyword? Who (persons and intuitions) were, are or will be in charge of the projects? How much money was, is or will be invested from government to those projects?
- How many patents have been issued, or have been applied in this sub-domain (/topic, subtopic, or keyword)? Who hold or are applying for those patents?
- Who from academia are doing research in this sub-domain (/topic, subtopic, or keyword), and what are their publications?
- Which sub-domain (/topic, subtopic, or keyword) is often addressed by academia-industry-government, and which is not?
- What are the relationships among technologies, research topics, researchers, and applications/products?

A Case Study: Vehicle-Related Fuel Cell Technologies

Here we introduce an application of this approach to a domain defined by two keywords, *fuel cell* and *vehicle*. With this domain, 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), the industry data set was obtained from the patent circulation database, Japan (http://www.ryutu.ncipi.go.jp/PDDB/Service/PDDBService), and 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). After getting these three data sets, by applying the hybrid method, a four-level ontology was constructed which includes 144 keywords, 106 sub-topics, 25 topics, and 10 sub-domains. A web-based support system was developed for helping researchers to explore the triple helix of academia-industry-government in this domain. Main functions of this system include:

Searching. Researchers can search the three data sets with any element in the ontology. Searching function will provide researchers an overlook about the triple helix of academia-industry-government for each sub-domain, topic, subtopic or keyword: who are working on it in academia; what projects are related to it, what patents have been granted, and so on.

Network Visualization. Here nodes in a network include elements of the ontology, researchers, publications, patents, and projects. Network visualization is helpful for understanding the relations among nodes. Fig. 2 shows an example of a network among researchers tied by sub-domains, in which T*i* (*i* = 1, ..., 10) denotes the 10 sub-domains, Rs*j* (*j* = 1,…, 94) denotes researchers.

Calculating distance/similarity. The network can provide rough distances between each two nodes which can be roughly calculated as the smallest number of connections between them. Some existing approaches and algorithms can provide more detailed distances based on different understanding and definitions of distances/similarity. Considering our data sets contains both numerical data and categorical data. In our system, we selected a method put forward by SiQuang Le and TuBao Ho (see Le S et al. 2004) to calculate distances between nodes.

Roadmapping between nodes. This function is to help researchers to identify connections between two specific nodes in networks. Thus if a researcher is doing work related to one technology, and now he/she is considering to do some work related to another technology, the system will tell the researcher what technologies might be the links between them, or we can say the system suggest something which maybe the researcher should have a look at.

Concluding Remarks

The computer-based approach introduced in this article can be looked as a starting point of a roadmapping process in academia. 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 context. For example, in the case study introduced in this article, data were from Japanese databases since in the project what the researchers cared 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. The ontology is not limited to four levels if a two or three-level ontology is found more appropriate.

Constructing ontology and the computer-based approach introduced in this paper itself does not generate research roadmaps. The approach help researchers to identify “where I am” and “where I want to go”, but does not give answers to “how can I get there”, instead it suggests something which might be important for getting there.

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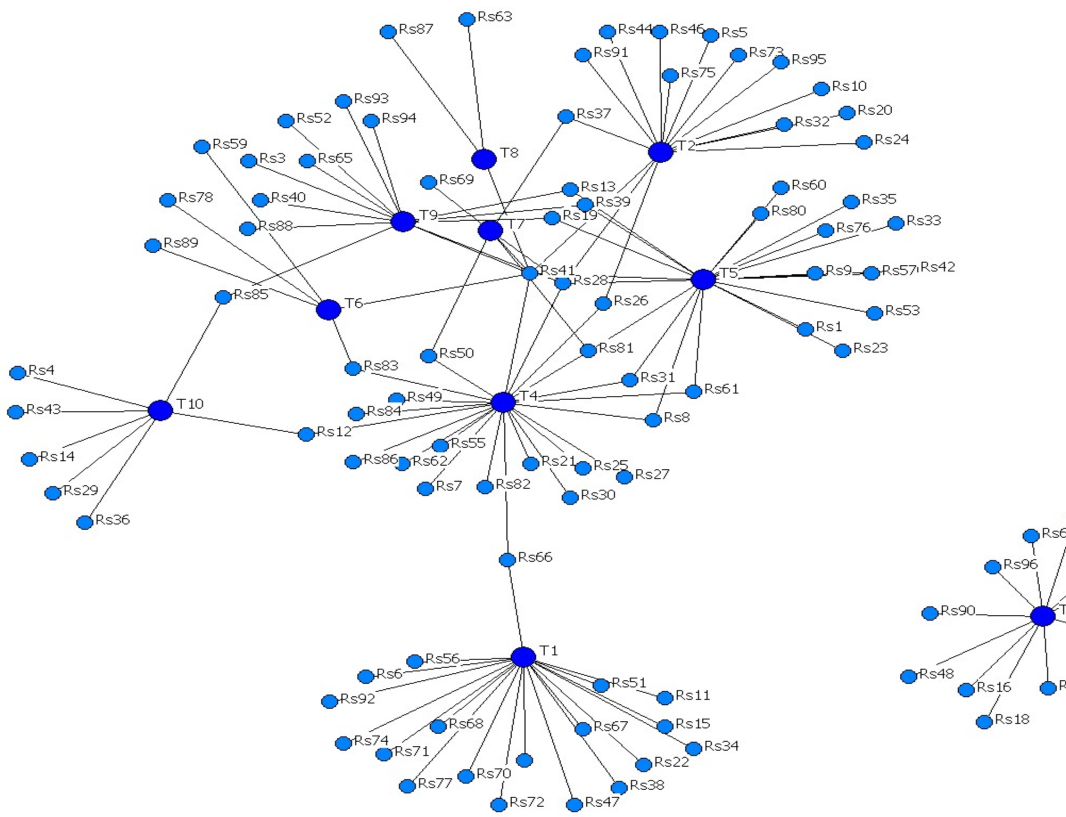

Fig.2 An example of a network

Researcher Column 3:

Constructing Ontology for the 21th Century COE Program *Technology Creation Based on Knowledge Science*

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The work presented here attempted to create an ontology characterizing the 21st Century COE Program *Technology Creation Based on Knowledge Science* at Japan Advanced Institute of Science and Technology (JAIST), based on a combination of a bottom-up and top-down approaches to ontology creation. An example of application of this ontology, related to an *adaptive hermeneutic agent* (AHA), is given.

1. The Goals and method of Constructing Ontology of the COE Program

We tried to construct the ontology of 21st Century COE Program *Technology Creation Based on Knowledge Science* at JAIST as a case study, with the following goals:

I. To clarify the use of the concept of Knowledge Science in this Program and make explicit (at least, as much as possible) assumptions about this concept that are often tacitly made;

II. To represent a vocabulary of terms used in this COE Program, together with a systematization of terms used;

III. To help in the development of a software system designed to support hermeneutic search of literature, and possibly in other projects related to the COE Program.

Known ways of constructing ontology can be treated not as absolute recipes, but hints how to proceed. There is a distinction of a top-down approach - actually, starting with an intuitive perception of the basic concepts in hermeneutical horizon (Król 2007) and specifying them in detail subsequently – and a bottom-up approach - starting, say, with the concepts actually used in a given field of knowledge and trying to interpret them and their structural relations. The top-down approach starts with issues related to meta-model functionality; the bottom-up approach starts with issues related to systematization and standardization (Dieng and Corby 2000). Obviously, we need a combination of both approaches in order to construct a useful ontology.

2. Bottom-Up Classification and Specification: Keyword Analysis

To build an outline of the ontology of COE program, we started with the paper presenting an introduction to this program authored by the program leader (Nakamori 2004). After analyzing the purpose and sub-projects of the program, we selected the key terms and concepts mentioned in the paper and organized an ontology outline with three levels of branches. The first level included five main topics: knowledge science, systems science and methodology, education in knowledge science, knowledge creation, and management of technology. In addition, we also referred to the program reports presented by the program leader in later periods to check and revise the outline.

Furthermore, we collected the papers authored by COE project members - as many as were available. Since we had to limit this search to electronic files, we finally considered only 43 papers, which were either included in Proceedings of International Symposium on Knowledge and Systems Sciences (JAIST, 2004), or Proceedings of the First World Congress of the International Federation for Systems Research (Kobe, 2005), or in the International Journal of Knowledge and Systems Sciences (Issues 1 to 6). We extracted the keywords from all papers and counted the frequency of their occurrences in the full body of papers by using a computer program designed by a member of our group. We have chosen the keywords with high frequency to supplement the outline of COE ontology as the fourth level.

Another attempt was a clustering of keywords based on their joint occurrence. We selected a simple QT (quality threshold) clustering algorithm, see, e.g. Heyer et al. 1999): if the frequency of occurrence of a pair of keywords equals or exceeds an assumed threshold t, the pair might be counted to belong to a candidate cluster; the largest of such candidate clusters is counted as an actual cluster, it is subtracted from the entire set of keywords, and the procedure is repeated on the remaining keywords. It turned out that the joint occurrence of keywords is not common, most frequencies of such co-occurrence are zero, thus the clustering was done at the threshold level $t = 1$. The result of a clustering of keywords showed us the correlations among the keywords and provided their comparison with the top-down outline of ontology.

3. Top-Down Approach: a Reflection on the Concept of Knowledge Science

Knowledge science (KS) is often confused with or tacitly assumed to be subordinated to *knowledge management* (KM), thus we first reflect on the origins and meaning of the second term. *Knowledge management* has much popularity in management science, but its technological origins are often forgotten. It was first introduced by computer technology firms in early 1980-ies – first in IBM, then Digital Equipment Corporation who probably was the first to use the term *knowledge management* – as a computer software technology in order to record the current work on software projects. This started the tradition of treating knowledge management as a system of computer technologies. Later this term was adopted by management science, and made a big career. This has led to two opposite views how to interpret this term, see, e.g. (Wiig 1997, Davenport and Prusak 1998):

- As *management of information relevant for knowledge-intensive activities*, with stress on information technology: databases, data warehouses, data mining, groupware, information systems, etc.
- As *management of knowledge related processes,* with stress on organizational theory, learning, types of knowledge and knowledge creation processes.

The first view is naturally represented by information technologists and hard scientists; the second by social scientists, philosophers, psychologists and is clearly dominating in management science. Representatives of the second view often accuse the first view of perceiving *knowledge to be an object* while it should be seen as *knowledge related to processes;* they stress that knowledge management should be *management of people*.

However, while it is correct that knowledge management cannot be reduced to management of information, such *a correct assessment is a pitfall* (an unfortunate impact of binary logic on our thinking): being sure that they are right, the representatives of the second view overlook both the complexity and the essence of the controversy. The complexity is that, historically, knowledge management has started with technology and cannot continue without technology; thus, both interpretations should be combined in adequate proportions. The essence of the controversy is that *management of people* should be also understood as *management of knowledge workers;* and knowledge workers are today often mostly information technologists, who should be well understood by managers. Thus, we believe that the two views listed above should be combined. Moreover, they incompletely describe what knowledge management is; there is a third, essential view, seeing knowledge management as the *management of human resources in knowledge civilization era,* concentrating on knowledge workers, their education and qualities, assuming a proper understanding of their diverse character, including a proper understanding of technologists and technology.

This is particularly visible concerning the concepts of *technology management* versus *knowledge management.* Management science specialists in knowledge management often tend to assume that *technology management* is just a branch of *knowledge management;* technologists specializing in *technology management* stress two aspects. However, an essential meaning of the word *technology* is *the art of designing and constructing tools or technological artefacts* (thus, *technology* does not mean *technological artefacts,* although such a meaning is often implied by a disdainful use of the word *technology* by social sciences, e.g., in the quoted above phrase *dumping technology*). In this sense, the term is used in the phrase *technology management.* Secondly, *technology management* might be counted as a kind of special *knowledge management,* but it is an older discipline, using well developed concepts and processes, such as *technology assessment, technology foresight* (see, e.g., Salo and Cuhls 2003) and *technology roadmapping* (see, e.g, Willyard et al. 1987, Phaal et al. 2004). Only recently, some of these processes have been also adapted to knowledge management, see (Ma et al. 2005).

All the above discussion implies that we are observing now an emergence process of a new understanding of *knowledge sciences* – an interdisciplinary field that goes beyond the classical epistemology, includes also some aspects of *knowledge engineering* from information technology, some aspects of *knowledge management* from management and social science, some aspects of *interdisciplinary synthesis* and other techniques (such as decision analysis and support, multiple criteria analysis, etc.) from systems science. This emergence process is motivated primarily by the needs of an adequate education of *knowledge workers* and *knowledge managers and coordinators;* however, also the research on knowledge and technology management and creation needs such interdisciplinary support.

The classical understanding of the words *knowledge science* might imply that it is epistemology enhanced by elements of knowledge engineering, knowledge management and systems science. However, the strong disciplinary and historical focus of epistemology suggests an opposite interpretation: knowledge science must be interdisciplinary, thus it should not start with epistemology, although it must be enhanced by elements of epistemology. The field closest to knowledge science seems to be systems science – at least, if it adheres to its interdisciplinary origins and does not suffer too much from the unfortunate (but unavoidable today) disciplinary division into *soft* and *hard systems science.* The noticeable tension between *soft* and *hard* systems science is just an older version of the tension between understanding *knowledge management* either from the perspective of knowledge engineering, or from the perspective of social and management science, mentioned above.

To summarize, we should thus require that *knowledge sciences* gives home to several disciplines (quoted here in an alphabetic order):

- *Epistemology and philosophy of science,*
- *Knowledge engineering,*
- *Management science and knowledge management,*
- *Sociological and soft systems science,*
- *Technological and hard systems science,*

On equal footing, with a requirement of mutual information and understanding, this basic classification should be also reflected in the proposed ontology of the COE Program.

4. Final Proposal of the Ontology

Based both on the bottom-up classification and on the above reflection as a basis of top-down approach, the ontology of the COE Program can be proposed. It is organized as an inverted tree, with fourth-level branches corresponding to keywords found in the papers of COE Program members. The general category of the domain of Knowledge Science includes the following eight sub-domains as the first lever of ontology of the COE Program:

- *Knowledge Creation and Transformation*
- *Knowledge Representation, Systematization, Acquisition*
- *Knowledge Management*
- *Systems Science*
- *Education and Knowledge Science*
- *Management of Technology*
- *Technology Creation*
- *Diverse Related Themes*

Each sub-domain is consisted of several topics (Second lever); the different topics include particular sub-topics (Third Lever). All keywords was summarized as and categorized into the sub-topics (Fourth lever). In addition, the clustering of the keywords gave us the hints to find the relations between the subtopics and the further relations between topics as well as sub-domains. The structure of the ontology is not only a simple tree, also a network. Because of the limitation of pages, I can not list the proposed ontology here. Our classification is naturally not absolute nor the ultimately final; it might be further enhanced and corrected as new data will become available.

5. An Application: Adaptive Hermeneutic Agent (AHA)

On the basis of requirements of researchers (Tian et al. 2006a, 2006b) and the phenomenon of *Hermeneutics* (Wierzbicki and Nakamori, 2006), a software tool for information and knowledge retrieval was designed, see (Ren and Wierzbicki 2007), (Ren et al. 2007), in order to help researchers in gathering and interpreting relevant knowledge or research materials; this software tool is called *Adaptive Hermeneutic Agent (AHA)*. The AHA is equipped with a simple and intuitive search interface and uses familiar search syntax, such as used by popular search engines (like Google, Yahoo). The search support can be extended to the definition of queries that will be automatically executed by the system with a fixed period of time. The definition of a query by the user is helped by ontological information; actually, the ontology described above is used in AHA as a basis of defining queries that can be selected from this ontology, supplemented or modified, for example, by adding new keywords that are relevant to the searched topic. After the query is executed, the AHA can also filter the obtained results by using a reinforcement learning approach that relies on a profile of the user's interests. The AHA could also use a visual interface for the clustering and graphical presentation of search results.

Therefore, the COE ontology as described earlier is an important element, first step in developing the software tool of AHA. The second step is the creation of user profile. The user, for example, a COE member, could extract the knowledge from COE ontology to formulate the outline of user profile, for example, select the domains (keywords) he are most interested in and give the weights for different keywords. Then, the user could gather relevant knowledge and information based on his profile by using search engines connected to AHA. The AHA will do adaptive selection automatically as following steps: text extraction (from MS-word file to text or from PDF file to text); keyword extraction and frequents calculation (extracting keywords from the search results by statistics method); measurement of the similarity of each file and user profile; giving a ranking list including top N results. The final step is user evaluation.

Other possible applications of the work on ontology formation described here include, for instance, the development of an ontology of the School Knowledge Science in JAIST, an ongoing project that will include the lessons from the work described here; or a construction of a Knowledge Map or a research network for professionals interested in related domain, etc.

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COE Center News

- *Prof. Andrzej P. Wierzbicki* left the Center and came back Poland as of April 2007. He will visit to JAIST on October 2007.
- *Dr. Zhu* stayed JAIST from April.17 to March 17 2007. He gave us a COE seminar. And he gave us a lecture about The JAIST Scool: Continuity and Future.
- *Dr. Adam Wierzbicki* visited to JAIST to give us the lecture about Modern Open Distributed Systems: Research Challenges and Applications.
- *Dr. Jing Tian* left the Center and was in Tokyo as of March 2007.
- *Dr. Homei Miyashita* left the Center and was in Tokyo as of April 2007.
- *Mr. Hiroyuki Asano* left the Center and was in Kanagawa in Japan as of April 2007.
- *Dr. Tomoko Kikuchi* joined the Center as postdoctoral researcher as of April 2007.

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(Details on page 18)

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