Translational Systems Sciences 5

Yoshiteru Nakamori *Editor*

Knowledge Synthesis

Western and Eastern Cultural Perspectives

Springer

Translational Systems Sciences

Volume 5

In 1956, Kenneth Boulding explained the concept of General Systems Theory as a *skeleton of science*. The hope was to develop something like a "spectrum" of theories—a system of systems which might perform the function of a "gestalt" in theoretical construction. Such "gestalts" in special fields have been of great value in directing research to wards the gaps which they reveal.

There were, at that time, other important conceptual frameworks and theories, including cybernetics. Additional theories and applications developed later, such as synergetics, cognitive science, complex adaptive systems, and many others. Some focused on principles within specific domains of knowledge and others crossed areas of knowledge and practice, along the spectrum described by Boulding.

Also in 1956, the Society for General Systems Research (now the International Society for the Systems Sciences) was founded. One of the concerns of the founders, even then, was the state of the human condition, and what science could do about it.

The present Translational Systems Sciences book series aims at cultivating a new frontier of systems sciences for contributing to the need for practical applications that benefit people.

The concept of translational research originally comes from medical science for enhancing human health and well-being. Translational medical research is often labeled as "Bench to Bedside." It places emphasis on translating the findings in basic research (*at bench*) more quickly and efficiently into medical practice (*at bedside*). At the same time, needs and demands from practice drive the development of new and innovative ideas and concepts. In this tightly coupled process it is essential to remove barriers to multi-disciplinary collaboration.

The present series attempts to bridge and integrate basic research founded in systems concepts, logic, theories and models with systems practices and methodologies, into a process of systems research. Since both bench and bedside involve diverse stakeholder groups, including researchers, practitioners and users, translational systems science works to create common platforms for language to activate the "bench to bedside" cycle.

In order to create a resilient and sustainable society in the twenty-first century, we unquestionably need open social innovation through which we create new social values, and realize them in society by connecting diverse ideas and developing new solutions. We assume three types of social values, namely: (1) values relevant to social infrastructure such as safety, security, and amenity; (2) values created by innovation in business, economics, and management practices; and, (3) values necessary for community sustainability brought about by conflict resolution and consensus building.

The series will first approach these social values from a systems science perspective by drawing on a range of disciplines in trans-disciplinary and cross-cultural ways. They may include social systems theory, sociology, business administration, management information science, organization science, computational mathematical organization theory, economics, evolutionary economics, international political science, jurisprudence, policy science, socioinformation studies, cognitive science, artificial intelligence, complex adaptive systems theory, philosophy of science, and other related disciplines. In addition, this series will promote translational systems science as a means of scientific research that facilitates the translation of findings from basic science to practical applications, and vice versa.

We believe that this book series should advance a new frontier in systems sciences by presenting theoretical and conceptual frameworks, as well as theories for design and application, for twenty-first-century socioeconomic systems in a translational and transdisciplinary context.

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Preface

Synthesis of various kinds of knowledge needs to combine *analytical thinking* and *synthetic thinking*. Systems science is expected to help people solve contemporary complex problems, utilizing interdisciplinary knowledge effectively. However, it has been divided into two schools of thought: one seeks a systematic procedure to search a correct, objective answer; and the other develops an emergent, systemic process so that the user can continue exploratory learning. Thus, analytical thinking and synthetic thinking has been developed in different schools independently.

This book tries to integrate these two schools using ideas in knowledge science that has been emerging recently under the influence of Eastern thinking. This book emphasizes the importance of utilizing intuition in systems approaches; whereas other books usually try to solve problems rationally and objectively, trying to eliminate subjectivity. This book never denies rationality and objectivity; however complex problems of today do not always accept complete analysis. The novelty of this book is to discuss knowledge synthesis from the Western and Eastern cultural perspectives, utilizing the ideas in systems science as well as knowledge science.

This book introduces a theory on *systemic knowledge synthesis* in an odd chapter, and presents an application of the theory in the next chapter, in order to contribute to developing *translational systems science*. The contributors of the first four chapters are Andrzej P. Wierzbicki and Janusz Granat, famous researchers in the field of decision analysis. They discuss the issue of knowledge synthesis on the basis of both Western and Eastern cultural backgrounds. The next four chapters are written by Chinese systems scientists, Jifa Gu, Xijin Tang, Zhongtuo Wang and Jiangning Wu. They are trying to integrate quantitative and qualitative approaches, with the background of Chinese philosophy. The last two chapters are the contribution of Yoshiteru Nakamori, the editor of this book. He also tries to integrate Western and Eastern approaches, by offering a theory of knowledge construction systems developed in the field of knowledge science.

Chapter "Systemic Synthesis and Metaphysics: Eastern versus Western Thinking" discusses the issue of *interdisciplinary systemic synthesis* deeply. This has been baffling experts in Western epistemology, possibly because of its methodological similarity to metaphysics, and the original dominance – during the twentieth century – of a negation of metaphysics characteristic in Western philosophy. Eastern thinking did not encounter any such difficulties, possibly because of its dominating, metaphysical concept of the *unity of contradictions* (*yin and yang*). Nevertheless, it is important to consider in more detail the differences and similarities between systemic synthesis and metaphysics, and Western and Eastern approaches to this issue.

Multiple criteria ranking is a natural and often used tool in contemporary network management. Its importance will grow in networks of future generations, such as Internet of Things (IT) or Content Aware Networks (CAN). Chapter "Multiple Criteria Ranking in Future Network Management" presents a review of diverse *multiple criteria ranking techniques*, then of their applications in network management and related fields, such as network search engines. A new network management task for IT or CAN is described: selecting services existing and described in the network in order to support their combination while forming a new service. An application of objective ranking for this purpose with support of *systemic synthesis* is described.

Chapter "Evolutionary Knowledge Creation from an Eastern Perspective" introduces important recent developments of Eastern approaches to the issue of *knowledge creation*, a subject partly neglected in Western philosophy. These approaches are essentially naturalistic and evolutionary, stressing the circular development of knowledge based on spiral-like development resulting from positive feedback. In such approaches, nature is the reason and cause as well as the effect of social development of knowledge.

Data mining is one of the techniques that are widely used for supporting diverse business tasks. However, the process of building data mining models and transforming results of models execution into useful business knowledge is a complex process that is a result of knowledge synthesis by a group of experts. This process is mostly intuitive and requires development of new scientific methods. *Systemic synthesis* might be one of the driving forces of such development. For example, Cao and Zhang have recently proposed *domain-driven data mining methodology* that considers *meta-synthesis*. In chapter "Data Mining of Telecommunications Data as an Example of Systemic Synthesis", some examples of applying *systemic synthesis* in data mining in telecommunication domain are presented.

Chapter "The Meta-synthesis System Approach" introduces a systems approach developed in China: *meta-synthesis system approach*, which is designed for solving the complex problems happened in the *open giant complex system*, such as the social system, the environmental system, the human body system, etc. It was proposed by Qian, Yu and Dai in 1990. There is a flowchart "Meeting I-Analysis-Meeting II" in using meta-synthesis approach. Three kinds of meta-synthesis are used often during the problem solving: qualitative meta-synthesis, the combination of qualitative meta-synthesis and quantitative meta-synthesis and from qualitative meta-synthesis to quantitative meta-synthesis. The tool for realizing the meta-synthesis system approach is the "hall of workshop for meta-synthesis". It consists of the knowledge system, the expert system and the machine system. Miscellaneous halls of workshop have been designed in the different areas in China, such as military, economy and industry areas.

Some typical frameworks proposed for the so-called *unstructured or wicked problem solving* and the relevant computerized support development are reviewed in chapter “Problem Structuring Process by Qualitative Meta-synthesis Technologies”. Those include two decision-making models for decision support systems development (Simon’s 3-phase model and Courtney’s framework), two problem structuring approaches in strategic decision-making (strategic assumption surfacing and testing (SAST) and Wisdom process proposed by UK researchers) and one model of creativity and relevant tasks for creativity software development. Such an analysis aims to explain the working philosophy of *meta-synthesis approach*, especially toward problem structuring which is actually a knowledge synthesizing process where supporting technologies are needed to help distill visions from those original or first-hand on-site community opinions. Finally two technologies, CorMap and iView for *qualitative meta-synthesis* for idea or assumptions generation for further verification and validation, are briefly addressed, together with practical applications on group discussion, social psychology mining and expert knowledge mining, etc.

Chapter “Knowledge Systems Engineering: A Complex System View” introduces a new discipline called *knowledge systems engineering* (KSE). This discipline was proposed by Z.T. Wang, one of the authors of this chapter, as an *engineering partner of knowledge science*. The main features of KSE are systematic and integrative thinking and investigations not only for knowledge management but also for the knowledge enabling (or knowledge facilitating) to innovation. The goal, function, architectures of knowledge system and the contents of the discipline are outlined.

To preserve historical documents and to mine precious knowledge involved, a *knowledge-based archive management system* (KB-AMS) was developed, which is introduced in chapter “A Practical Case of Knowledge-Based Archive Management System”. From a socio-technical perspective, the system is designed as a both human centered and IT-based system which not only provides access to archives but also facilitates knowledge sharing and creation, and therefore enhancement of knowledge services. Based on the conceptual model, people, resources, processes, and technologies within the system are described and analyzed by introducing a practical case in the context of historical archive preservation.

Chapter “Systemic Knowledge Synthesis and Justification” introduces a procedural, but virtually systemic, approach to knowledge synthesis: a *theory of knowledge construction systems* that is a systems approach to synthesize a variety of knowledge and to justify new knowledge. The theory consists of three parts that relate to each other, which are: a knowledge construction model, analysis of actors’ abilities against social structures, and knowledge justification principles. This theory deals with different types of knowledge integration such as specialized integration, interdisciplinary integration, or intercultural integration.

Regional development and vitalization is a major social problem especially in an aging society. Various activation projects by local governments, enterprises, or citizens can be regarded as service providing systems in which value will not be created unless there is a big contribution of users. Chapter "Community Service Systems Development" proposes a methodology of developing *community service systems* based on the *theory of knowledge construction systems*, emphasizing service value co-creation between providers and users. As a concrete example of this methodology, this chapter introduces a social experiment for developing a community health care system.

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Contents

Systemic Synthesis and Metaphysics: Eastern versus Western Thinking

Andrzej P. Wierzbicki

Abstract This chapter discusses the issue of interdisciplinary *systemic synthesis*, its methodological similarity to *metaphysical reduction*, its reliance on intuition, together with the tensions due to the differences between the Western and Eastern thinking about these issues. The concept of systemic synthesis is summarized and discussed, a short overview of last century developments in Western epistemology and metaphysics is given, the basic differences with Eastern thinking about these issues are highlighted, and recent Eastern theories of systemic synthesis and knowledge creation are discussed together with the scientific, naturalistic and evolutionary theory of intuition which are motivated by these theories.

Keywords Systemic synthesis • Metaphysical reduction • Intuition • Western and Eastern thinking

1 Introduction

The issue of interdisciplinary systemic synthesis has usually baffled experts in Western epistemology, possibly because of its methodological similarity to metaphysics and the original dominance – during the twentieth Century – of a negation of metaphysics characteristic in Western philosophy. Eastern thinking did not encounter any such difficulties, possibly because of its dominating, metaphysical concept of the *unity of contradictions* (*yin and yang*). Nevertheless, it is important to consider in more detail the differences and similarities between systemic synthesis and metaphysics, and Western and Eastern approaches to this issue. This chapter is devoted to such analysis.

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2 Systemic Synthesis

In the development of humanity in all history of civilization, we observe both the useful and inescapable tendency toward *disciplinary specialization*, based on closer contact with a selected fragment of reality, such as when a carpenter specializes in wood processing and an astronomer in observations of stars and planets. This tendency, however, resulted in the opposite need for an *interdisciplinary reflection*, in at least two essential aspects. Firstly, there is the need to take into account or to complement knowledge belonging to many disciplines for the purposes of any broader practical application; this aspect is the subject of *engineering*, but also of *systemic analysis and synthesis* or the intersection of these disciplines, *systems engineering*.

Secondly, there is a more general need to rethink, to achieve a theoretical reflection on the general conclusions derived from the results of individual disciplines. Initially, in the time of Babylonian civilization for example, such a role was attributed to *religion*, later to *mathematics*, but as both of them became specific disciplines, this role is fulfilled today by *philosophy in its general interdisciplinary sense*, and especially by *metaphysics* – see next section. Large parts of philosophy also became specific disciplinary fields, which resulted in the need for new approaches to interdisciplinary synthesis, in common with *systemic analysis and synthesis*.

What is systemic synthesis and how it is performed methodologically? We should start with the concept of systemic analysis or *systems analysis*. This concept is today understood differently by the representatives of *hard systems thinking* – mostly engineers using mathematical modeling in *virtual laboratories* in order to prepare and make the actual tests of any technical construction less expensive (see, e.g., Makowski and Wierzbicki 2007), and those of *soft systems thinking* – mostly social scientists trying to prove that mathematical modeling enslaves people and that all systemic thinking originated in social science (see, e.g., Midgley, 2003).

Historically, however, there is no doubt that systems analysis originated from the *general systems theory* of Ludwig von Bertallanfy (1951, 1956) who stressed the generality of systems research methods, the importance of interdisciplinary and holistic approaches and the effect of *synergy* (*the whole is bigger than the sum of its parts*). It is telling that Bertallanfy substantiated the necessity of development of the *general systems theory*, pointing out the increasing specialization of disciplinary sciences, the dearth of interdisciplinary approaches and the possibility of using the same mathematical models in diverse disciplines, while the need of holistic approaches resulted, according to Bertallanfy, from the frequent occurrence of teleological problems.

The use of similar mathematical models in diverse disciplines is today the essence of hard systems analysis. Such a possibility was first noted by the technical *theory of automatic control*, stressing the generality of mathematical models of control systems based on the feedback principle, their independence from the specific technical discipline of applications, established in 1940–1944 by the works of Smith (1942), Hall (1943), Oldenbourg and Sartorius (1944), and later Oppelt (1947), even if it actually originated much earlier (starting with Watt, Airy, Maxwell and many others). It was concentrated on the interdisciplinary analysis of the dynamics of technical control systems, and later was generalized to arbitrary control systems, also those occurring in nature, and called, in such general cases, *cybernetics* (Wiener, 1948). Bertallanfy observed that this possibility occurs not only for feedback systems: mathematical models used in diverse disciplines might be different from each other, but the methodology of their analysis is similar.

In fact, for any broader technical application, it is necessary to combine mathematical models from several disciplines – how is such a combination performed? A hard systems analyst achieves such a combination by using the art of modeling, through a creative, intuitive act that takes into account the possibility of synergy. Moreover, because of issues of computational complexity (see, e.g., Wierzbicki, 2011), a hard systems analyst cannot express with mathematical models all knowledge of the specific disciplines involved; thus, any systemic model is a creative simplification – a *systemic synthesis*, even if it combines knowledge from several disciplines. Therefore, how can we be certain that such a combination is correct?

In fact, hard systems analysts achieve such certainty by testing several conclusions resulting from systemic modeling, and evaluating such conclusions intuitively, in a process very similar to the *metaphysical reduction* described in the next section. This evaluation of systemic synthesis is not necessarily individual, but is sometimes performed by an entire group of modelers, who discuss the importance and correctness of such conclusions and modify the combined model if they feel it is necessary. However, it is not a deductive process, just the opposite – it is a kind of metaphysical reduction supported by intuition.

3 Epistemology and Metaphysics

In the Eastern hermeneutic perspective that we discuss in more detail in the next section, there is no contradiction in the name 'knowledge science'. However, in the Western perspective we can find philosophical writings (e.g., Motycka, 2010) that stress the differences and contradictions between philosophy and science; thus, epistemology is then understood as a part of philosophy concerned with reflections on the development of science, not as knowledge science. This is concerned even more with metaphysics, understood broadly as a part of philosophy concerned with reflections on being, truth, higher values, and foundations of humanity. The difference between science and philosophy, according to Alina Motycka, is that philosophical reasoning is different than scientific reasoning. The latter is mostly logical and deductive, inductive only in earlier times. This way of reasoning was sharply criticized by Karl Popper (1934, 1972), who demanded falsification of theories by empirical testing, but other approaches (Kuhn, 1962) noted that falsification actually occurs due to a comparison to paradigmatic exemplar theories.

Philosophical reasoning, according to Motycka (2010), is based on reflection and intuition, including a process similar to metaphysical reduction (see, e.g., Morawiec, 2009; Pietka, 2009). Metaphysical reduction is an intuitive substantiation of metaphysical conclusions, actually using deduction in a reverse direction rather than logical deduction. Logically, this operation can of course lead to false conclusions, but this objection is countered by metaphysicians with the statement that in metaphysical reduction they seek a substantiation which can provide them with intuitive certainty. According to the evolutionary and rational theory of intuition discussed in a later section of this chapter, this argument does have some value (intuition is 10,000 times stronger than logical deduction), but with the reservation concerning its absolute character: even intuition can be fallible.

This is related to a general crisis in Western philosophy, both in epistemology and in metaphysics that developed during the twentieth century. In epistemology, this crisis is usually attributed to the works of Willard Van Orman Quine (1953) – who has shown that logical empiricism is fundamentally illogical, that knowledge can be only approximate and it is a "*fabric constructed by people that touches the reality only along its edges*". According to Wilfried S. Sellars (1956) – who criticized the concept of 'given data' (actually, such a critique results directly from the work of Werner Heisenberg 1927, on uncertainty of measurements) to Richard McKay Rorty (1980) – who criticized the concept of knowledge and philosophy as a mirror of nature. In metaphysics, this crisis started earlier with the works of Gottlob Frege and Bertrand Russel for example, which developed logical empiricism, but is best illustrated in the conclusion of the first book of Ludwig Wittgenstein (1922) "*wovon man nicht sprechen kann, dar´uber muβ? man schweigen*" (whereof one cannot speak, thereof one must be silent) that actually indicated a prohibition of speaking about metaphysics. This ban was actually taken seriously by many philosophers which was one of the reasons for the crisis in philosophy. A revival of metaphysical thinking was observed first at the turn of the twentieth and twenty-first centuries (see, e.g., Motycka, 2009, 2010), together with the theory that the metaphysical way of thinking is actually what distinguishes philosophy and science.

However, an intuitive conviction of a philosopher about the truth of certain judgments is also not sufficient because it is possible that our intuition relies on observations of the meso-cosmos surrounding us (see, e.g., Vollmer, 1984; Wuketits, 1984), and becomes fallible if we change the conditions of observation. For each "true from definition" a priori synthetic judgment of Kant (1781), we can find conditions where such judgment ceases to be true. For example, "two plus one is three and is greater than two" is not absolutely ("in all worlds") true, because if we count modulo two (as in flip-flop switches, basic elements of computers), then two plus one is one and is smaller than two. The statement "a square is different from a circle" is also not an absolutely true judgment, because if we define a circle as the set of elements of a plane equidistant from its origin and use the Chebyshev distance (thus, use a different topology), then a square is a circle. Such examples can be multiplied, even if it sounds a bit disconnected.

Therefore, an intuitive conviction of a philosopher about absolute truth can be fallible – in other words, there are no absolute verities. Thus *what is truth?*

I believe that an answer to this fundamental question requires an approach from the perspective of civilization evolution. That entire epistemology requires an approach such as that was shown already by Michel Foucault (1972). He has changed the meaning of the word *episteme to denote the way of creating and substantiating knowledge characteristic for a given civilization epoch* and has shown that such a way indeed changes with a civilization epoch. Thus, the crisis in Western philosophy might be related to the anticipated change of a civilization epoch.

As it is usual in critical situations (see, e.g., Kuhn, 1962), this crisis in Western philosophy included a destruction of fundamental assumptions concerning, in this case, the concepts of *knowledge* and *truth*. The classical (since Plato) and even today broadly used concept of "*knowledge is justified true belief*" depends, however, on the concept of *truth*. However the concept of truth was undermined by the development of science in the twentieth century. Although many theories of truth were developed (e.g., correspondence theory, coherence theory, social constructivist and consensus theory, pragmatic theory, deflationary theory, pluralist theory, semantic meta-logical theory, etc.) most of them ignore the fact that since the work of Heisenberg (1927) we cannot expect a full correspondence of words to reality. Thus, *truth should be interpreted rather as a higher value* that is unattainable in full, like justice, but is in the social and evolutionary interest of humanity. The interpretation of objectivity of science should be thus understood by extending the argument of John Rawls (1971): if we are uncertain about the position of our children in the future, it is rational to promote the most just social solutions – and, by the same argument, also the most objective knowledge transmitted to them by science (see Wierzbicki, 2011).

4 Eastern Versus Western Thinking; Eastern Theories of Systemic Synthesis

As mentioned in the introduction, the most characteristic concept of Eastern thinking is the assumption of the unity of contradictions, the *yin and yang* principle. This principle is based on the observation that many natural dualities (such as shadow versus light, female versus male, etc.) describe how opposite forces are interconnected in reality, give rise to each other or are interdependent. This principle is dominant in most Eastern schools of thinking: in Taoism, Buddhism, Confucianism, etc., in Eastern science and philosophy, medicine, and even in martial arts.

For this reason, some theories of Western philosophy and logic are incomprehensible for an Eastern mind. Proof by contradiction (when we want to prove a theory, we assume that the opposite is true and show that such an assumption leads to a contradiction) was a familiar concept in Western logic. Although it was shown by Brouwer (1922) that proof by contradiction relies on the principle of the excluded middle and thus is in many situations incorrect, Western philosophy used this way of providing proof in its arguments against naturalism (see, e.g., Wierzbicki, 2011).

For example, Bruno Latour (1987, p. 99) uses the following argument against naturalism: "since the settlement of a controversy is the cause of Nature's representation not the consequence, we can never use the outcome – Nature – to explain how and why a controversy has been settled". This is actually a proof by contradiction, ignoring the fact that both in nature and in contemporary technical systems there are many cases of feedback, when the outcome becomes a cause. From the perspective of the *yin and yang* principle, a proof by contradiction is clearly incorrect.

Moreover, Eastern thinking is accustomed to naturalism, especially in Japanese co-existence of Buddhism and Shinto, as well as to circular arguments and developments; thus, feedback principles are most natural to Eastern minds. Contrariwise, in Western logic and philosophy there is traditionally a reluctance to admit circular reasoning, with concern for the so-called *vicious circle*. For example, Leszek Kołkowski (1988, p. 13 of Polish edition) writes (my translation): "From the time of ancient sceptics it has been known that all epistemology, that is, any attempt to establish a universal criteria of validity of knowledge, leads either to an infinite regress, or to a vicious circle, or to a not surmountable paradox of self-reference (not surmountable, of course, if not apparently resolved by reformulation to an infinite regress)." But for a technician (see Wierzbicki, 2011), as well for an Eastern mind, a logically valid epistemology must rely on the concept of circular or spiral-like relations resulting from positive feedback.

This can be observed in recent Eastern theories of systemic synthesis and knowledge creation. The Western controversy of hard and soft systems analysis, mentioned above, motivated two Japanese thinkers, Yoshikazu Sawaragi and Yoshiteru Nakamori, to propose a systemic synthesis of these two approaches, called the '*Shinayakana Systems Approach*' (Nakamori and Sawaragi, 1992). '*Shinayakana*' is a Japanese concept simultaneously expressing the elasticity of a willow twig and the hardness of a sword; here it is used to signify a synthesis of the *soft and hard systems analysis* following the *yin and yang* principle.

Independently and almost parallel, Ikujiro Nonaka and Hirotaka Takeuchi developed a theory of knowledge creation in organizations (Nonaka and Takeuchi, 1995), motivated by the need to understand how to create knowledge not in the long historical perspective (a subject of philosophy which might be called a *macro-theory of knowledge creation*), but for the needs of today and tomorrow resulting from the development of a knowledge-based economy (Nonaka and Takeuchi considered it to be a subject of management science; this might be called a *micro-theory of knowledge creation*).

The method of development of the theory of Nonaka and Takeuchi was actually a systemic synthesis similar to metaphysical reduction: using their knowledge about Japanese organizations, they developed their theory intuitively, later checking it by comparing it with the examples of specific organizational knowledge creation processes. The theory of Nonaka and Takeuchi has a breakthrough character to it, because they stressed interplay between explicit and tacit knowledge and a circular, spiral-like development of new knowledge; this is illustrated by Fig. 1 where their *SECI spiral* is represented.

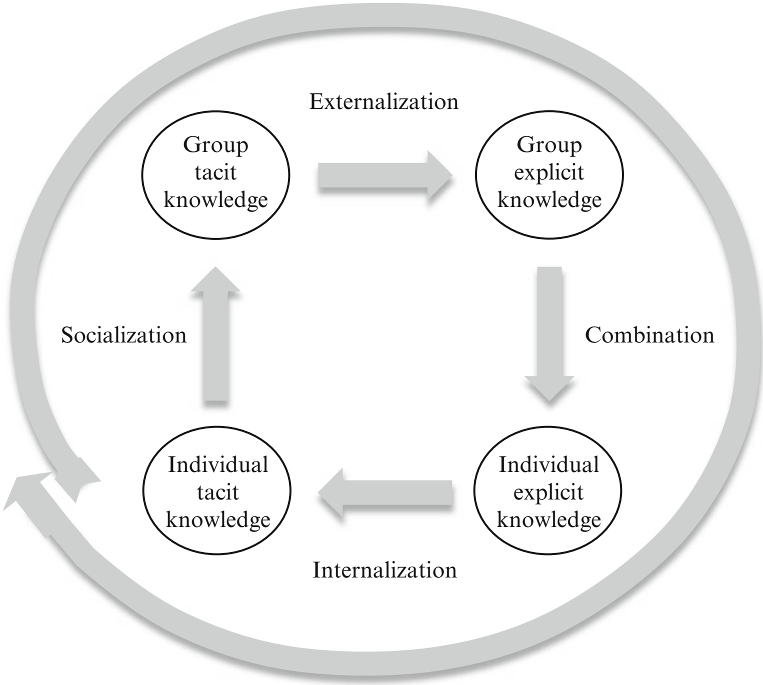

Fig. 1 SECI spiral of knowledge creation in Japanese organizations (Nonaka and Takeuchi, 1995)

Later, many micro-theories of spiral-like knowledge creation were developed (see Wierzbicki and Nakamori, 2006, 2007); this is related to the concept of *Creative Space*, generalizing the *SECI spiral* and showing the possibility of distinguishing many spirals of knowledge creation (see Fig. 2). Another related development was the concept of the *Nanatsudaki process of knowledge creation*, combining seven spirals to support more complex knowledge creation processes (see Fig. 3).

All these developments were actually examples of systemic synthesis, using methods similar to metaphysical reduction. However, even more significant might be two other developments directly aimed at systemic synthesis. First, Yoshiteru Nakamori (2000) proposed a more extensive model of systemic synthesis for processes of knowledge creation, expressed by the *Pentagram of* I^5 *system* (see Fig. 4), which is called the *i*-System in chapter "Systemic Knowledge Synthesis and Justification".

Two fundamental nodes of this pentagram, *Intelligence* and *Involvement*, can be approximately treated as equivalent to the two basic dimensions of creative space: epistemological and social dimension. However, the remaining nodes characterize other aspects of knowledge creation. *Imagination* is related to intuition, but can also be treated as a separate dimension. *Intervention* is in a sense a starting node for the pentagram – it expresses the will to take up the problem. *Integration* is an

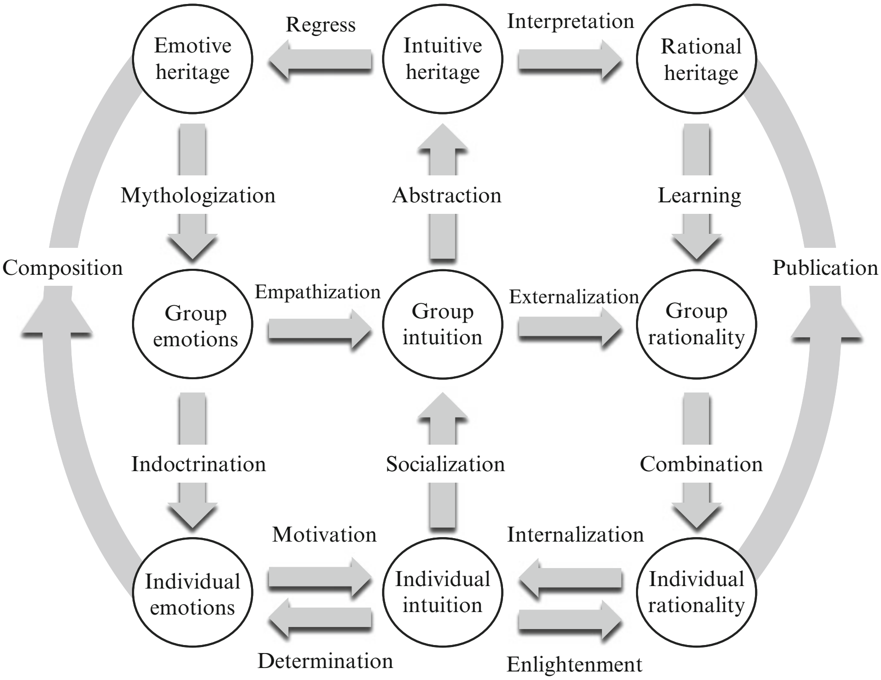

Fig. 2 Creative space in its fundamental dimensions: epistemological (rationality, intuition, emotions) and social (individual, group, heritage of humanity)

interdisciplinary synthesis, usually based on a systems approach, and represents the final, concluding node. The *Pentagram of* I^5 *system* (see Fig. 4) stresses the importance of *Integration*, of systemic synthesis.

The second, almost parallel development was the '*Metasynthesis Systems Approach*' (see Gu and Tang, 2003, 2005) developed in order to combine expert opinions in a group evaluation of a topic of study. Similar to the *SECI spiral*, *metasynthesis* stresses the role of a group in knowledge creation processes; however, it directly addresses the issue of systemic synthesis and indicates its *meta* (metaphysical on a higher semantic level) character. After group discussion and debate, the expert members of the group achieve a joint opinion intuitively, in a manner very similar to metaphysical reduction. Recently, *Metasynthesis* acquired broad recognition and has motivated research, e.g., on agent-based software systems, and also in Western communities.

The examples described above indicate how different Eastern thinking is from Western philosophy and how the *yin and yang* principle of the unity of contradictions enabled Eastern thinkers – or Westerners influenced by the Eastern way of thinking, see next point – to respond to the needs of the beginnings of a knowledge-based economy and civilization.

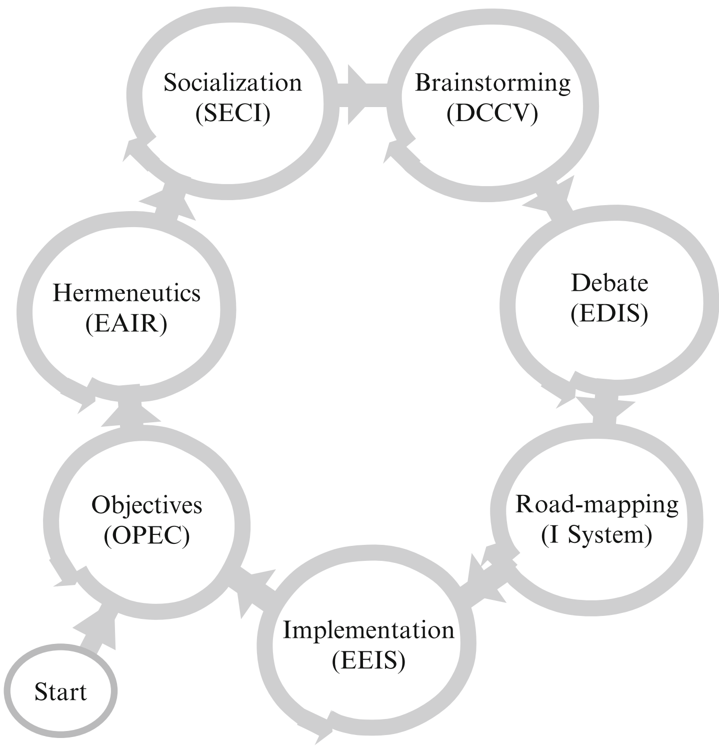

Fig. 3 Nanatsudaki Septagram of seven spirals of knowledge creation for bigger research projects (Wierzbicki and Nakamori, 2007)

5 An Evolutionary, Naturalistic Theory of Intuition

From Plato to Kant, even to Jung (see, e.g., Motycka, 2010), intuition was considered in philosophy to be a cognitive power which should "provide certain and necessary knowledge" (Motycka, 2010) while interpreting this cognitive power as a transcendental, extra-sensual, infallible ability (see also Jung, 1971). However, while recognizing the role of intuition in creating both technical tools and scientific theories, I felt the necessity to develop a naturalistic (strongly realistic) and evolutionary theory of intuition – thus a scientific theory; *all our knowledge of the history of the development of human civilization indicates that this development is evolutionary, in the sense of group evolution*, treating intuition as a natural human ability, powerful but fallible (see Wierzbicki, 1997, 2004, 2011).

This development was motivated, on the one side, by the influence of Japanese naturalism and the '*Shinayakana Systems Approach*' mentioned in the previous section, on the other side by the technical *information theory* and *informational complexity theory*. It relies on the comparison of the informational content of speech and of the immanent, preverbal perception by all senses, estimated by the

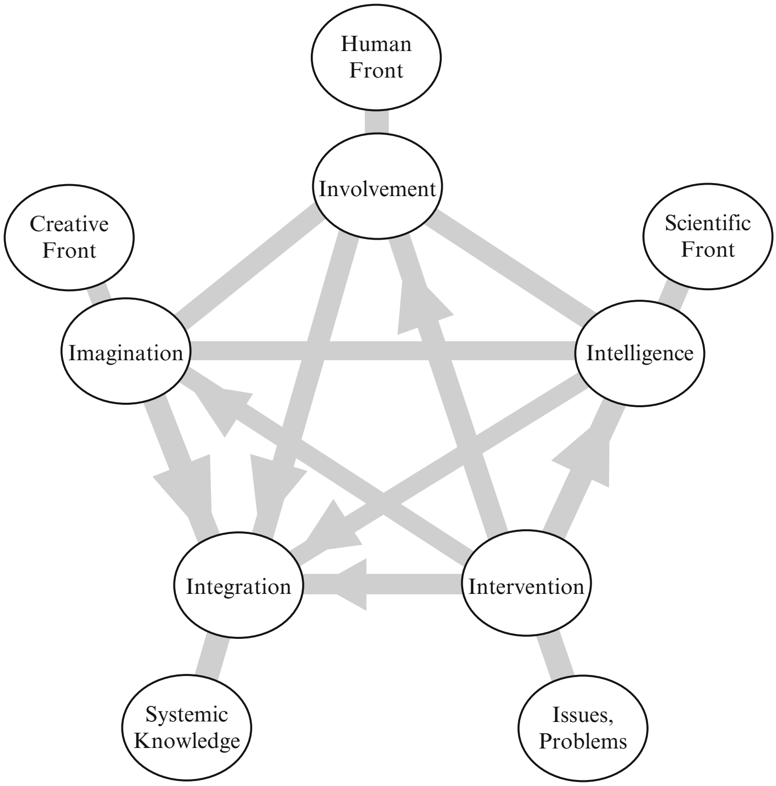

Fig. 4 Pentagram of I^5 system (Nakamori, 2000)

informational content of vision. According to the information theory (Shannon, 1948), we transmit an amount of information corresponding to a given frequency bandwidth (no matter how it is shifted, say, by modulation). For words, we take as an upper estimate the bandwidth of sound – 20 kHz. For immanent perception we take as a lower estimate the bandwidth historically developed for television – 2 MHz. Therefore, the informational content of immanent perception is at least 100 times higher than that of speech. However, the informational complexity theory states that the complexity of processing information depends usually nonlinearly on informational content; if we take, again as a lower bound estimate, a quadratic dependence, then the computational complexity of processing words is at least 10,000 times lower than that of processing images (and other signals of immanent perception): *an image is worth at least 10,000 words*.

This means, however, that the development of speech in human communities was an excellent evolutionary shortcut: it simplified the perception and reasoning at least 100, perhaps 10,000 times. It started or co-defined (depending on what we count as the essence of humanity, whether only speech and communication, or also tool-making and curiosity) the evolution of civilization. However, it also resulted in the concentration of rational reasoning within verbal communication, it suppressed to some extent the powerful possibilities of preverbal perception and reasoning, which, with a lack of other words, we can call *intuitive reasoning*, even if a deeper analysis shows that it has the three most important elements: *intuition*, *emotions* and *instincts* (the latter two can be treated together, because they are mostly inherited, while intuition is only partly inherited, mostly learned).

This evolutionary shortcut enabled the transfer of information and tradition between subsequent human generations, and we started to build a *cultural and intellectual heritage of humanity*; the rational, verbal part of this heritage can be identified as *World 3*, a concept introduced by Karl Popper (1972) . The biological evolution of people slowed down (some biologists even say that it stopped), and we substituted this with an acceleration of cultural, intellectual and civilization evolution. Many biologists consider *why* our biological evolution stopped; this has led Alfred R. Wallace to formulate the *Wallace paradox*: why primitive human tribes have practically the same brains as most advanced people in the world, if they cannot use those brains as intensively?

It appears that the above discussions give a sufficient explanation – *why* it has happened: after the invention of speech it turned out that *we have an enormous excess of the capabilities of brain and mind*. This excess can be estimated as 10^4, 10,000 times, in other words, only 0.01 % of our brain capacity would suffice for language processing and logical reasoning, hence it was not necessary for our brain to further develop biologically (a modest increase of human brain did occur, and our brain is several times larger than in other apes, but this growth could be as well a result of using the excess capacity of our brains for the purposes of intuitive construction of more complex tools). This tremendous surplus explains many problems, with some philosophical questions included, e.g. the question of an apparent *redundancy* of the concept of mind in relation to the concept of brain. If we have such a large excess of brain capacity over rational, verbal needs, and we imagine the functioning of our brains in a simplified, cognitive verbal model, then we can under-estimate this excess and maintain that our minds are larger than our brains.

This tremendous excess explains also the functioning and the higher role of the *inward man* when compared to the *outward man* (see, e.g., Jung, 1971; Motycka, 2010). It also provides a different understanding of the human predisposition to *transcendence*, understood here not as the existence of an absolute being above reality, but as our predisposition to abstract thinking, to transcend our *existential* experience. Evidently such abstract or even metaphysical reasoning was useful in the evolution of civilization, and it was possible because of the excess of our brains.

We use this tremendous excess, between others, for intuitive reasoning. The following *rational evolutionary definition of intuition* results from the above premises: *intuition is the ability of preverbal, holistic, unconscious (or subconscious, or quasi-conscious) processing of signals from our environment and memory, motivated by experience and imagination, an ability which is a historical reminder of the preverbal stage of human evolution* (a quasi-conscious action in this definition means an action that we consciously start but do not concentrate our whole consciousness on, such as walking, driving a car, etc.). Therefore, we admit that apes, cats, dogs, etc., have also intuition and use intuitive reasoning.

There are many conclusions that follow from the evolutionary, naturalistic theory of intuition, such as: *if you want to be creative, limit your contact with television; or every intuitive idea, before being communicated to other people, requires rationalization, putting this idea into words and providing arguments for it*; etc., (see Wierzbicki, 2011). However, this theory does not indicate that our intuition is infallible; on the contrary, since it is a natural phenomenon, it might be very powerful but still fallible. I believe, as a technician should, that even the best idea requires testing. Therefore, intuition is powerful, it is the source of our ideas, especially in technology that relies on intuitive creation of tools and artifacts, but it is fallible, and new tools require testing or falsification.

6 Conclusions

From the perspective of a comparison of the Eastern versus Western way of thinking and accepting the Eastern *yin and yang* principle of the unity of contradictions, we cannot agree that the philosophical way of thinking differs fundamentally from the scientific way: both philosophy and science use metaphysical reduction or systemic synthesis that are very similar to each other methodologically.

Both philosophy and science can have either more naturalistic or more idealistic inclination; generally, the Eastern way of thinking is more naturalistic than the Western way.

Eastern thinking on the issues of systemic synthesis and knowledge creation for the needs of today and tomorrow resulted recently in many theoretical advancements; it influenced also the author of this chapter to develop a naturalistic, evolutionary theory of intuition.

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Multiple Criteria Ranking in Future Network Management

Janusz Granat and Andrzej P. Wierzbicki

Abstract Multiple criteria ranking is a natural and often used tool in contemporary network management. Its importance will grow in networks of future generations, such as Internet of Things (IoT) or Content Aware Networks (CAN). This chapter presents first a review of diverse multiple criteria ranking techniques, then a review of their applications in network management and related fields, such as network search engines. The concept of objective ranking is stressed and its importance is illustrated by an application to a local search engine *PrOnto*. A new network management task for IoT or CAN is described: selecting services existing and described in the network in order to support their combination while forming a new service. An application of objective ranking for this purpose similar as used in *PrOnto* is described.

Keywords Ranking techniques • Objective ranking • Future networks • Creation of a new service

1 Introduction

The network management has changed significantly during the last years. There is a trend of moving management and operations functionalities from hardware to software (see Fahy et al., 2008; Jammal et al., 2014; Jennings et al., 2009). The software gives more elasticity in providing new functionalities of network elements, new management functionalities and network functions virtualization (NFV). NVF is a network architecture concept that proposes using IT virtualization related technologies to virtualize network node functions. Available building blocks may be connected, or chained, to create communication services. In such virtualized

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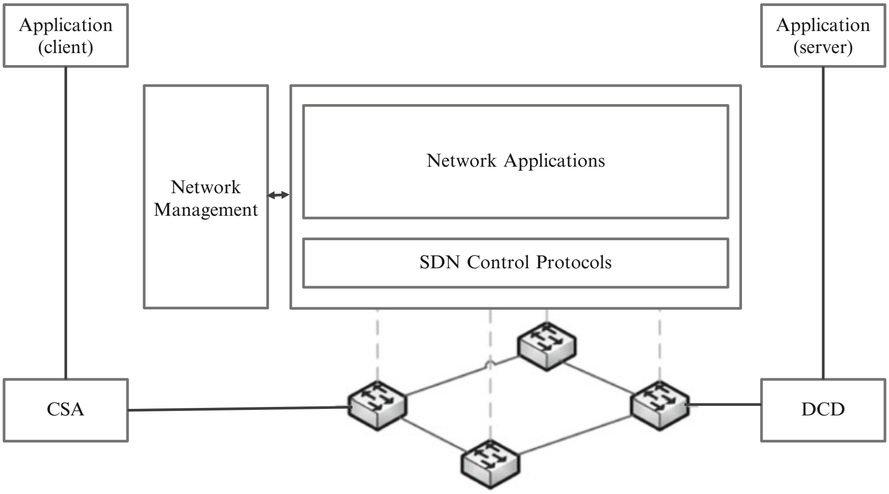

Fig. 1 Architecture of PI-DSS based on software defined network

network management, the need for manual management and the human involvement the network level management should be reduced (e.g. Self-organizing networks – SON, Automated Network Organization – ANO). There are also new concepts that help in designing of network management functionalities such as: dynamic graph query primitives for SDN-based cloud network management, event-based network management, real-time insight into network and services, service orchestration.

Figure 1 shows the architecture of a prototype of Parallel Internet with Data Streams Switching (PI-DSS) (see Granat et al., 2014a). PI-DSS network is one of Parallel Internets proposed in IIP System (see Burakowski et al., 2012) developed by the national project "Future Internet Engineering". The IIP System allows creating so called multiple Parallel Internets (PI). Different PI operate with full isolation between them. Traffic in a single PI does not interfere with the other PI traffic. Particular PI may use various communications protocols stacks. In the "Future Internet Engineering" project three Parallel Internets were proposed: PI IPv6 QoS, CAN and DSS. PI-DSS was intended to provide the services with Quality of Service similar to that of the classical circuit commutation. In the work by Granat et al. (2014a) PI-DSS implementation is based on SDN networks concept PI-DSS should provide lossless transmission of flows through the network, while minimum delay and low delay variance should be preserved. Data transmitted by PI-DSS are transmitted within the dedicated flow. Individual flows are understood as the transmission channels between the access ports of edge nodes. Those channels provide a certain guaranteed transfer rate. Flows are defined dynamically at the request of users. Quality parameters are guaranteed through the use of network dimensioning and CAC (Call Admission Controll). It is necessary to ensure that, for each node in the network, the total flow rate on each output interface is less than or equal to the total rate available for the PI-DSS on that interface. These condition results in no accumulation of traffic in nodes. Therefore, there is no need to discard packets due to lack of resources on the output interface, and output interfaces can have much shorter queue. In PI-DSS packet forwarding is based on SDN and the OpenFlow protocol. SDN-based implementation significantly reduced the complexity of the system, resulting in easier and faster implementation. The result of this work is a working demonstrator of PI-DSS realized on the basis of the specifications developed in the first phase of work. The following modules have been developed:

- Network Applications of PI-DSS – functional control plane elements responsible for traffic control and control over the allocation of network resources.
- The Network Management module – a set of tools for configuring and monitoring PI-DSS network and network dimensioning module.
- Forwarder – basic network element responsible for switching of packets, as well as the assignment of user data to the corresponding flows.
- Signaling of the PI-DSS – client signaling system for contracting service parameters, as well as system or communication between network control modules and forwarders, used to configure flows and transmission paths in the network.
- Sample application VoD
- CSA (Client Signalling Agent) and DCD (Domain Contents Description)

Management module for PI- IPv6 QoS has been presented in Granat et al. (2012). Experiences gained in developed management subsystems stimulated further development of specific management functionalities.

In this chapter we will consider service orchestration (or composition). The multicriteria ranking techniques will be applied for service orchestration. Rodrigues et al. (2011) have presented an innovative approach to the development of a semantic model in the domain of multiservice networks. This model formally specifies concepts related to network service management, configuration and auditing. They have also proposed ontology specification in the domain of multiservice networks.

2 Multiple Criteria Ranking Techniques

Even if there is an extensive bibliography concerning multiple criteria decision support and ranking (see, e.g., Wierzbicki et al., 2000) specific aspects of multiple criteria ranking, especially its subjectivity, are less frequently discussed in literature. This might have many reasons: on the one hand, it might be convenient to overlook the subjectivity of most commonly used ranking techniques, while on the other hand ranking techniques became an essential element of business strategies of such powerful companies as Google and other network search engines.

If there are many criteria or quality measurements $q_i, i \in I = \{1, \cdots, n\}$, then an essential step, often decisive for their aggregation and resulting ranking, is the *scaling* of criteria that might have diverse dimensions. If we have data on many instances of quality measurements $q_{ij}, j \in J = \{1, \cdots, m\}$, then we can determine *upper bounds* $q^{up_i} = \max_{j \in J} q_{ij}$ and *lower bounds* $q^{lo_i} = \min_{j \in J} q_{ij}$ for each $i \in I$. Such upper and lower bounds naturally depend on the context, that is, on the set of data $\{q_{ij}\}$. Some specialists believe that this is a disadvantage and prefer to determine some arbitrarily selected *ranges of measurements* Δq_i in order to convert these measurements into a dimension-free, percentage scale $q_{ij} \longleftarrow q_{ij}/\Delta q_i$. However, if we want that criteria aggregation and ranking of *alternatives* $j \in J$ depend on the *decision situation*, the context $\{q_{ij}\}$, then it might be better to select $\Delta q_i = q^{up_i} - q^{lo_i}$. In further text, we assume that quality measurements are already dimension-free and in such a scale that they are *minimized* (even if quality should be obviously *maximized*, this is a question only of convention and an appropriate change of sign in formulae).

The most popular (even if faulty in some applications) method of multiple criteria aggregation and ranking consists in a subjective determination of *weighting coefficients* ρ_i. If quality measurements are already dimension-free, then weighting coefficients express the importance of individual criteria q_i (and should sum up to 1); otherwise, they combine importance and (inverse) ranges of measurements. If we denote $\mathbf{q}_j = \{q_{1j}, \cdots, q_{nj}\}$, etc., then the aggregated quality measurement in *weighted average approach* is:

$$\sigma_{\text{way}}(\mathbf{q}_j) = \sum_{i \in I} \rho_i q_{ij} \tag{1}$$

while the ranking corresponds to an ordered list of alternatives $j \in J = \{1, \cdots, k\}$ starting with the lowest (when minimizing) value of $\sigma_{\text{wav}}(\mathbf{q}_j)$. There are many methods of automation of the selection of weighting coefficients, such as Analytical Hierarchy Process (see, e.g., Saaty, 1980), but all of them are highly subjective, consist in asking the decision maker many questions (in order to partly determine and model her/his preferences, utility or value function) and letting a computer program determine what the weighting coefficients should be. In more contemporary, *human centered approach*, weighting coefficients should be known transparently to the decision maker (best determined directly by her/him) and be consistent with her/his perception of the importance of individual criteria.

Another popularly used method is *distance minimization approach*, where a *goal point* $\mathbf{q}^g$ in the space of objectives or quality measurements is selected (explicitly or tacitly) and a distance to this goal serves as an aggregated quality measurement:

$$\sigma_{\text{goal}}\left(\mathbf{q}_j, \mathbf{q}^g\right) = \| \mathbf{q}_j - \mathbf{q}^g \|_{l_p} \tag{2}$$

where $\| \cdot \|_{l_p}$ denotes a selected l_p norm, starting with $p = 1$ (sum of component modules) up to Chebyshev norm $p = \infty$ (maximal component module). Clearly, the choice of the norm and the scaling of objective values influences the aggregation and the resulting ranking. Even more important is the selection of a goal point $\mathbf{q}^g$. A good theoretical basis has a selection of the goal $\mathbf{q}^g$ as a *displaced ideal point* (dominating all data on quality measurements $\{q_{ij}\}$, that is, lower on all components $i \in I$ than the corresponding q^{lo_i}) (see, e.g., Zeleny, 1974). However, this requirement is often not respected, as in *goal programming approaches* (see, eg., Charnes and Cooper, 1977) where the distance (2) is minimized without checking whether the goal point is a displaced ideal or whether its components are outside or inside the range $\left[q^{lo_i}, q^{up_i}\right]$. If they are inside this range, the ranking based on aggregated quality measurement (2) can give paradoxical results. On the other hand, in network applications quality measurements have usually only positive values, hence the choice $\mathbf{q}^g = \mathbf{0}, \sigma_{\text{goal}}\left(\mathbf{q}_j, \mathbf{q}^g\right) = \| \mathbf{q}_j \|_{l_p}$ results in a displaced ideal point. Such quality measurement aggregation is often applied in network practice, even if it is still dependent on scaling and the choice of the norm.

Another distinct group of approaches contains *reference point methods* where instead of a goal point $\mathbf{q}^g$ a *reference point* $\mathbf{q}^r$ is used. These points are similar in nature, thus these methods are often confused in literature; but there is an essential difference between these two groups of methods. *Instead of a distance and norm, in reference point methods another function is used to aggregate quality measurements*, called an *achievement function* (because of its name, we shall assume that it is maximized even if quality measurements are minimized). An achievement function, as opposed to a norm, remains *monotone with respect* $\mathbf{q}_i$ *changing according to the partial order in quality measurements space* (say, expressed by diminishing all components in this space if quality measurements are minimized; an achievement function should increase then). This property results in efficiency of maximal points of an achievement function no matter whether $\mathbf{q}^r$ is a displaced ideal or not, or is shifted sidewise (some components of it are increased, some decreased as compared to a displaced ideal), or even is attainable (coincides with some $\mathbf{q}_j$). There are many functions that are monotone in that sense (but not norms that cease to be monotone if their arguments cross 0). A convenient form of an achievement function (to be maximized, while quality measurements are minimized and are assumed to be dimension-free) is as follows:

$$\sigma_{ach}\left(\mathbf{q}_j, \mathbf{q}^r\right) = \min_{i \in I}\left(q_i^r - q_{ji}\right) + \frac{\epsilon}{n} \sum_{i \in I}\left(q_i^r - q_{ji}\right) \tag{3}$$

where the second term is a regularizing component, with a small coefficient $\epsilon > 0$, n is the number of components of quality measurement. The second term results in a property that maximal points of (3) with respect to $\mathbf{q}_j$ are always *ϵ-properly Pareto efficient* (see Wierzbicki, 1986) – that is, have trade-off coefficients not only bounded, but a priori bounded by $[\epsilon, 1/\epsilon]$, thus weakly Pareto efficient points are excluded. The advantage of using arbitrary, including attainable reference points is that we can define reference points statistically from available data, what is used in the concept of *objective ranking* explained below.

3 Objective Ranking and Its Application in a Local Search Engine

In many decision situations, the decision maker might be interested in a ranking not expressing her/his personal preferences, but *as objective as possible*. We agree that there is no absolute objectivity, because there are no absolutely precise measurements (see, e.g., Heisenberg, 1927). However, objectivity might be a desirable even if not fully attainable goal – e.g., to promote the interests of our children in face of future uncertainty we should equip them with knowledge as objective as possible (see Wierzbicki, 2011); this is similar to the justification of the ideal of justice by Rawls 1971). In multiple criteria ranking, it is difficult to achieve objectivity since even the choice of ranking method expresses some subjective judgment. However, it is possible to select a method that is as objective as possible; it is sufficient to choose a method that does not depend strongly on the preferences of the decision maker, much rather on the data characterizing the decision situation, say – on the set of quality measurements $\{q_{ij}\}$. Such a method was proposed in Wierzbicki (2008) as an extension of a ranking based on reference point approach, with a statistical determination of a double reference point. Actually, a single reference point as used in (3) above would also suffice, but the use of a double reference point gives better intuitive perception of results.

We assume that quality measurements are aggregated statistically and that we use them in order to determine *aspiration levels* q_i^{as} and *reservation levels* q_i^{re} (because we assumed that all quality measurements are minimized, hence $q_i^{as} < q_i^{re}$):

$$q_i^{av} = \frac{1}{m}\sum_{j\in J} q_{ij}; \quad q_i^{as} = \frac{1}{2}\left(q_i^{lo} + q_i^{av}\right); \quad q_i^{re} = \frac{1}{2}\left(q_i^{up} + q_i^{av}\right) \tag{4}$$

If we used only one reference point $\mathbf{q}^r$, then $q_i^r = q_i^{av}$. If we use double reference point $\mathbf{q}^{as}$, $\mathbf{q}^{re}$, then it is convenient to transform all quality measurements into *partial achievement values*:

$$\sigma_i\left(q_{ij}, q_i^{as}, q_i^{re}\right) = \begin{cases} \frac{\alpha\left(q_i^{up} - q_{ij}\right)}{q_i^{up} - q_i^{re}}, & \text{if} q_i^{re} \le q_{ij} < q_i^{up} \\ \alpha + \frac{(\beta-\alpha)\left(q_i^{re} - q_{ij}\right)}{q_i^{re} - q_i^{as}}, & \text{if} q_i^{as} \le q_{ij} < q_i^{re} \\ \beta + \frac{(10-\beta)\left(q_i^{as} - q_{ij}\right)}{q_i^{as} - q_i^{lo}}, & \text{if} q_i^{lo} \le q_{ij} \le q_i^{as} \end{cases} \tag{5}$$

where α, β are coefficients signifying the achievement value of reaching reservation level and aspiration level, correspondingly, while partial achievements are measured on the scale $[0, 10]$ and $0 < \alpha < \beta < 10$ (e.g., $\alpha = 3, \beta = 7$). The overall achievement function is then similar to (3):

$$\sigma_{av}\left(\mathbf{q}_j, \mathbf{q}^{as}, \mathbf{q}^{re}\right) = \min_{i\in I} \sigma_i\left(q_{ij}, q_i^{as}, q_i^{re}\right) + \frac{\epsilon}{n}\sum_{i\in I}\sigma_i\left(q_{ij}, q_i^{as}, q_i^{re}\right) \tag{6}$$

with a small $\epsilon > 0$. Ranking corresponds then to a list of best achievements (starting with the highest one).

Objective ranking was tested diversely: on management examples in Wierzbicki (2008), but also in an application to a local network search engine *PrOnto* (see Chudzian et al., 2011; Granat et al., 2014b) and in an application to support electronic commerce in art objects (Jin et al., 2013). We present here shortly its application in *PrOnto* search engine.

The system *PrOnto* supports the user in response to her/his individual, personalized ontological model, called *hermeneutic profile*, composed of three layers:

- A lower layer of *keywords* and *key phrases* that is subject to semantic and logical analysis with the use of tools of ontological engineering;
- An upper layer of intuitively defined *concepts* that have not far reaching logical interpretations because they might be highly intuitive; and
- A middle layer of relations between concepts and key phrases containing weighting coefficients defined subjectively by the user.

The definition of such hermeneutic profile is not highly automated, it is fully controlled by the user. The response of the system to the user consists in a ranking list of documents interesting for him. The ranking is also controlled by the user, who can choose one of four multiple criteria ranking methods (applied to ontological measures of importance of keywords aggregated by weighting coefficients into measures of importance of concepts for a given document):

A. Essential multiple criteria – such that all criteria should have reasonably high measures;
B. Compensable multiple criteria – such that high measure for one criterion might compensate lower measures for other criteria;
C. Fuzzy logical concepts with fuzzy ‘or’ aggregation;
D. Fuzzy logical concepts with fuzzy ‘and’ aggregation.

Extensive testing of the *PrOnto* system have shown that the best results for the user are obtained when using the method A, while the method D gives usually worst results. The system *PrOnto* was subject to diverse tests, including a test on Internet commerce by a cooperating Chinese doctoral student (Jin et al., 2013), a test on internal library of the National Institute of Telecommunications, etc. The results confirmed that *PrOnto* system is more user-friendly than known global search engines (who usually do not make their rankings transparent because of commercial reasons), and that the most efficient ranking method is A. The tests on digital libraries resulted in a demand for changing the user interface of *PrOnto* (which was designed originally to support research group cooperation) to support typical enquiries of a library user.

As mentioned in the introduction, multiple criteria ranking is an essential tool in many network management tasks and its importance will even increase in the management of future networks. Thus, tools such as *PrOnto* local search engine might be modified for future network management tasks.

4 New Management Task: Creation of a New Service

As mentioned in the introduction, network management consists of a variety of management tasks and new network management will include new management tasks; one of them might be creation of a new service. In its essence, this task is creative: a network manager must use her/his intuition to define a new service, its architecture and its supporting components. However, this creative activity might be supported by diverse tools of decision support.

Network services become increasingly important and there already exists a large variety of network services. Therefore, a new service might include elements or the use of existing services. In order to improve network management, it is assumed that each service in new generation networks will have a short summary characterizing its essential aspects (or a reference to its Internet page where such a summary will be included). Such services might be found by applying existing search engines, but then the ranking of such services will be influenced by the commercial interests of the owners of global search engines.

In a future network the manager has a vision of a new service and would like to search for existing services (see Fig. 2) that might be useful to her/him, then such management task might be supported by as objective as possible search engine built along the lines of the *PrOnto* system. An outline of the functionality of such management support tool might be as follows.

The system must contain a repository of summaries or addresses of services existing in the network; given any set of keywords or key phrases, the system should *index* these summaries according to these key phrases, that is, determine the frequencies of key phrases occurrence in the summary description of each service converted to the measure TF-IDF (Term Frequency – Inverse Document Frequency; this measure is increased if a key phrase occurs often in the summary description, but decreased if it occurs in most of descriptions).

The user of this system – a future network manager – starts with determining her/his *hermeneutic profile*, expressing the intuitive idea what type of existing services might be useful when creating a new service. Similarly as in *PrOnto* system, such hermeneutic profile shall consist of:

- A lower layer of *keywords* and *key phrases* that describe important aspects of the required services and will be used for indexing the summary descriptions of existing services;
- An upper layer of intuitively defined *concepts* describing desired properties of the new service; and
- A middle layer of relations between concepts and key phrases containing *weighting coefficients* defined subjectively by the user (how important is a given key phrase for a concept defined by the user; the definition of such coefficients might be supported graphically).

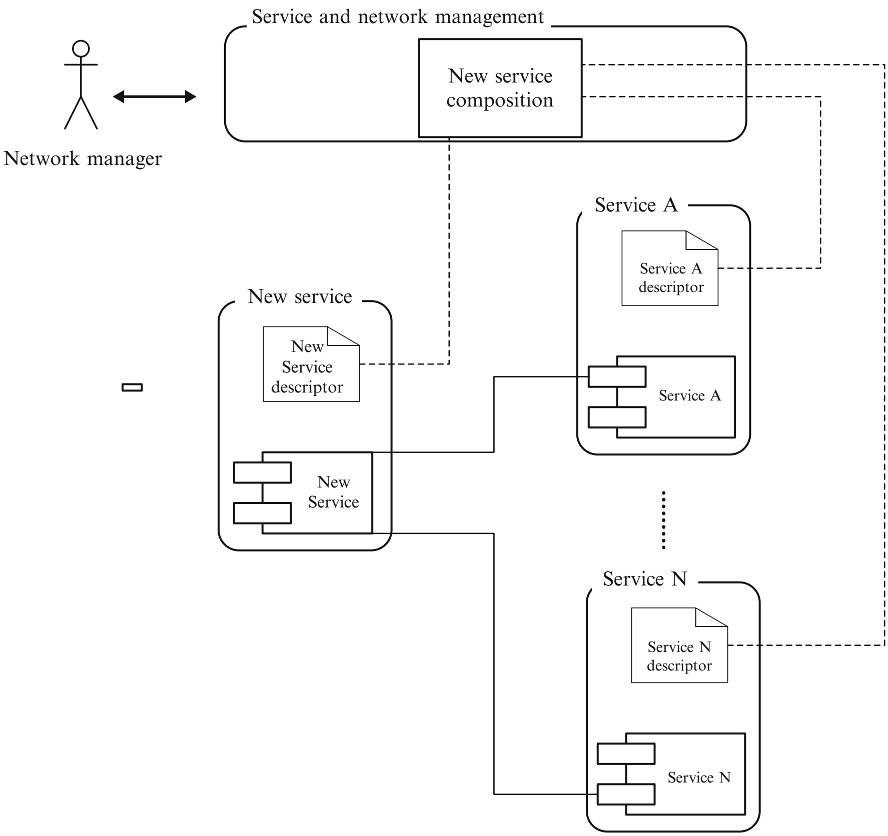

Fig. 2 Service composition

Note that after the definition of the lower layer, the system should start indexing the summary descriptions of services; in order to shorten the time needed for indexing, a local repository of service descriptions might be organized in the system (descriptions of services from their network pages might be imported to this repository beforehand).

Once the service descriptions are indexed with respect to a given set of key phrases, it is easy to rank their importance according to the given hermeneutic profile. We must first determine importance indexes of service descriptions d_i with respect to specific concepts c_j:

$$h\left(d_i, c_j\right) = \sum_{k \in K} f\left(c_j, k_k\right) g\left(d_i, k_k\right) \tag{7}$$

where k_k or $k \in K$ is a denotation of a key phrase, while $f\left(c_j, k_k\right)$ is user-determined importance coefficient of key phrase k_k for the concept c_j (if the user considers a concept less important than other concepts, she/he can express this conviction by assigning lower importance coefficients $f\left(c_j, k_k\right)$ uniformly for all k_k for the less important c_j) and $g\left(d_i, k_k\right)$ is the (converted to the measure TF-IDF) frequency of occurrence of key phrase k_k in the description document d_i. The average importance index $h_{av}(c_j)$ is computed by averaging over description documents as:

$$h_{av}\left(c_j\right) = \frac{1}{\mid D \mid} \sum_{i \in D} h\left(d_i, c_j\right) \tag{8}$$

where $\mid D \mid$ is the number of description documents.

If we assume that only objective ranking is used, then we might use the following formula to compute importance coefficients of description documents d_i with respect to entire hermeneutic profile (all concepts C):

$$h_{ess}\left(d_i, C\right) = \min_{j \in C} \left(h(d_i, c_j) - h_{av}(c_j)\right) + \epsilon \sum_{j \in C} \left(h(d_i, c_j) - h_{av}(c_j)\right) \tag{9}$$

where ϵ is a small positive coefficient. Equation (9) is actually a simplification of Eq. (6) similar to Eq. (3). These importance coefficients are then used directly for ranking.

If we would like to give the user the possibility of choice of the method of ranking, then we might also compute other versions of importance coefficients:

$$h_{comp}\left(d_i, C\right) = \sum_{j \in C} \left(h(d_i, c_j) - h_{av}(c_j)\right) \tag{10}$$

$$h_{fuzor}\left(d_i, C\right) = \max_{j \in C} h(d_i, c_j) \tag{11}$$

where $h_{comp}\left(d_i, C\right)$ corresponds to the assumption of compensable criteria and $h_{fuzor}\left(d_i, C\right)$ corresponds to fuzzy *OR* aggregation. The user can thus compare three different rankings of service descriptions and select ranking that gives her/him most interesting results.

It must be stressed again that the rankings employed in evaluation of existing services play only the role of decision support, and the final selection of existing services that might contribute to the new service, as well as the final functionality and architecture of the new service, are the results of systemic synthesis, a creative, intuitive activity of the network manager.

5 Conclusion

Multiple criteria ranking is one of basic tools of network management and its importance will grow with future generation networks. Particularly useful is so called objective ranking – ranking as objective as possible, limiting the impact of personal preferences of the decision maker or network manager, even if not excluding it completely. This chapter presented the use of such objective ranking combined with ontological tools in localized search engines and in a future application of new service creation.

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Evolutionary Knowledge Creation from an Eastern Perspective

Andrzej P. Wierzbicki

Abstract An important recent development is Eastern approaches to the issue of knowledge creation, a subject partly neglected in Western philosophy. These approaches are essentially naturalistic and evolutionary, stressing the circular development of knowledge based on spiral-like development resulting from positive feedback. In such approaches, nature is the reason and cause as well as the effect of social development of knowledge.

Keywords Evolution of knowledge • Knowledge creation • Eastern perspective

1 Introduction

It was indicated in chapter "Systemic Synthesis and Metaphysics: Eastern Versus Western Thinking" that a characteristic feature of Eastern thinking is a horizontal belief in the unity of contradictions (*yin and yang* principle) and a good understanding of circular development together with a naturalistic inclination. All this resulted recently in new approaches to the issue of knowledge creation for the needs of today and tomorrow, motivated by the demand for new knowledge in a knowledge-based economy. Western philosophy has devoted much attention to the issue of knowledge development in the long historical perspective; such philosophical models of knowledge creation in the long-term sense might be called *macro-theories*, such as the Kuhnian concept (Kuhn, 1962) of paradigmatic knowledge development, or the Popperian falsification theory (Popper, 1934, 1972), or the Lakatosian scientific programmes (Lakatos, 1976), etc. However, a knowledge-based economy created a demand for prescriptions of how to create knowledge for current needs, which might be called *micro-models* of knowledge creation. This subject was mostly neglected by Western philosophy and was taken up by the Eastern perspective; a decisive development was the work of Ikujiro Nonaka and Hirotaka Takeuchi

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(1995) introducing the S*ECI Spiral* of organizational knowledge creation, described briefly in chapter "Systemic Synthesis and Metaphysics: Eastern Versus Western Thinking".

This caused an increased interest in the issues of organizational knowledge creation and processes of knowledge creation in general, described in more detail in the following sections. However, from an Eastern perspective we can also develop not only micro-models, but also a naturalistic, evolutionary macro-theory of general knowledge development in the form of a spiral of improving the intellectual heritage of humanity described in the last section of this chapter.

2 The SECI Spiral and Its Impact

The *SECI spiral* (see Fig. 1 in chapter "Systemic Synthesis and Metaphysics: Eastern Versus Western Thinking") consists of four nodes and four transitions between them. The nodes are: *individual explicit knowledge* that can be transformed[1] into *individual tacit knowledge* by a transition called *Internalization* (e.g., increasing individual intuition when learning by doing), and *group tacit knowledge* that can be transformed into *group explicit knowledge* through a transition called *Externalization* (e.g., discussing conclusions and writing them down). However, what is essential are the transitions between the individual and group level: *Socialization* between *individual tacit knowledge* and *group tacit knowledge* (this is a specific Japanese tradition called *nomification* – meeting together after working hours, drinking together and informally discussing diverse subjects, including issues of working), and the *Combination* of *group explicit knowledge* and *individual explicit knowledge* (actually, synthesizing new group conclusions with previous individual explicit knowledge).

Since knowledge can be only increased at each transition, this circular procedure describes a positive feedback loop and results in a spiral-like development of knowledge. As noted in chapter "Systemic Synthesis and Metaphysics: Eastern Versus Western Thinking", Western philosophy tries to avoid circular procedures and spiral-like developments, because of the fear of the Western logic of vicious circles, self-supporting arguments and infinite regress; thus, it was an important contribution of the Eastern type of thinking to propose a model of knowledge creation in a spiral-like form. Other important aspects of the *SECI spiral* were stressing the role of tacit knowledge and the interaction between individuals and groups in knowledge creation; these aspects were the reason for many other attempts to present spiral-like models of knowledge creation – see the next section.

The great impact of the *SECI spiral* does not mean, however, that it was the first or the ultimate model of knowledge creation. There were earlier models, such as the

[1]Nonaka and Takeuchi propose the word converted, but conversion implies that the original resource is used up, while knowledge is not diminished by its use.

brainstorming model described in the next section, or the *'Shinayakana' Systems Approach* that led to diverse developments in systemic synthesis and *Metasynthesis*, described in chapter "Systemic Synthesis and Metaphysics: Eastern Versus Western Thinking". The importance of *tacit knowledge* was stressed by the *SECI spiral*, and referred to the concept of *tacit knowing* from Michel Polanyi (1966), but without a deeper analysis of its meaning, character and components. Moreover, the *SECI Spiral* accounted for only two social levels of the processes of knowledge creation, the individual and the group, while actually none of the processes occurs without using results from a third social level, the *intellectual heritage of humanity*. Splitting *tacit knowledge* into at least two components – *intuition* and *emotion* – and including the third social level results in a three by three matrix of *Creative Space* (Wierzbicki and Nakamori, 2006), presented in Fig. 2 of chapter "Systemic Synthesis and Metaphysics: Eastern Versus Western Thinking". *Creative Space* suggests that there might be many other spiral micro-models of knowledge creation.

3 Other Spiral Micro-models of Knowledge Creation

In actual fact, the oldest micro-model of knowledge creation, *brainstorming*, is of Western origin (Osborn, 1957), but it was formalized in a spiral-like model first in Kunifuji et al. (2004, 2007), possibly because of the reluctance of Western thinking to circular development models. The *DCCV spiral* of brainstorming (see Fig. 1) consists of four transitions:

1. *Divergent thinking* (*Divergence*), such as in the divergent phase described above;
2. *Convergent thinking* (*Convergence*), appraisal and selection of ideas;
3. *Crystallization of ideas* (*Crystallization*), their more specific development (particularly of analytic character, since the earlier phases are highly intuitive); and
4. *Verification of ideas* (*Verification*) for example in *learning by doing*, or in *debating*, quite a different method of knowledge creation described below.

Generally, brainstorming refers to group generation of ideas with a postponement of their evaluation (*Divergence*) until the next phase (*Convergence*), but specifically this aspect creates the conceptual difficulty of switching from the fully liberal attitude of the first phase to a critical attitude in the second phase. Another unresolved question during brainstorming is that of intellectual property; it is only tacitly assumed that the results of brainstorming belong to the organizer of that process, or to the entire group or organization. For this reason, the *DCCV spiral*, similar to the *SECI spiral*, describes an *organizational process of knowledge creation*; this might explain the fact that brainstorming is practically never used in academic knowledge creation.

Another organizational process of knowledge creation was described from the Western perspective, even if this was motivated by the *SECI spiral*, by the *OPEC spiral* of Gasson (2004), consisting of practically the same (even if differently named) nodes as the *SECI spiral*, but with different transitions going in the oppo-

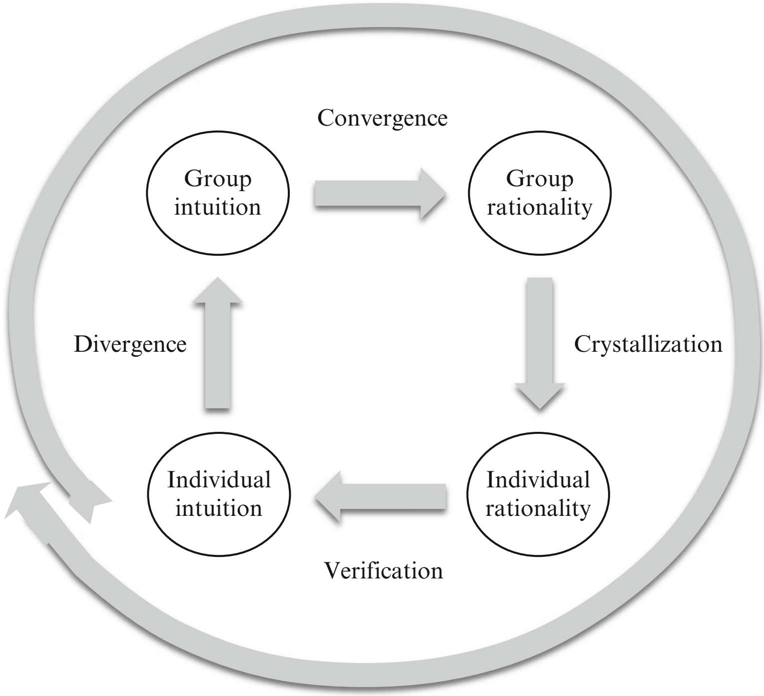

Fig. 1 DCCV spiral of brainstorming (Kunifuji et al., 2004, 2007)

site direction: *Objectives* (setting goals), *Process* (performing tasks), *Expansion* (expanding tacit knowledge into explicit knowledge) and *Closur*e (summarizing). Actually, its author was reluctant to admit that a circular positive feedback process leads to knowledge creation, hence added a typical Anglo-Saxon disclaimer: if there is not enough knowledge in the organization, hire external experts (see Fig. 2).

All these three micro-models (*SECI spiral*, *DCCV spiral* and *OPEC spiral*) describe processes of organizational knowledge creation. As noted above, such processes are seldom used in academia. Academic knowledge creation, although it is often supported by a group, has mostly an individual character and goals (for example, obtaining a doctoral degree). We can also distinguish three basic micro-models of academic knowledge creation. The first of them is debate which can be represented by the *EDIS spiral* of debate (see Fig. 3).

An individual researcher, due to her/his intuition, has an idea (a small or big one) and the idea must be rationalized, or expressed in words or equations; this transition might be called *Enlightenment*. A group can support the researcher by giving her/him a forum to discuss the ideas – the more incisive the discussion, the better the support of the group, and we call this transition *Debate*. We know these two stages well, but here a new stage appears resulting from the rational theory of intuition described shortly in chapter "Systemic Synthesis and Metaphysics: Eastern Versus

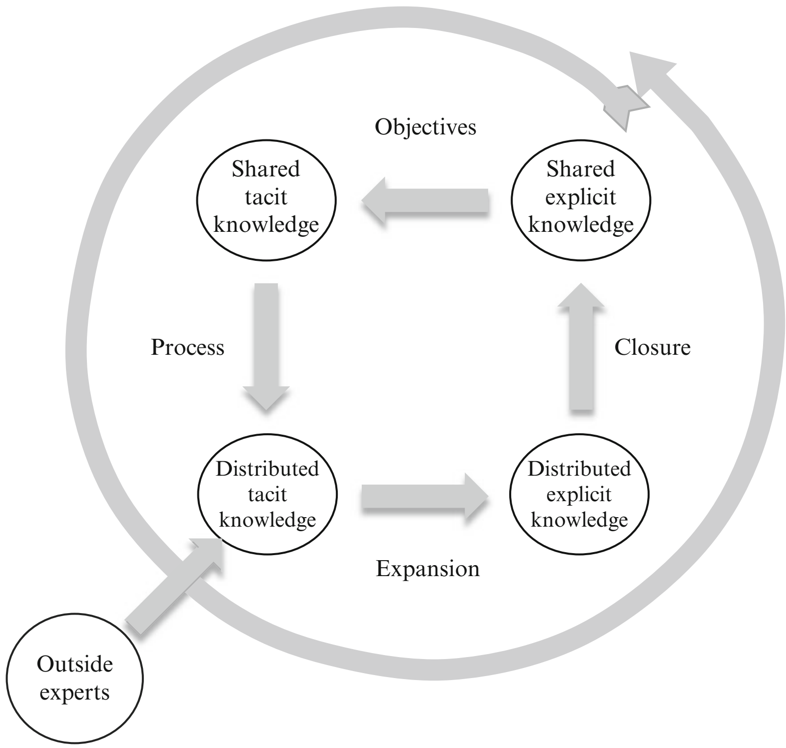

Fig. 2 OPEC spiral of knowledge creating in Western organization (Gasson, 2004)

Western Thinking"; this theory indicates that a deeper, more incisive discussion will be achieved if we give the group some time for reflection, for the ripening of comments, for a transition which is called here *Immersion* of the group rationality in the group intuition. Hence a practical conclusion, which may be called the *double debate principle*: the discussion of new ideas should be repeated after a week or two, if we want to support the researcher not only with the explicit knowledge of the group, but also with its tacit or intuitive knowledge. After obtaining the comments of the group, the individual researcher makes a choice, *Selection*, of those comments that should be taken into account in further research. We all know that this choice is made on an intuitive level, that it is not necessarily rational.

Experimental processes of knowledge creation are described by a modification of the *EDIS spiral* that represents situations where the verification of new ideas occurs through an experiment. Such a modified *EEIS spiral* (*Enlightenment-Experiment-Interpretation-Selection*) is illustrated in Fig. 4.

The *Experiment* transition describes experimental verification of a new idea obtained in the *Enlightenment* phase. Each experimental researcher understands that raw experimental data do not reveal much, hence their *Interpretation* is necessary. In this model, an essential novelty in the description of experimental processes is

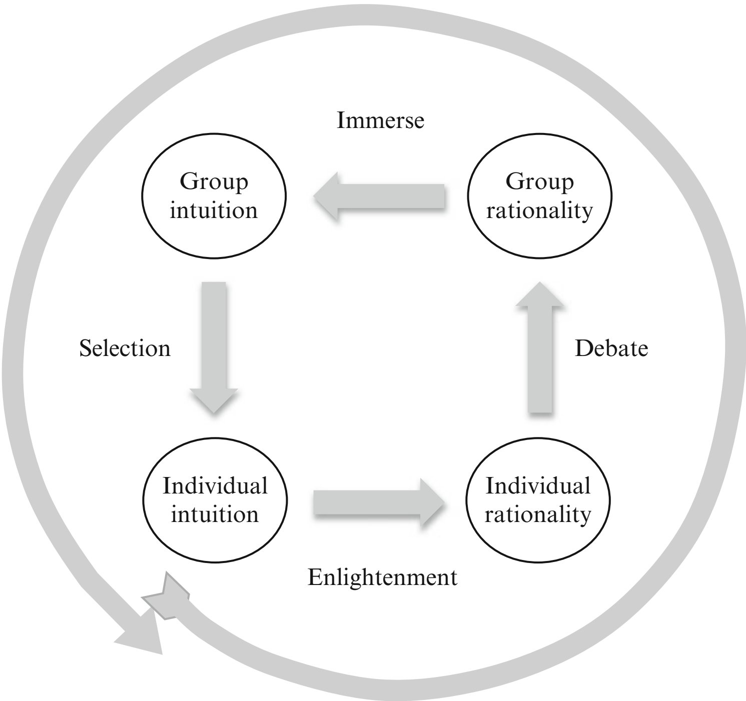

Fig. 3 EDIS spiral of debate (Wierzbicki and Nakamori, 2006).

the suggestion that an interpretation of experimental data is actually an immersion of raw data in the experimental intuition of the researcher –, intuition based on experience. Similarly as in the *EDIS spiral*, a *Selection* of conclusions occurs, this time concerning those aspects of experimental data that have the most important impact on further development of research ideas. Sometimes experiments have individual character, although larger experiments are often organized and conducted by groups of researchers.

The third type of the basic processes of academic knowledge creation (although actually not limited to academia, since it occurs whenever we make use of the intellectual heritage of humanity) is hermeneutics, understood here as *the art of interpreting knowledge given in any form*: usually as a text, nowadays very often also in multimedia form. Hermeneutics was originally understood as the art of interpreting the Bible, and then any text was treated as a typically humanistic activity, even one that distinguishes humanistic sciences from other sciences (see Gadamer, 1960). However, during the twentieth century hermeneutics began to be treated as a broader concept, encompassing all sciences. Thus, hermeneutics is a part of any research, including academic activities: the gathering of materials relevant for a given theme from libraries or from the Internet, and their interpretation and reflection on them. Hermeneutic creative activity is described by the *EAIR hermeneutic*

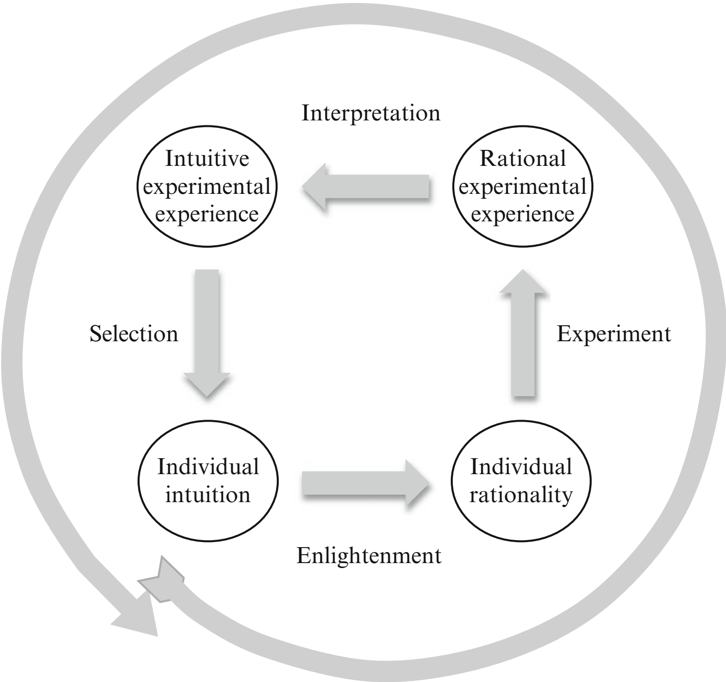

Fig. 4 EEIS spiral of experiments (Wierzbicki and Nakamori, 2006)

spiral (see Fig. 5). This is another interpretation of the *hermeneutic circle* with the distinction that its interpretation is naturalistic: it is not closed by transcendence, as postulated by Gadamer, but by the power of natural human intuition.

A new idea often comes from individual intuition, *abduction* or *illumination*, called here *Enlightenment*. In order to expand this idea, we search for related materials in libraries and on the Internet and analyze them rationally, which might be called *Analysis*. In order to obtain a hermeneutic perception of them: we must subject them to *Hermeneutic Immersion* into our unconsciousness and intuition, and transform them into intuitive perception. According to the rational and naturalistic theory of intuition explained in chapter "Systemic Synthesis and Metaphysics: Eastern Versus Western Thinking", we must give our unconsciousness the chance for an intuitive *Reflection* that might be the source of new ideas. It should be stressed that this is not only a description of the work of a specialist in humanities in a *hermeneutic circle*; it is much more broadly applicable – a technician working on new technological ideas reviews her/his research materials in the same way.

The *Hermeneutic spiral* is the most individual process of knowledge creation, occurring mostly (but not only) in academic knowledge creation. Here it should be stressed again that almost all academic micro-processes of knowledge creation, even if they assume participation of a group (as in a *debate*), are nevertheless individually motivated: a group only helps in improving individually created

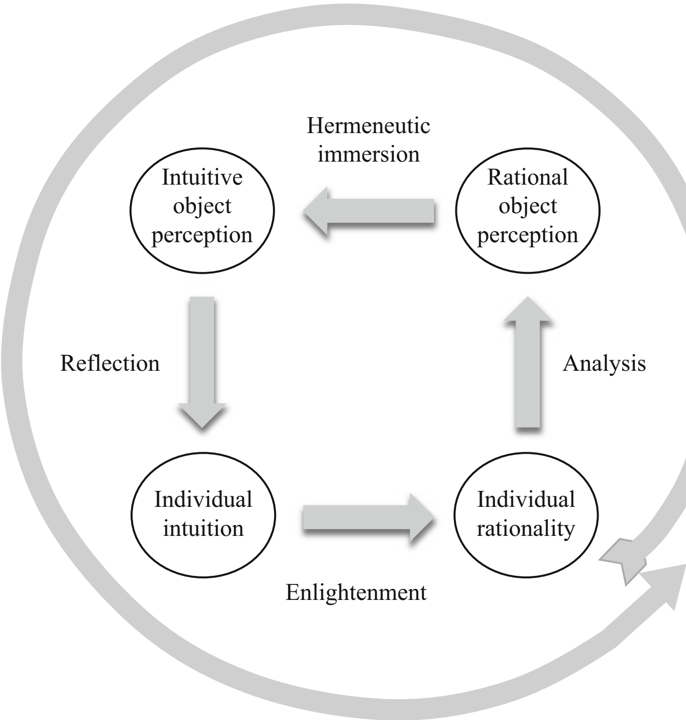

Fig. 5 EAIR hermeneutic spiral (Wierzbicki and Nakamori, 2006)

knowledge – the goal being a publication or an academic degree. On the other hand, all organizational processes of knowledge creation, brainstorming, the *SECI spiral*, the *OPEC spiral* etc., are group-motivated: it is assumed that the knowledge created will belong to the entire group or to the organizers of that process. This might be the main reason why the old and rather well-known process of brainstorming did not find a broader appreciation and application in academic situations. It implies, however, that the academic and organizational processes of knowledge creation are essentially different, which might be one of main reasons for the difficulties and delays in transferring knowledge from academia to industry. On the other hand, if we understand these differences and difficulties well, we can try to counteract them, for example to combine organizational and academic knowledge creation, as in the *Nanatsudaki septagram* described briefly in chapter "Systemic Synthesis and Metaphysics: Eastern Versus Western Thinking". The *Nanatsudaki septagram* combines seven spirals: six described above and an additional *Road-mapping spiral* described below, in the following order: Objectives (*OPEC*), Hermeneutics (*EAIR*), Socialization (*SECI*), Brainstorming (*DCCV*), Debate (*EDIS*), Road-mapping (*I System*), and Implementation (*EEIS*).

The *Road-mapping* (*I System*) *spiral* is an interpretation of the I^5 *system* described in chapter "Systemic Synthesis and Metaphysics: Eastern Versus Western

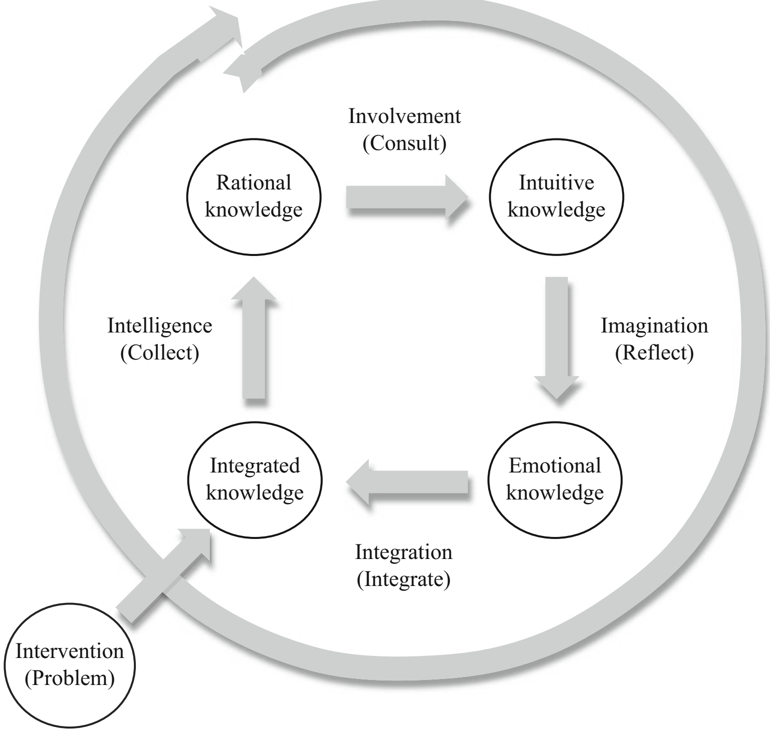

Fig. 6 Pentagram I^5 as the road-mapping spiral (Ma et al., 2007)

Thinking". The concept of *Road-mapping* denotes a specific process of forecasting the future and planning. This spiral, proposed in Ma et al. (2007), is illustrated in Fig. 6; the initial node is *Intervention*, and the nodes of the pentagram are treated as subsequent transitions in the order of *Intelligence-Involvement-Imagination-Integration*. The nodes between them stand for rational, intuitive, emotional and integrated knowledge.

A general question related to the developments described above is as follows: are the long term, historical processes of knowledge creation linear (in the sense of lack of recursion) or rather are they circular and spiral-like? This question is addressed in the next section.

4 A General Spiral of Evolutionary Knowledge Creation

Motivated by curiosity, supported by intuition and emotions, and with the use of our brains or minds, we, people, observe reality and construct hypotheses about the properties of nature, other people, human interrelations, and also construct tools that support us in our contacts with nature or other people; together, we call all this knowledge. There is no doubt that knowledge develops in a punctuated evolution – punctuated by scientific revolutions as observed by Thomas Kuhn (1962), but also gradually accumulated by all people constructing knowledge.

People test and evaluate knowledge constructed by them through an application of this knowledge to reality: they conduct destructive, critical tests of new tools and artefacts, they invent critical empirical tests for theories describing nature, they try to apply and assess theories concerning social and economic relations, they perfect mathematics as an interdisciplinary (intuitively grounded) language for models describing our knowledge. All this is possible because we have and can utilize a tremendous excess and redundancy of our brains and minds, released by the development of speech, as discussed in chapter "Systemic Synthesis and Metaphysics: Eastern Versus Western Thinking".

However, the punctuated evolutionary character of knowledge development suggests a spiral-like process. Such a process can be described with the help of a general spiral of evolutionary knowledge creation presented in Fig. 7; as discussed above, the spiral-like form of this model indicates that it was constructed under

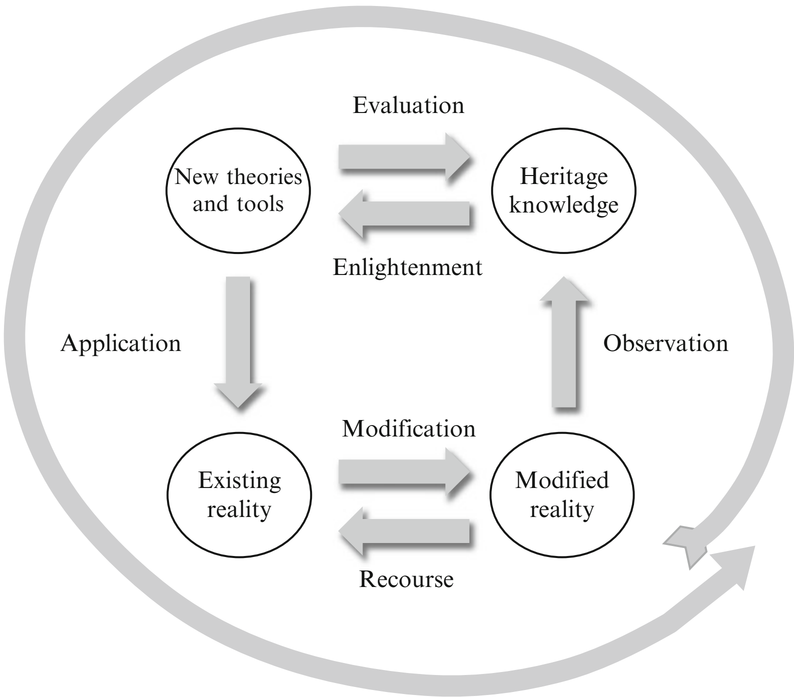

Fig. 7 A general OEAM (*Observation-Enlightenment-Application-Modification*) spiral of evolutionary knowledge creation (see, e.g., Wierzbicki, 2008)

an Eastern influence. The outer spiral in this figure indicates an avalanche-like growth of knowledge resulting from positive feedback: older effects (knowledge already gathered) become new causes (foundations of newly created knowledge).

The transition *Observation* indicates that we observe reality (in nature or in society) and its changes, and we compare our observations with our intellectual heritage. This heritage consists of its rational part, *World 3* of Karl Popper, but also of its intuitive and emotional elements. Our intuitive and emotional knowledge helps us in generating new hypotheses (the transition of *Enlightenment*, called also abduction, illumination, brainstorm, eureka) or in constructing new tools; we then apply them to reality (*Application*), usually in order to achieve a desired change (*Modification*); finally we return to observation.

The spiral is complemented by other transitions. The first one results from a natural evolution in time: a modified, new reality becomes actual reality (*Recourse*). The second additional transition is most important and makes this spiral evolutionary, since it consists of evolutionary adaptation, of a selection of tested knowledge (*Evaluation*): a majority of new knowledge can be recorded somewhere, but only its positively tested portion, resistant to falsification attempts, remains an essential part of the intellectual heritage of humanity. This can be also interpreted as objectifying, stabilizing feedback.

This *objectification of knowledge* is especially important. The importance of selection of knowledge as objective as possible (I stress that there are no absolute verities, but we should strive for objectivity as an ideal) is related to the fact that avalanche-like growth always results in diverse threats: *we must leave to our children the best knowledge possible in order to prepare them for threats of the future unknown to us*.

In this, the concept of *objectivity* is similar to the concept of *justice* as understood by John Rawls (1971): because of the uncertainty concerning the future of our children, the social solutions that are rational are the most just ones, thus justice is interpreted as a concern for the welfare of children in an uncertain situation. Similarly, it is rational to strive for maximal objectivity of knowledge conveyed to our children. Thus, *an absolute justice just as an absolute objectivity is of course an unattainable idea, but they both arise as paramount ideas, irreducible to secondary ones, such as power, money or market*. Therefore, I do not believe that knowledge and the intellectual heritage of humanity are a *reflection of nature* (see also Rorty, 1980), but that they are an *image of nature* created by people and useful in civilization evolution.

In that sense, objectivity is a metaphysical idea that can be expressed in the following form of a *falsification principle*, which is slightly generalized when compared to the original formulations of Karl Popper (1934, 1972):

- *Evolutionary falsification principle*: Hypotheses, theories, models of knowledge develop evolutionarily and the measure of their evolutionary fitness used in their assessment (*Evaluation*) is either the number of unsuccessful attempts to falsify them in a short term (as in technology) by critical experiments, or their permanence against long term falsifications by scientific revolutions (as in strict sciences), or a number of critical tests by social discourse aimed at achieving an intersubjective agreement as to their validity.

In the model presented in Fig. 7, *nature* is not only an effect of knowledge construction by humans, nor it is only a cause of knowledge, it is both cause and effect in a positive feedback loop, where more knowledge results in more modifications of nature and more modifications results in further growth of knowledge, but we try to control this growth through knowledge objectification. As in most positive feedbacks, the general result is an avalanche-like growth, and such a growth, if not stabilized by additional stabilizing feedbacks, brings great opportunities but also various threats, often not anticipated but lurking in the future. One of possibly biggest threats is additional positive feedback that can be observed in relation to knowledge development and the capitalist market: the market income resulting from an application of new technologies of course supports also further development of new technologies, but the profits resulting from this process are recently enriching only the richest people in the world, as admitted by The Economist (2014).

We must somehow limit the dangers resulting from an excessive stratification of the world, otherwise the development of human civilization, based on positive feedback between science and technology on the one hand and the capitalist market on the other hand, can lead to self-destruction. An example of such a possibility is the phenomenon of *eerie silence* (the lack of response from the cosmos to more than 50 years of our radio signalling the existence of intelligence on Earth (see Davies, 2010)). One of possible explanations of this phenomenon is an assumption that civilizations such as ours are rare in the cosmos, since they usually lead to self-annihilation.

5 Conclusions

In recent decades, we observed an increased interest in the *micro-models* of knowledge creation for the needs of a knowledge-based economy. Following the ideas expressed in the *SECI spiral* of Nonaka and Takeuchi (1995), such micro-models are usually expressed in the form of positive feedback spirals, describing circular, avalanche-like development. While Western thinking usually tries to avoid circular development models, from the Eastern perspective it is possible to present such a spiral-like model of the punctuated evolution of human knowledge. This model helps us understand not only the great opportunities created by the evolutionary development of knowledge, but also the related threats. One of the related threats is the danger of self-annihilation of human civilization resulting from positive feedback between science and technology on the one hand and the capitalist market on the other hand.

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Data Mining of Telecommunications Data as an Example of Systemic Synthesis

Janusz Granat

Abstract Data mining is one of the techniques that are widely used for supporting diverse business tasks. However, the process of building data mining models and transforming results of models execution into useful business knowledge is a complex process that is a result of a synthesis of the knowledge of a group of experts. This process is mostly intuitive and requires development of new scientific methods. Systemic synthesis might be one of the driving forces of such development. For example, recently the Domain-Driven Data Mining methodology has proposed to apply meta-synthesis. In this chapter, examples of applying systemic synthesis in data mining in telecommunication domain are presented.

Keywords Data mining • Knowledge discovery • Systemic synthesis

1 Introduction

Traditional data mining methods are applied in the process of knowledge discovery from databases (see Fayyad et al., 1996). However, data mining can be classified as only one of the approaches to the analysis of data. We shall focus in this chapter on the use of systemic synthesis in data mining. The question is whether we apply only analysis of data or as well systemic synthesis in a data mining process.

Data mining is a process of discovery of useful patterns from data. We can observe two streams of work in the area of data mining. The first one is the development of new algorithms that improve the results of mining data and the second is the development of data mining models in the industry. We will focus on the second stream of work because it is concerned with applications of data mining. Ho et al. (2007) stressed that the data analysis process should be

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performed repetitively, using several interactions with analysts or other stakeholders of the results. Such interactive approach does not correspond to pure data mining according to its usual definition. However, the interactive approach is often the only way to obtain useful results in practice.

Cao and Zhang (2006) proposed a Domain-Driven Data Mining methodology. They observed an imbalance between the large number of algorithms published versus the number of algorithms actually applied to support business processes and business decisions. They proposed a next-generation general methodology, called the concept of *Domain Driven Actionable Knowledge Delivery*, or D^3M. According to the authors, Domain Driven Data Mining refers to the set of methodologies, frameworks, approaches, techniques, tools and systems that cater for human, domain, organizational and social, and network and web factors in the environment, for the discovery and delivery of actionable knowledge. They stress the role of meta-synthesis that synthesizes in-depth data intelligence, human intelligence, domain intelligence, organizational and social intelligence, and network and web intelligence in domain driven actionable knowledge delivery.

The complexity of development of contemporary information and telecommunications systems increases considerably. This complexity is a result of increasing number of elements of telecommunication infrastructure, more advanced services (see Dolk and Granat, 2012), integration with external sensors and increasing number of users. Such complex teleinformatics systems require at least continuous monitoring. However, more advanced functions are needed, such as self-adaptation, self-management or self-healing. Data sets grow in size in part because they are increasingly being gathered by cheap and numerous information-sensing mobile devices, aerial (remote sensing), software logs, cameras, microphones, radio-frequency identification (RFID) readers, and wireless sensor networks.

In this chapter we shall consider a specific problem of event detection in a data stream. Algorithms for event detection are very important in the process of finding changes in the system (see Granat, 2005, 2006). The system under consideration can be a telecommunication network, a stock exchange, a patient that is monitored by medical devices or a set of cars on the road that are monitored by video cameras. It can be seen that event detection algorithms can be applied in diverse fields.

Despite such differences in fields of applications there are many common properties that allow application of general purpose algorithms; however, there are also significant differences that might improve the detection quality, if they are taken into account. Therefore, in this paper we will stress the importance of *systemic synthesis* in development of detection algorithms that is often underestimated in the process of algorithm development. Most papers related to event detection focus on development of specific class of algorithms or detecting anomaly in specific domain by using various types of algorithms. In this chapter we will show the importance of systemic approach.

2 Data Stream Processing and Event Detection

We shall address here the specific problem of data stream processing and mining. We assume that there is a continuous observation of a system in form of data streams. These observations can be unidimensional or multidimensional. Unidimensional data stream can be defined as a sequence of data items. In general data items can have diversified types like real numbers, strings, integers, bits etc. We will analyze sequence of data records observed in a given window:

$$y = \{\cdots, y(i), \cdots, y(i_w), \cdots, y(i_w + j), \cdots, y(i_w + (n-1)), \cdots\}, \quad y(i) \in R$$

where

i_w —beginning of sequence of observations in a window w
n —the number of observations
i —index of any observation
$y(i)$ —an observation

An observation $y(i) = \{a_1, a_2, \cdots, a_m\}$ can consist of m attributes a_i. We can also consider multidimensional data stream:

$$Y = \{\cdots, Y(i), \cdots, Y(i_w), \cdots, Y(i_w + j), \cdots, Y(i_w + (n-1)), \cdots\}, \quad Y(i) \in R^p$$

where

i_w —beginning of sequence of observations in a window w
n —the number of observations
i —index of any observation
p —dimension of the observation
$Y(i)$ — multidimensional observation

$$Y(i) = \begin{bmatrix} y_1(i) \\ y_2(i) \\ \vdots \\ y_p(i) \end{bmatrix}$$

Stream data processing is often applied in event base systems. According to Oxford dictionary the event is “a thing that happens or takes place”. We can consider a sequence of events:

$$E = \{\cdots, e(i), \cdots\}$$

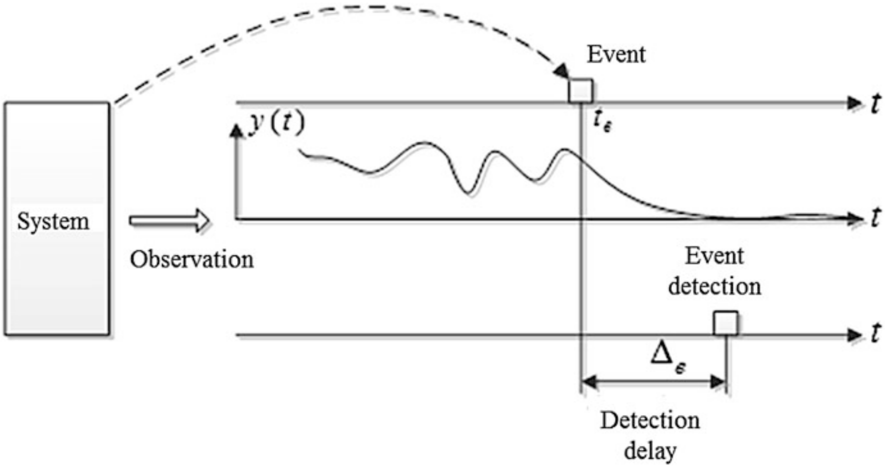

Fig. 1 An event detection

where

i —index of sets of events in the sequence
$e(i)$ —an event characterized by a set of attributes $e(i) = (a_1, \cdots, a_m)$

In examples we will consider simple structures of data. We assume that observation is given in the form of time series $y(t)$. In Fig. 1, we see that we have observation of the system in form of time series $y(t)$, an event happens at time t_e and after some time that is needed for detection (delay Δ_e) information about event is signaled.

Increased complexity of contemporary production and service systems as well as information systems requires development of a new monitoring, control and management systems. Moreover, there are requirements for real-time or on-line data processing. These problems stimulate the development of new stream data processing, stream data mining, event detection, complex event processing and finally event-based systems.

Stream data processing is class of systems that focus on stream processing that we can call Data Stream Management System (DSMS) (see Babcock et al., 2002). In such systems it is assumed that:

- Data elements in the stream arrive on-line;
- Data streams are unbounded in size;
- There is no control over the order in which data elements arrive to be processed;
- Once an element from a data stream has been processed it is discarded or archived; and
- It should have various window operators.

Stream data mining is an area of research and algorithms design focused on on-line data mining. One of the most popular open source framework for stream mining is MOA[1] (Massive Online Analysis). This system includes a collection of machine learning algorithms (classification, regression, clustering, outlier detection, concept drift detection and recommender systems) and tools for evaluation of algorithms.

Event detection and analysis is related to stream data processing and mining. It is focused on detection of events based on observation of the system in the form of unidimensional or multidimensional data streams. Here also important is opposite analysis that means that we have knowledge about events but we want to detect causality in observations.

Complex event processing is class of methods that searches for various relations between events. Sets of events can be organized in various structures or structural types, such as sequences, temporal sequences, graphs, spatial-temporal structures, etc.

Event-based systems are class of systems that are based on event based mode of operation instead the conventional request-reply mode of interaction.

3 Meta-synthesis in New Algorithms Design

In this section we will show how *meta-synthesis* is applied to the development of event detection algorithms. In the process of algorithm development four types of knowledge is important (see Fig. 2):

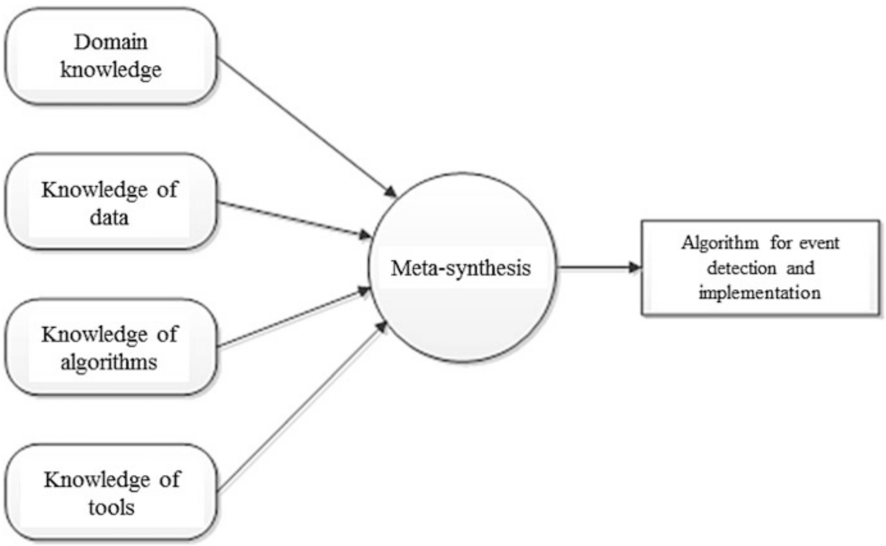

Fig. 2 Meta-synthesis in algorithm development

[1] http://moa.cms.waikato.ac.nz/, 2015

- Domain knowledge;
- Knowledge about data;
- Knowledge of algorithms;
- Knowledge about tools.

Domain knowledge is essential for appropriate problem solving. Very often researchers, who work on data mining algorithms, do not want to go into details of the problem that they solve. Here, it is important to organize a collaboration team that will work on solving a specific problem. Meta-synthesis of knowledge from various disciplines gives a new perspective to solve the problems. It should be also stressed that not only actual knowledge but also past experiences plays a great role in solving similar problems. If an analyst solved the problem several times in various telecommunications companies he cumulates past experiences and can build much better solution. Cao et al. (2010) stressed the gap between algorithms design and its practical use. It can be observed that as the complexity of models increases, willingness to applying such solution decreases. Therefore, the value for the business should be precisely assessed. Domain knowledge is also important in validation of the designed algorithms. Such algorithms are usually evaluated with the use of a reference solution but they should be also evaluated from the point of view of achievement of business goals.

Knowledge of data is knowledge about data like data formats, basic statistics, number of records, missing values, name of attributes. Sometimes data formats are simple such as text files, but often a data format requires specific knowledge such as binary files, XML files or dedicated databases. We assume that here there is no domain specific information. However, we should have information about a method of access of this data, an estimated extraction time and place for storage of this source data. Recently, very important are legal aspects related to data. It is also worth to mention the idea of open data that can be freely available to everyone to use. Therefore, data analyst should have knowledge about various repositories of data that can be used for analysis as well as repositories of data for evaluation of performance of the algorithms.

Knowledge of algorithms includes a whole spectrum of data modeling approaches such as statistical, stochastic, logic based and machine learning models. The algorithms are often developed by two groups of researchers who represent theoretical science and applied science. In addition, there is a narrow specialization in algorithms: For example, there are variety of approaches to event detection: change point detection, event detection, detection of abrupt changes, anomaly detection, novelty detection, concept drift. Such narrow specialization is contradictory to the needs of applying algorithms to practical problem solving. In this case the broad knowledge of algorithms is needed and the competence of applying these algorithms in practice is also required.

Knowledge of tools is complementary to the previous types of knowledge. Usually, the group of researchers who work on algorithm design have knowledge about some tools for implementation of algorithms. But these tools are well tuned to verify the correctness of the algorithms and for an evaluation of the performance of algorithms. The business needs for distinct tools. Here important is stability of the tool, ability to process large volumes of data and the number of analysts who know these tools. Here there is also possibilities to work in the teams of advanced researchers who work on theoretical parts of algorithms and developers who implement the general ideas in detail.

We will show how meta-synthesis is applied in new algorithm development and implementation for stream data mining algorithms. It is worth to emphasize that most often algorithm developers are not aware of applying meta-synthesis. We can distinguish the following phases in the process of algorithm development, implementation and use:

1. *Problem formulation*: Each process of algorithm development must always be preceded by an analysis and detailed formulation of the problem to be solved. There are four most important catalysts for starting the work on new algorithms. The first one are the business needs that come from the actual business operations. The people that run the processes observe the bottlenecks in business processes that need intervention. The second stimulus comes from the new tools that are launched on the market and open new possibilities of process improvement that were not possible without them. The next are the ideas of a new products or services that might require new algorithms. Finally, the competition between firms might result in innovations that give the competitive advantage, thus there might be a need to follow this innovation in order to protect company from losing markets.
2. *Checking the availability of data*: Once we have the problem formulation we might recognize that for solving the problem we need to start with inventory of available sources of data. This is a simple list of available data sources. Each source of data should be analyzed from the point of view of access method (e.g. text files, Excel files, csv files, direct access to database), window time when data can be accessed, internal and external data sources, available history of data, where historical data are stored and how history can be accessed. Moreover, possible legal aspects of data access and use should be checked and analyzed. However the most important aspect is to understand the data from business point of view, and to understand the business processes or technical systems that are sources of the analyzed data. In this stage it is needed to have access to the domain knowledge through collaboration with the business process owners or people who possess the knowledge about technical systems. At this stage it is also important to evaluate the available documentation. The preliminary analysis can also lead to the conclusion that new data should be acquired and the realistic project of data acquisition should be prepared.
3. *Preliminary data analysis*: In this step the analyst starts to do preliminary experiments with the data. Samples of data are taken and simple techniques are applied for analysis of these samples like visual analytics, calculation of basic statistics (e.g. number of record, number of missing values, max and min values, mean) and analysis of outliers. In addition, the quality of data is evaluated. The evaluation is being undertaken from the point of view of data knowledge as well as domain knowledge. At this step the close collaboration should be established

with business groups and the database analyst for gathering information that helps in understanding the data form the point of view of domain knowledge.

4. *Design the ETL (Extract Transformation and Load) process including data quality improvement*: Preliminary data analysis gives a base for designing the ETL procedures. We can distinguish traditional ETL and real-time ETL for streaming data. Traditional ETL process has been running in a batch process. Originally, it was applied for population of data warehouses. The position of ETL in analytical systems is evolving. At present it is related to any information system, not only data warehouse. Moreover, it is applied in the development of processes for data streams. Traditional ETL processes consist of three phases. In the first phase, the data are loaded from various sources to the operational data storage area like ODS (Operational Data Store). In the next phase, the data are transformed from its original form to the form relevant to data analysis. This phase should be started with data cleansing (also called data cleaning) that are responsible for detecting and removing errors and inconsistencies from data. This leads to an improvement of the quality of data. Than the data should be transformed to the forms that are relevant to analysis or input to the algorithms. Here the data are aggregated, new attributes are calculated or units are converted. In the last phase data are loaded in the batch process to the warehouse or other data storage e.g. HDFS (High Distributed File System) that is used, e.g., by Hadoop system.[2] Real-time ETL for streaming data has to be focused on fast processing of huge volume of data streams. Therefore, new concepts for massive data streams are being developed; traditional ETL are not applicable for massive stream data. There are functionalities that allow defining input streams and sets of rules for processing and filtering stream data.
5. *OLAP and algorithmic design*: The data will not have any value without tools for analyzing them or using them as an input to an algorithm. One of the most popular tools for data analysis belongs to the class of OLAP (On-Line Analytical Processing) tools. The characteristic feature of OLAP is multidimensionality. It means that the data are stored in multidimensional tables called cubes where we can distinguish measurements and dimensions. The dimensions can have hierarchies (e.g. for time dimension we can have hierarchy: year, month, day, and hour). On the top of multidimensional structure we have user friendly navigation and visualization tools. The data are also inputs to advanced algorithms and analytical models. We can distinguish the following most often used classes of algorithms in data mining (including statistical methods), optimization, on-line optimization, stream data mining and CEP (Complex Event Processing). Moreover, the data are also used in analytical simulation models. The development of a new algorithm requires meta-synthesis of various types of knowledge.
6. *Executing data processing and algorithms*: For execution of data processing and algorithms an operational environment should be built and closely integrated with existing or new business processes in the organization. New personnel should be allocated to the process of operation and maintenance of developed

[2] http://hadoop.apache.org, 2015.

solutions. The tasks of software operations include operation of software and services, monitoring of hardware and services, and scaling hardware. Software maintenance can be defined as the process of modifying software after delivery to correct faults, improving performance (or other software quality attributes) and adapting to a changed external environment that has an influence on the system. It should be stressed that operation and maintenance requires different knowledge and competence than at the stage of software and algorithm development.

4 Example of Meta-synthesis in the Design of Event Detection Algorithms

In this section we will show an example of meta-synthesis in algorithmic design for event detection.

4.1 Domain Knowledge Related to Problem Formulation

We consider a local network that consists of five switches that are nodes of the network. All switches are connected (see Table 1). The first column in this table shows link number (the column A is a beginning of a link and the column B is the end of a link). In Table 1 we have information about 8 links (e.g. the second row of the table shows the link 2 that connects the port 2 of the switch 1 to the port 1 of the switch 4). The designed network topology is robust to single link failure. The administrator of the network has the tools for network monitoring. However, it would be useful to analyze network data on-line and generate alarm that informs the administrator about unusual changes (events) in the network.

4.2 Knowledge of Data and Domain Knowledge Related to Data

Table 2 shows the part of data that comes from the network monitoring system. From the point of view of knowledge about data we see that we have table of data

Table 1 Links of the network

	A	B
1	1-1	4-4
2	1-2	4-1
3	1-3	5-2
4	2-2	3-4
5	2-3	4-4
6	3-1	4-2
7	3-3	5-1
8	4-4	5-1

Table 2 Data from network monitoring system

Hour	Min	Sec	s1-p1-i	s1-p1-o	s1-p2-i	s1-p2-o	s1-p3-i	...
18	30	15	24,532	26,592	29,026	2,134,091	315,357	···
18	30	30	24,532	23,221	27,903	1,529,407	333,335	···
18	30	45	24,345	25,468	28,277	1,930,532	418,354	···
18	31	0	24,719	25,094	27,154	2,036,338	326,031	···
18	31	15	7865	8240	10,487	479,777	102,248	···
18	31	30	25,281	23,970	26,966	1,939,895	345,320	···
18	31	45	24,157	24,719	28,277	1,682,591	396,069	···
···	···	···	···	···	···	···	···	···

(originally it is a text file) that has number of rows and columns. The data are of integer type. During the preliminary analysis we can additionally calculate basic statistics from these data. Without domain knowledge it is impossible to say more about the data. We can gain much more information from domain knowledge. It is a field for collaboration between data scientists and experts in telecommunication. In this table, there is information about measurements of traffic on input and output ports of the switches. The first three columns contain information about time of measurement: hour, minutes and seconds. We see that we have four measurements per minute. The next columns contain information about traffic measurements on a given ports (e.g. the column s1-p1-i contains results of measurement on the switch 1, the port 1 and input interface; the column s1-p1-o contains results of measurement on the switch 1, the port 1 and output interface). The results of measurements of traffic on the ports are counted in bits/s.

4.3 Knowledge of Algorithms and Domain Knowledge Related to Algorithms

The design of algorithms for event detection is a meta-synthesis of knowledge related to data, algorithm and domain knowledge. It is worth to mention also knowledge about tools because they decide about feasibility of provisioning of developed solution. We can start the design process with the discussion about possible set of network faults. In this discussion the telecommunication specialist should be involved. This discussion (or sometimes brainstorming) allows to preliminary synthesize the domain and data scientists knowledge. In our case we can distinguish the failure of any elements of the networks, links or nodes, unusual traffic due to the intensification of work of the researchers who use the network, or unusual traffic due to the external activities such as cyber-attacks. The failure of some links results in different patterns of traffic flows but not in unavailability of network services. The data scientists start with the problem of detection of link failure. They have proposed a broad spectrum of event detection algorithms. Some of them are based on observation of unidimensional data streams. Therefore, the analysis starts with this type of algorithms. We will show here two approaches: threshold checking of processed values of data stream (or calculated parameters) and BOCD (Bayesian On-line Change point Detection) algorithms. The algorithms have been selected due to criteria of simplicity of implementation and on-line detection properties.

The simplest approach to event detection is threshold checking for values of the data stream:

$$\underline{y} \le y(t) \le \overline{y}$$

where

$\underline{y}$ —the lower threshold of the values of data stream
$y(t)$ —the values of data stream
$\overline{y}$ —the upper threshold of the values of data stream

We assume tree level alarm $alarm(t)$ that is generated according to the value of function $F(t)$. In the event detection algorithms the information function about alarms has two values that is equivalent to existent or not of the event. In the detection algorithms it is useful to have information about the strength of the event. This feature can be represented by function $F(t)$, which can be defined as follows:

$$F(t) = \begin{cases} 0, & \text{if } \underline{y} + \delta \le y(t) \le \overline{y} - \delta \\ 1, & \text{if } \underline{y} - \delta \le y(t) < \underline{y} + \delta \text{ or } \overline{y} - \delta < y(t) \le \overline{y} + \delta \\ 2, & \text{if } y(t) < \underline{y} - \delta \text{ or } y(t) > \overline{y} + \delta \end{cases}$$

The function $F(t)$ is equal to 0 if the values of stream data are inside a given range and 2 if the values are outside a given range (with tolerance δ). This function is equal to 1 if we are close to the boundary of a given range (with tolerance δ). More advanced functions $F(t)$ can be defined. The $alarm(t)$ function is defined as follows:

$$alarm(t) = \begin{cases} 0.0, & \text{if } F(t) \le 0 \\ 0.5, & \text{if } 0 < F(t) < 2 \\ 1.0, & \text{if } F(t) \ge 2 \end{cases}$$

Figure 3a shows two graphs. The upper graph shows data stream monitored on the input port 1 of the switch 1 (see Table 1). At certain time there is a failure of the link 2 (see Table 2). We assume thresholds: $\underline{y} = 0$, $\overline{y} = 0.3$. The lower graph shows the values of function $alarm(t)$. We see that there is alarm generated about index 250. Nevertheless, after that we see many alarms generated without any further failures in the network. We can see that presented approach do not give a

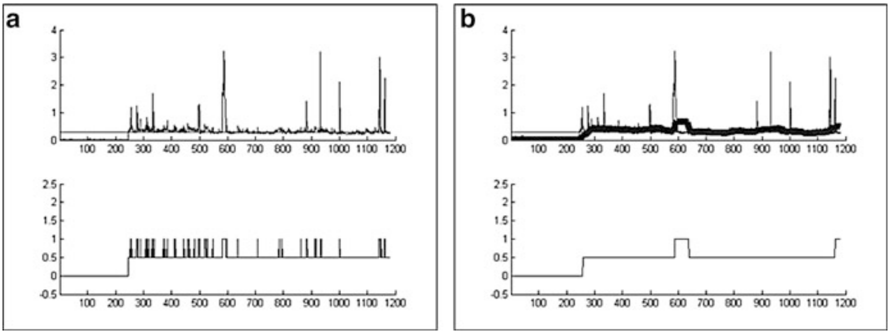

Fig. 3 Threshold checking

stable solution. Therefore we need further improvement of the algorithm. The next simple improvement is calculation of moving average:

$$y_A(t) = \frac{1}{m} \sum_{i=0}^{m-1} y(t-i)$$

$$\underline{y} \leq y_A(t) \leq \overline{y}$$

The moving average fixes the irregular fluctuation in observed data stream. In Fig. 3b, the moving average is displayed by the bold line. By the lower graph we see that the alarm generation is more stable.

The disadvantage of the presented approach is that we have to define the threshold levels. Therefore, further experiments are needed.

Adams and MacKay (2007) have designed BOCD (Bayesian On-line Change point Detection) algorithm. In this algorithm the change point probabilities are calculated:

$$P(r_t = 0, y_{1:t}) = \sum_{r_{t-1}} P(r_{t-1}, y_{1:t-1}) \pi_t^{(r)} H(r_{t-1})$$

where

$P(r_t = 0, y_{1:t})$ –probability that the run length r_t drops to 0
$P(r_{t-1}, y_{1:t-1})$ –joint distributions over run length and observed data
$\pi_t^{(r)}$ –predictive probability
$H(r_{t-1})$ –hazard function

Figure 4a shows the results of execution of this algorithm for data stream monitored on the input port 1 of the switch 1 (see Table 1) and Fig. 4b for moving

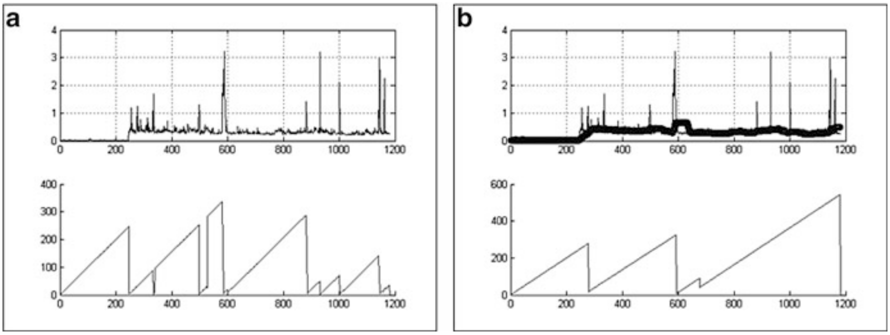

Fig. 4 Bayesian on-line change point detection

average of monitored data. The lower graph in this figure shows run lengths r_t. The run length which either continues to grow or in a case of a change point occurs its value is equal to 0. We can observe by the lower graph in Fig. 4b that the result of change detection is similar to the method based on thresholds (see Fig. 3b). However, in Fig. 4b we do not display three alarm levels. The BOCD method does not require specifying threshold levels.

The design of the algorithm may continue in the direction of analysis of multidimensional streams that will take into consideration measurements in several points of the network. The design of this algorithm is a process of meta-synthesis of data, domain and algorithmic knowledge. The knowledge of tool allows developing the code for experiments. In our case the experiments have been developed by using Matlab software.

5 Conclusion

This chapter showed how important meta-synthesis is in applied science. We have shown the process of data processing, algorithmic development and use of algorithms. A detailed example of the process of event detection algorithm design has been shown. The chapter stressed the importance of domain knowledge in reducing the gap between algorithm design and its practical application in solving business problems.

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The Meta-synthesis System Approach

Jifa Gu

Abstract This chapter introduces the meta-synthesis system approach, originally proposed by Qian, Yu and Dai in 1990, which is designed for solving complex problems happened in open giant complex systems, such as the social system, the environmental system, and the human body system, etc. Three kinds of meta-synthesis are often used during the problem solving: qualitative meta-synthesis, the combination of qualitative meta-synthesis and quantitative meta-synthesis, and from qualitative meta-synthesis to quantitative meta-synthesis. The tool for realizing the meta-synthesis system approach is the hall of workshop for meta-synthetic engineering, which consists of the knowledge system, the expert system and the machine system. Miscellaneous halls of workshops have been designed in different areas in China, such as military, economy and industry areas.

Keywords Open giant complex systems • Meta-synthesis system approach

1 Origin of the Meta-synthesis System Approach

At the start of the 1980s under the guidance of X.S. Qian, some projects related to complex weapon systems had been conducted using quantitative studies. Qian then turned his attention to another social economic project related to the comprehensive balance in price subsidies for rice by the state, and prices and salaries in China during the period 1983–1985. In this project, system researchers solved the problem through close collaboration with economists by using both quantitative models and expert knowledge. They carried out full discussions and investigations dozens of times, and in this project they collected ten thousand items of data. The system modeling was divided into two parts, one based on national income allocation and the market, which included 115 variables, 44 developing equations, 7 times series models and 64 relational models, and the other based on the relationship between the input and output of the various 237 sectors; all sets of models running policy

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simulation and doing economic forecasting. Finally they successfully solved the problem by using primitive meta-synthesis thinking (Yu, 1989; Yu and Tu, 2002).

Then Qian met with some other problems in the fields relating to society, the economy, military, the environment, geography, and the human body etc. which were very difficult to solve with original systems engineering methods or the so-called hard systems approach, which mainly uses data and mathematical models. Qian, Yu and Dai formally proposed the meta-synthesis system approach (MSA) for solving open complex giant system problems in 1990. They listed the following systems as representative of the open complex giant system: the social system, the economic system, the military system, the geographical system and the human body system. If we wish to obtain more quantitative analysis and results, difficulties are also encountered with the soft systems approach. The meta-synthesis approach uses simply the data, information, models, knowledge, experience and wisdom in synthesizing and integrating all of these to solve issues in the open complex giant system (Qian et al., 1990 (Chinese version), 1993 (English version)).

2 Main Contents of the Meta-synthesis System Approach

2.1 The Open Complex Giant System

Qian et al. proposed the concept of the open complex giant system in differentiating other kinds of systems, such as the simple system, the closed system, the complex system, the large system and their various combinations. The main features of the open complex giant system are as follows:

1. There exists exchanges between the system itself and its environment, including matter, energy and information, referring to its openness;
2. 'Giant' system refers to the inclusion of many subsystems and elements. They amount to thousands upon thousands, even billions of billions;
3. There are many/complex types and interrelations between the elements; and
4. There are many levels of hierarchy in the system.

2.2 From a Qualitative to a Quantitative Meta-synthesis Approach

In this approach Qian et al. simply wish to integrate and synthesize data, information, models, knowledge, experiences and wisdom, emphasizing the characteristic of qualitative to quantitative but not the general combination of qualitative with quantitative. The essence of this approach is that starting from qualitative analysis, the approach should company with deep quantitative computation. As a matter of fact in order to synthesize the various literature and evidence in the fields of

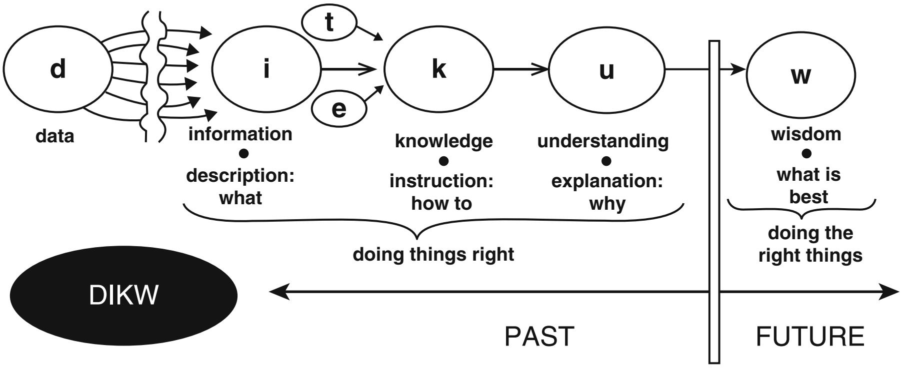

Fig. 1 DIKW by Ackoff (Wikipedia, 2011)

health and education, many Western scholars have put forward systematic reviews, meta-analysis methods etc. Systematic reviews and meta-analysis are important research tools in modern medicine and education. They serve to condense and clarify large amounts of data into resources that can educate researchers, help formulate guidelines, and guide future research endeavors.

But scholars soon found disadvantages in these kinds of methods and at the end of the twentieth century Sandelowski and Barroso put forward their research on a Qualitative Meta-synthesis approach. Note that they didn't pay too much attention to the quantitative aspect of meta-synthesis (Sandelowski and Barroso, 2007). From another angle Zeleny and Ackoff put forward the hierarchy of Data-Information-Knowledge-Wisdom (DIKW), with attention paid to the movement from DIK to Wisdom – a very important step in considering wisdom (see Fig. 1) (Wikipedia, 2011). In Qian's idea he pays attention to both experiences and wisdom. If we divide the knowledge into explicit and tacit, thus in tacit knowledge the experiences play a key role, then for knowledge creation, wisdom is a crucial point.

The following principles are followed in the MSA:

1. It stands for the combination of machine and human but with an emphasis on human;
2. It combines both the left and right brains;
3. It combines both qualitative and quantitative methods; and
4. It combines both hard and soft systems approaches.

2.3 Systematology

The other difference between Qian's approach and the approaches of scholars in the fields of information science and knowledge science is the theory of systematology, which Qian studied starting from the beginning of the 1980s. He uses a lot of advanced system theories from the Western world, such as general system theory, dissipative structure, synergy, chaos, fractal and super cycles etc., and also some from the Eastern world, such as the differential dynamic system and traditional Chinese medicine.

Starting from 1986 a series of seminars under his guidance for the in-depth discussion of various scholars of Western and Chinese system theories and similar thoughts were run at the Beijing Institute of Information and Control and the Ministry of Aerospace. This series of seminars lasted for 9 years. The main speeches by Qian in these seminars were collected in a special published book edited by Jiang (2011). Qian also published his main ideas and thoughts on Systematology in his book 'Creating Systematology' (Qian, 2007).

2.4 The Hall of Workshop for Meta-synthetic Engineering

As a tool for operating this meta-synthesis approach, at the start of 1992 Qian proposed the Hall of Workshop for Meta-synthetic Engineering (HWMSE), which includes expert systems, knowledge systems and machine systems. The main ideas of HWMSE gather together the following theories, techniques and thoughts (Qian, 1992a, 1995):

1. Scientific seminars;
2. C3I system and war gaming;
3. From a qualitative to a quantitative meta-synthesis approach;
4. Information and communication techniques;
5. Artificial intelligence;
6. Virtual reality;
7. Intelligent systems with the combination of humans and computers; and
8. Systematology etc.

2.5 The Meta-synthesis of Wisdom

Xiong Shili, a famous Chinese philosopher and the founder of Neo-Confucianism, defined wisdom as two kinds of wisdoms: natural wisdom (xing zhi) and magnitude wisdom (liang zhi) (Guo, 2011). Guided by this philosophy Qian divided all natural science, social science, culture and art into two parts: art and culture belong to natural wisdom and science belongs to magnitude wisdom. Qian assumed that it is not enough to only mention the wisdom related to science and technology; but that we must pay attention to another source of wisdom- traditional art and culture. So he suggested that wisdom should include both natural wisdom and magnitude wisdom.

Fig. 2 Meta-synthesis of wisdom

At the end of 1992 Qian proposed the meta-synthesis of wisdom, which integrates individual wisdom, collective wisdom and wisdom combining humans and computers. Or we may say: synthesize knowledge and wisdom from experts personally; synthesize knowledge and wisdom from organizations, community and society; synthesize knowledge and wisdom from humans and computers. Finally we wish to make a decision or create a new or alternative, idea and consensus (see Fig. 2). Qian wanted to extract wisdom from both ancient and modern times, western and eastern worlds, and wanted to combine natural wisdom and magnitude wisdom. According to his idea we have to educate people to be wiser and more moral (Qian, 1992b).

The principles for meta-synthesis of wisdom are as follows (Gu, 2013):

1. Integrate various disciplines of science – *interdisciplinary*;
2. Integrate various cultures – *cross-cultural*;
3. Integrate knowledge, experiences and wisdom from a group of experts – *coordinative and corporative*;
4. Integrate human wisdom and computer wisdom by using human-computer interactions emphasizing human wisdom – *interactive*;
5. Integrate wisdom from the past and future, and carry it forward and forge ahead – *inheritance and creative*; and
6. Integrate natural wisdom and magnitude wisdom.

3 International Comparisons

We try to compare the European scholars, US scholars and Chinese scholars from different aspects: people, theory and method (see Table 1). This is certainly not a complete list for the whole world. We just wish to point out the main emphasis on differences between these three scholars, however we will not name other important scholars and their research content (Gu et al., 2014b).

Table 1 A comparison of three scholars of system theory

	European scholar	US scholar	Chinese scholar
Person	Ludwig von Bertalanffy; Ilya Romanovich Prigogine; Hermann Haken	(Santa Fe Institute) Andrew P. Sage	Xuesen Qian
Theory	General system theory; self-organization; dissipative structure; synergy; catastrophe; super cyclic theory	Complex adaptive system (CAS); emergence; system of systems (SOS)	Open complex giant system (OCG); meta-synthesis methodology (MS); systematology; differential dynamic system; noetic science
Methods	Differential dynamic equations; strange attractors; chaos; order; fractals	Complex network analysis; Multi-agent simulation; genetic algorithms; system of systems engineering (SOSE)	Hall for workshop of meta-synthesis engineering (HWMSE); Meta-synthesis of wisdom (ME)

4 Some Developments in the Meta-synthesis System Approach

The author wishes list a few achievements in China in the theoretical, technical and practical aspects using the MSA approach.

4.1 Theoretical Achievements

Here we list some of their theoretical achievements:

1. Three kinds of meta-synthesis and the research approach by Hu;
2. Flowchart for meta-synthesizing – "Meeting I – Analysis – Meeting II";
3. Consensus and meta-synthesis of opinions;
4. Modeling approaches and model integration;
5. Expert mining;
6. Knowledge synthesis; and
7. Systems science and systems engineering.

We will introduce them one by one, but note that theoretical achievements are not limited to these achievements.

4.1.1 Three Kinds of Meta-synthesis and the Research Approach by Hu

There are three kinds of meta-synthesis: qualitative meta-synthesis, qualitative and quantitative meta-synthesis, and from qualitative to quantitative meta-synthesis (see

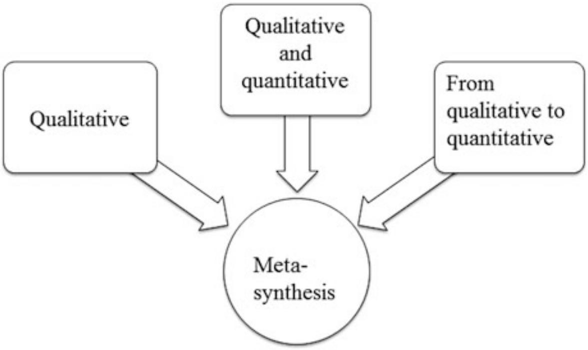

Fig. 3 Three kinds of meta-synthesis

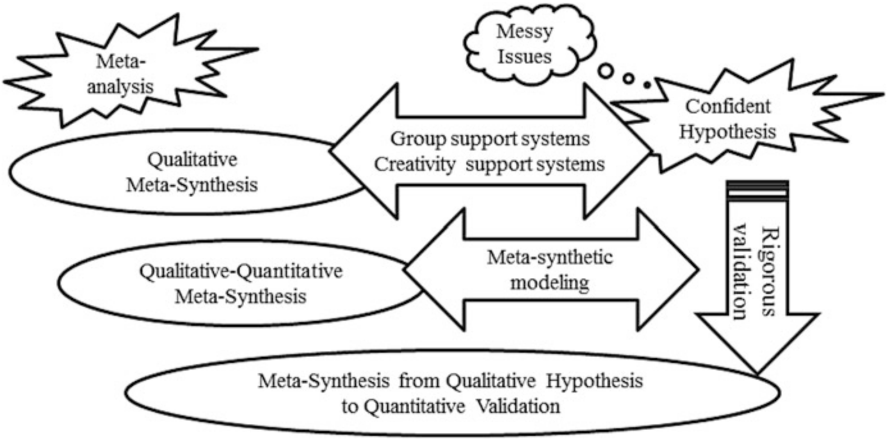

Fig. 4 Meta-synthesis content linked from hypothesis to validation

Fig. 3) (Yu and Tu, 2002). We have tried to link them in the research approach by the famous scholar Hu Shih "Bring up hypothesis boldly while prove it conscientiously and carefully". From the point of view of a meta-synthesis approach, at first we shall use qualitative meta-synthesis to obtain a hypothesis boldly and reasonably, then use qualitative-quantitative meta-synthesis to prove it conscientiously and carefully. Finally we will use the 'from qualitative to quantitative meta-synthesis' to obtain scientific and quantitative results and conclusions (see Fig. 4).

Here we wish to point out that Hu Shih is a scholar with a background in social science, and Qian is a scholar with a background in natural science and technical science, who not only wishes to explain and prove some scientific phenomena and their laws, but wishes to solve the practical issues in natural science and technical science, and in particular in his late years also wishes to help solve some practical social issues on the basis of both qualitative and quantitative analysis.

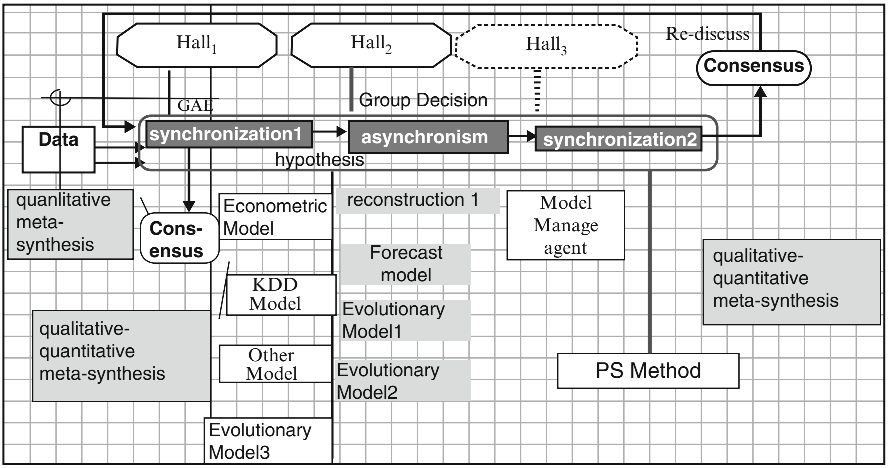

Fig. 5 Complete flowchart for “Meeting I – Analysis – Meeting II”

4.1.2 Flowchart for Meta-synthesizing: “Meeting I – Analysis – Meeting II”

We ran a major program related to studying this MSA approach, which was supported by the NSF (National Natural Science Foundation) of China (1999–2004) (Dai et al., 2003). During the implementation of this major program a new flowchart for realizing this approach was suggested: “Synchronous – Asynchronous (Analysis) – Synchronous” or in short “Meeting I – Analysis – Meeting II” (see Fig. 5).

In the “Meeting I – Analysis – Meeting II” flowchart we emphasized the expert’s intuition, opinions, knowledge, experience and wisdom. It was used firstly to convene an experts’ meeting (“Meeting I”) to collect good ideas from experts, and in order to raise the quality of the meeting, the necessary data, information and knowledge had to be prepared well in advance. In order to meet this requirement some databases, cases and web sources were provided. Then some tools and methods for helping, promoting and analyzing the discussion in the meeting were used or newly designed. Usually in this Meeting I a divergence of thinking is required, but some reasonable and meaningful scenarios have to be obtained for further analysis.

After this “Meeting I” we may obtain some meaningful scenarios. This is also called the stage for qualitative meta-synthesis. Then we move to the “Analysis”. In this stage we will use different models and their integration to create a quantitative analysis for different scenarios obtained from the first meeting stage. Finally we again convene a meeting (“Meeting II”), and here the first difference with “Meeting I” is that the participants are different. For the first one – “Meeting I” – the participants are experts in professional domains, but for the second one – “Meeting II” some participants must be users, decision makers and managers who will implement the decision, but will also include some experts from special domains. This is because in this meeting we wish to ask them to verify and validate the models, computation programs and results from these models. Secondly in order to make a final decision we have to use some consensus building methods and tools for convergence of thinking. In most cases this process will be iterative till the satisfactory and implementable conclusion is obtained.

In this major program two crucial issues were identified by the project leaders:

1. We wish to use the experiences of different experts to analyze and explain the particulars of problems, but if their points of view are not the same, how can we synthesize their opinions and experiences?
2. Since in solving such giant systems we will use a lot of different models, how can we construct appropriate models and if there are many, how can we integrate the models?

4.1.3 Consensus and Meta-synthesis of Opinions

Here we wish to describe the first issue: how can we synthesize the opinions of different experts? We consider three methods for collecting and meta-synthesizing expert opinions:

1. *Meta-synthesis of opinions with text*: By means of opinion with text, experts express their opinions in printed text or on the web. How can we synthesize their opinions? We just list some of them by: simple survey (narrative), systematic review, meta-analysis, qualitative meta-synthesis, text mining and web mining.
2. *Meta-synthesis of opinions with a meeting*: We often convene meetings to collect the opinions from expert-attendees. Only here we will investigate the different aspects related to the quality of the meeting.

   - *Types of meeting*: There are three types of expert meetings:

     a. *Brainstorming type* for collecting vivid and frank opinions, the more the opinions the better;
     b. *Studying type* for collecting and studying opinions on the basis of detailed investigation in advance, the more in-depth and wider the opinions the better; and
     c. *Decision type* for concentrating on the opinions and making a decision, the more focused the opinions the better.

   - *Meetings using modern discussion types*: We wish to recommend three modern discussion types:

     a. Syntegration (Beer, 1994);
     b. Meeting on the Web (WebScope); and
     c. Nominal group meeting.

- 'Ba', facilitation, mediation: Now in terms of convening a high quality meeting we must take care of the 'Ba' – the environment for the meeting, which includes both the physical and mental environment in order to provide a good atmosphere for expressing opinions by the attendees (Nonaka et al., 2000). Then, facilitation and mediation are required in convening a large conference with different nations or different benefit groups for an appropriately converging discussion. Now even in very important and large international conferences with large numbers of participants from various countries, the convener starts to invite facilitators and mediators to raise the efficiency and effectiveness of the meeting.
- DMTMC system: For easily obtaining a consensus we also suggest the so-called DMTMC system to promote the quality of the meeting. Here D means the necessary data and information provided as required in advance or on-line during the meeting process, the first M is meeting, T is advanced technical tools and equipment for the meeting, the second M is the methods and models prepared for further analysis, and the final C is consensus. By using this DMTMC system we will easily obtain a consensus (see Fig. 6).

3. *Meta-synthesis of opinions with in-depth interviews*: Sometime experts don't want to express their opinions in the public environment, or what they say publicly is not necessarily expressing their real meaning. In this case we may use interviews with them after an open meeting or use *Psychology mining* to mine their detailed ideas (Gu, 2001, 2004; Tang, 2013). In our monograph we have described methods for collecting and meta-synthesizing expert opinions in detail (Gu et al., 2007c). At the beginning we paid much attention to consensus building theory and methods, and simply wished to find the common points of consensus which were assumed to be a solution, but very soon we started to understand that convergence is a good thing, but not necessary a valid and correct thing, and that sometimes divergence may lead to new creation and new truth. Truth is sometimes kept by the minority. Thus necessary argumentation and debate are

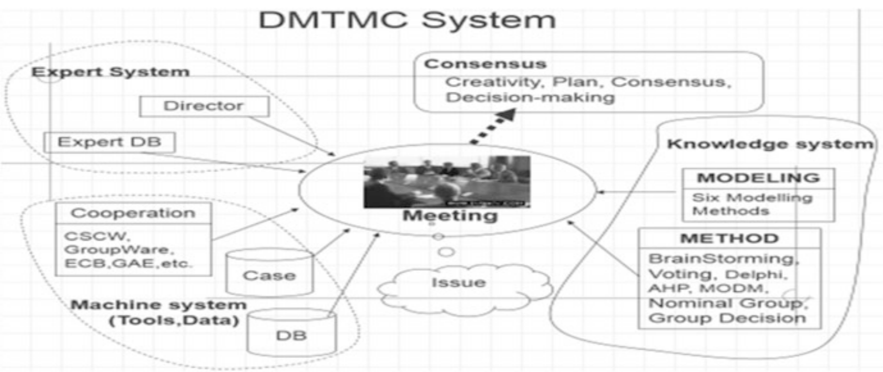

Fig. 6 DMTMC system

needed (Gu and Wierzbicki, 2007). Tang and Liu (2002) developed a tool for computerized support for group argumentation.

4.1.4 Modeling Approaches and Model Integration

For solving the second issue we summarized six modeling approaches and three kinds of model integration techniques and finally a special multi-agent technique for integrating models which may integrates a lot of forecasting economic models, as proposed by Hu in our major program (Gu and Tang, 2005; Gu et al., 2007c).

4.1.5 Expert Mining

From late 2004 we participated in a research project supported by the Chinese Academy of Sciences on social harmony problems, and when we again wished to use the MSA approach we found the human factors even more emphasized. So in 2005 we proposed the so called ‘mining six’ to help solve the social harmony problems: data mining, text mining web mining, model mining, psychology mining and opinion mining (Gu, 2006, 2010). We may use data mining to analyze a massive amount of data to discover some useful knowledge. We may use text mining to extract some useful textual information from the text in documents. We may use web mining to extract useful information from the Internet, etc. We may use model mining to obtain some new results which humans will obtain only by simple mind calculation with difficulty, e.g. the results from the calculations derived from complicated equations, the results from forecasting models etc. We may use psychology mining to dig up some ideas and thoughts behind human psychology (Tang, 2013).

Besides the above-mentioned ‘mining six’, finally we will ask the experts to analyze all the opinions, which sometimes contradict each other and also need an expert to make the final judgment for the obtained results derived from other mining techniques. In 2005 we called it ‘opinion mining’, but soon we changed ‘opinion mining’ to ‘expert mining’. In 2006–2010 we joined another large program supported by the State Support Plan of Science and Technology (grant 2007BAI10 B06-04). This program was related to study on mining methods for analyzing group laws in dialectic treatments by veteran and famous TCM (Traditional Chinese Medicine) doctors. In this program we directly contacted expert-TCM doctors from Xiyuan Hospital, Chinese Academy of TCM and tried mining their experiences and thoughts with the help of some useful mining techniques which we developed by ourselves or techniques we borrowed from abroad and called them expert mining in general (Gu et al., 2007b, 2008a; Gao et al., 2010).

During our contact with social harmony problems and collecting experiences from Traditional Chinese Medicine Masters we paid much attention to expert mining. Expert mining is much wider and more in-depth than opinion mining, since we wish not only to collect the opinion expressed, but their thoughts and something

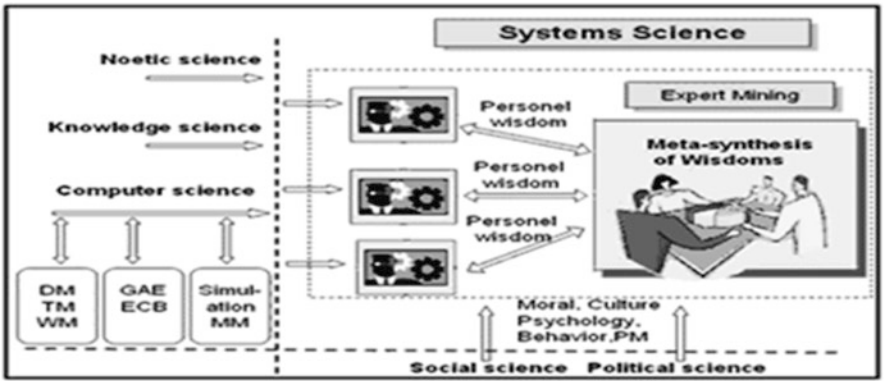

Fig. 7 Six mining in combination

behind their expression on the surface, in other words it means we not only wish to collect explicit knowledge, but also tacit knowledge. In addition we will ask experts to create some new ideas, methods, techniques or theories, and new alternatives for making a decision; it means using wisdom to create something which originally does not exist. Finally we wish to use the combination of the 'mining six' (see Fig. 7)

4.1.6 Knowledge Synthesis

Knowledge synthesis is the aggregation of existing knowledge about a specific question by applying explicit and reproducible methods to identify, appraise, and then synthesize studies relevant to that question. The best-known products of knowledge synthesis are systematic reviews and meta-analysis (Bos and Kammen, 2007; Gu, 2011).

Knowledge synthesis is a branch of knowledge science. It is based on separate knowledge and making the synthesized knowledge more useful and creative. Especially for solving complex system problems, knowledge synthesis is required. Nakamori put forward the *i*-System approach as a useful way to synthesize knowledge in different stages (Nakamori, 2008, 2009; Nakamori and Wierzbicki, 2010).

4.1.7 Systems Science and Systems Engineering

The Systems Engineering Society of China (SESC) has paid much attention to the development of systems science and systems engineering, and they published their first book on systems science, which is a kind of textbook on systems science introducing the main concepts, and the theories developed both in China and abroad (Xu et al., 2000a). SESC edited a second book which introduced the development of

Fig. 8 HWMSE developed by the Institute of Automation, CAS

theory and application in systems science and systems engineering in China within the period of around 20 years (Xu et al., 2000b). In memory of contributions by Qian in the fields of systems science and systems engineering SESC organized a Library of Systems Science Thoughts by X.S. Qian. This library includes four monographs: "Engineering Cybernetics", "On Systems Engineering", "Creating Systematology" and "The Studies on Systems Science Thoughts by X.S. Qian" (SESC and Shanghai Jiaotong University, 2007).

4.2 Technical Achievements

We paid much attention to studying the meta-synthesis system approach and its technical realization. As a matter of fact, during implementation of this major program, the Institute of Automation, at CAS, developed HWMSE (see Fig. 8) and some collaborative tools for meeting in the HWMSE, such as the Electronic Common Brain (ECB) developed by Xian Jiaotong University, the Group Argumentation Environment (GAE), developed by the Institute of Systems Science, CAS, which can support both the 'Meeting I' & 'Meeting II' in our flowchart (Gu et al., 2007c).

During the period of implementation of this major program and after this program my colleague Tang and her graduate students set up a group on meta-synthesis and knowledge science. They developed GAE and other computerized techniques and tools such as CorMap iView, and AIS for Web mining and consensus building etc. (Tang et al., 2007a; Tang, 2010). After running a project related to the TCM master experiences in 2006, we started to pay more attention to collecting experiences from some masters separately and also more in-depth, then found their commonality in a horizontal way, called 'master mining' by Tang (see Fig. 9) (Tang et al., 2007b).

Song designed an MSIM platform for TCM Masters' Experience Mining, lacking of too much practice (Song and Gu, 2009). Xiyuan Hospital, the Chinese Academy of TCM and the Academy of Mathematics and Systems Science (Chinese Academy

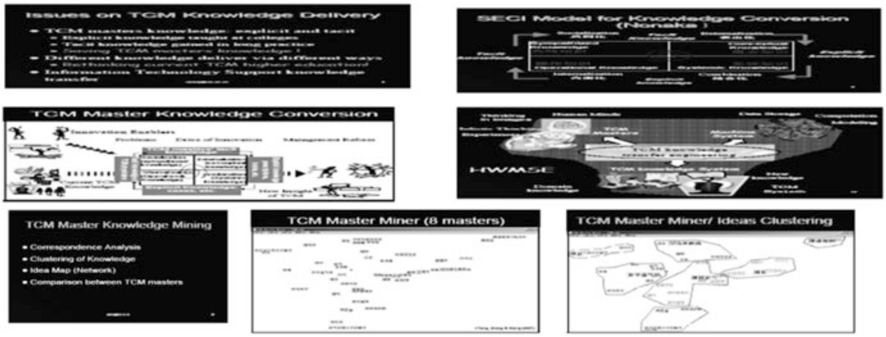

Fig. 9 Traditional Chinese medicine knowledge mining by Tang et al. (2007b)

Fig. 10 The platform for digging the academic thoughts from veteran and famous TCM doctors

of Sciences) have compiled “A Platform for digging the academic thoughts of veteran and famous TCM doctors”, which has been widely used in Xiyuan hospital (see Fig. 9). In this platform there are various knowledge discovery and visualization techniques covered. It includes a preprocessing subsystem which may easily help the doctor transfer the input data into an expert mining format by computer.

This platform included a lot of useful expert mining methods covering statistical methods, network analysis and machine learning etc., but also emphasized the interaction of human TCM doctors with computer, and the interaction between the expert designer and the TCM doctor. With the help of this platform, an instructor TCM doctor may also dig their own thoughts and knowledge without learning the complex expert mining algorithm in much detail (see Fig. 10) (Zhu, 2010).

While managing the Workshop on Meta-Synthesis and Complex System (MCS) and Knowledge and System Sciences (KSS) conferences starting in 2006 and 2007 with the exception of running general conference business on line, Tang and her students also tried to use *iView* and *Cormap* to mine the common knowledge behind the participants, and they called such mining 'conference mining'.

Our group also applied some useful tools developed by outsiders, such as PathMaker (a computerized tool for convening meetings and analyzing the opinions from meetings), UciNet (a software for computing Complex Network Analysis), Multi agent simulation (Swarm, Starlog, MatLab etc.).

Expert mining is just one of the useful methods and tools for realizing the MSA, with emphasis on collecting experience and wisdom from experts. But it may also be useful for other purposes. Our group has developed some theories, methods and useful tools for expert mining (Gu et al., 2009, 2008b).

During our studies on expert mining we also found that some researchers abroad had also concerned themselves with expert mining but from the artificial intelligence perspective (Gu et al., 2014a).

4.3 Practical Applications

There are a lot of different fields that have used the MSA approach and HWMSE in practice:

1. *Military*: In a meeting on "War complexity and information war gaming" convened at the National Defense University in 2003, there was a lot of HWMSE developed by different arms covering the space war, war decision making, demonstrations of weapons equipment, and the network war etc. Due to military classifications we were not able to obtain too much detail about their real applications (Si and Hu, 1999; Si, 2003).
2. *Economics*:

   a. We have mentioned the economy-related project related to comprehensive balance in price subsidies for rice by the state, and prices and salaries in China during the period 1983–1985, and in the end, the government adopted their main conclusions and obtained high evaluation from top central leaders (Yu and Tu, 2002).
   b. The second project concerned the research and development of an intelligent decision support system for macro-economy (MEIDSS) during the period 1992–1996 supported by the Research Laboratory of the State Council, 863 plan supported by the Ministry of Science and Technology. The whole system is designed according to a MSA approach. The system was developed with success, the one limitation was found early, that the system didn't consider the network environment. So a third project was being concocted (Yu and Tu, 2002).
   c. In 1999 the third 4-year major project involving the implementation of a pilot Hall of Workshop for Meta-Synthetic Engineering (HWMSE) demonstration for macroeconomic decision making (Grant No. 79990580) supported by the

National Natural Sciences Foundation of China had been investigated, and this project was supported by Qian from the beginning (Gu et al., 2007c).

3. *Industrial systems*: There are a lot of industrial projects related to using the MSA approach and HWMSE such as the large research and industrial project CIMS, the HWMSE developed in the State Grid Corporation (Zhou et al., 2008; Tang et al., 2008; Hu and Shan, 2009), some large engineering projects: Sutong Changjiang highway bridge, which combines the MSA approach and engineering management (Sheng and You, 2007; Sheng et al., 2008); the operation and monitoring system for the Qinghai-Tibet Railway, which collects a huge amount of various data and information and integrates and synthesize them straight away (Jia and Qin, 2007); water operation and scheduling for the South-to-North Water Diversion Eastern Route Project (Liang et al., 2009). And some enterprises have applied HWMSE in helping their decision making.
4. *Social systems*: The MSA was also applied in solving many social system problems, for example how to keep social stability (Gu et al., 2005); how to analyze taxi driver strikes (Liu et al., 2007); earthquake disaster management that operated during the Sichuan earthquake (Xu, 2011); how to analyze large amounts of data from public opinion on the web; managing the queuing service at the Shanghai World Expo (Gu et al., 2013); a recycling economy (Xu et al., 2011); the wisdom city (Song, 2012) etc.
5. *Human body system*: The large object of research is the national health system by using MSA in the Institute of Health System Engineering, Peking University. The author also participated in researching and inheriting experiences and systemic thoughts in Traditional Chinese Medicine. Professor Z.S. She and her students from Peking University ran an interesting project related to sport training, in which they tried to use MSA to help athletes train for the Canoe Slalom event at the Olympic Games, and won the Olympic champion in 2008, etc.

4.4 Tests for the MSA Approach

During our investigation of the MSA approach we ran a lot of social tests by testing the verification, validation and availability of MSA, and here we list just some of them. The first two tests are linked to forecasting the GDP growth rate, and the third test is linked to analyzing social problems.

4.4.1 Forecasting the GDP Growth Rate (JAIST Case, 2003)

This test was conducted at the School of Knowledge Science (Japan Advanced Institute of Science and Technology; JAIST) in January of 2003. The aim of the test was to go through the working process as shown in Fig. 2 and acquire some direct experiences about MSA and HWMSE. Since most computerized research work is in China, here we applied only some tools available at JAIST to this test. PathMaker by SkyMark Corporation was chosen as a cooperative support tool for our synchronous meeting. We also made full use of some of the advanced facilities at JAIST, such as the specific collaboration room. We invited one professor and eight graduate students from the School of Knowledge Science, and one economist from the National Development and Reform Commission (People's Republic of China). In order to facilitate formal discussion, several preparation meetings were held to introduce the knowledge and information related to the main topic of the project – forecasting GDP growth in China in 2003. The whole procedure for the test underwent three phases: synchronous (rough) discussion, analysis and synchronous (extensive) discussion (Gu and Tang, 2003).

1. *Synchronous Discussion* about GDP growth – 'Meeting I'. Here we undertook (1) Establishing the Meeting Agenda, (2) Scenario generation, (3) Preliminary consensus.
2. Then we ran some *Asynchronous Analyses*:
   a. We forced a review of GDP growth;
   b. We conducted a Cause and Effect Analysis; and
   c. We conducted consensus building.
3. *Synchronous Discussion* about GDP growth – 'Meeting II'

In Meeting II, the participants were no longer only experts as in Meeting I. Decision makers were also invited. In our test, the chairman of Meeting I served as a decision maker in Meeting II. After the analysis stage every participant of Meeting II had a prediction about the growth rate of China's GDP in 2003. Then we synthesized their opinions based on the weighted sum method. If given the same weight, the average of the predictions given by all participants is 7.31 %. If decision makers and general experts were given different weights, the weighted average of the predictions is 7.83 %. If we increase the weight of the decision maker to four times, the final prediction result of the GDP growth rate goes up to 7.99 %.

The whole test lasted several days (January 14–21, 2003). In fact, the preparation meeting took the longest time at a total of 9 h. Meeting I took 3 h and Meeting II lasted 2 h on separate days. From the test, the three systems of HWMSE were clearly reflected. Initially, difficulties about the machine system were underestimated until much time was invested. The role of the expert system is critical towards further processing of discussion.

4.4.2 Forecasting the GDP Growth Rate Under the Impact of SARS (IIASA Case, 2004)

In September of 2004, we finished a test on discussing the impact of SARS on the growth rate of GDP in China by using MSA. This test was conducted in the International Institute for Applied System Analysis (IIASA), with eight experts from a major program supported by the NSFC, and eight experts who participated in the workshop organized by IIASA. We used the software PathMaker again, as the main tool to run this test. We wished to organically use the data, information, knowledge, models, expert opinions and advanced computer technology to forecast the economic situation with consideration for SARS impact.

We designed a meeting flowchart for MSA: synchronous meeting I → asynchronous analysis → synchronous meeting II. The flowchart for the test was divided into the following steps; M0 (Prepare meeting); M1-1 (Free discussion); M1-2 (Topic discussion); Brief summary; M1-3 (Further discussion); Analysis; M2 (Detailed discussion). In each step we assigned different tools provided by PathMaker to help the discussion and the test. Connections were made to some other tools to facilitate the discussion, such as group argumentation environments, an econometric model, a neural network model and data mining, etc.

For focused discussion, opinions about GDP growth trends in 2003 were divided into three levels (high, medium, low) in consideration for the three kinds of SARS impacts (no impact, light impact and heavy impact). Then nine scenarios for GDP growth in 2003 were acquired. And then all participants were expected to study different scenarios by using the different models provided for analysis. After all the testing processes some conclusions were expected. If participants or decision makers were not satisfied with this conclusion, the test process was iterated until some consensus or compromise was achieved. This test ran under some prerequisite and limited resources, thus we wish to extend this test to operate in a much more realistic situation.

This test was designed for a special session on meta-synthesis immediately after the 17th JISR-IIASA Workshop on Methodologies and Tools for Complex System Modeling and Integrated Policy Assessment held at IIASA during the period September 8–10, 2003. It took 5 h on September 11, and there were eight international experts invited by IIASA who watched the demonstration and made suggestions for further research (Gu et al., 2007c).

4.4.3 Test Study 3: Social Harmony System

On June 27 – July 13, 2006 we ran a scientific test on discussing social harmony problems with expert mining, psychology mining and model mining in an MBA course at the Graduate University, Chinese Academy of Sciences. We divided all of the MBA students into six groups to attend discussions on six selected topics separately: I. corruption, II. housing, III. health and insurance, IV. employment, V. peasant workers and VI. social safety. In each group we assigned one facilitator who used different discussion methods with some useful tools and methods, such as PathMaker, GAE, UciNet, GIS, interview and game theory. Most of the participants were satisfied with this new kind of scientific discussion test (Gu et al., 2007a).

Here we will only describe the discussion on Topic II Housing with some excerpts (see Table 2) and pictures (see Figs. 11, 12, 13, 14, and 15).

Table 2 Using PathMaker to collect and analyze opinions from experts

Topic II: Housing problem (Y.J. Liu and W.Q. Song)
Using PathMaker to analyze the discussion

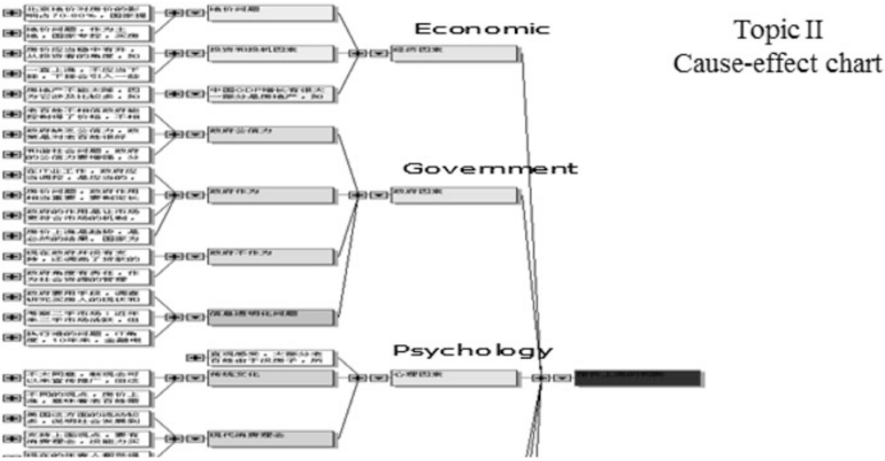

Fig. 11 Cause and effect chart for discussing housing problems

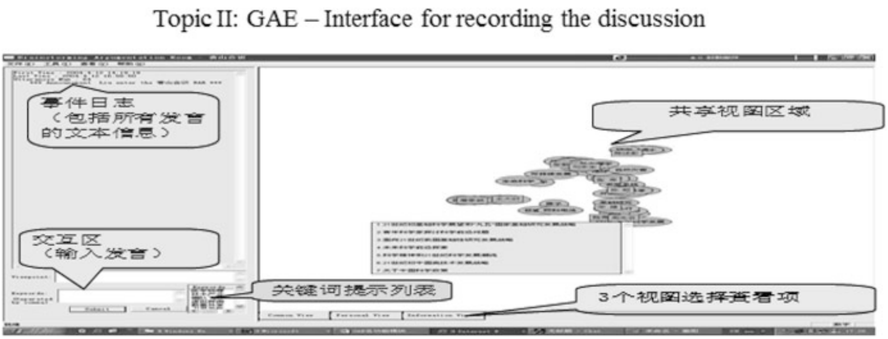

Fig. 12 Using GAE to describe to discussion process for housing problems

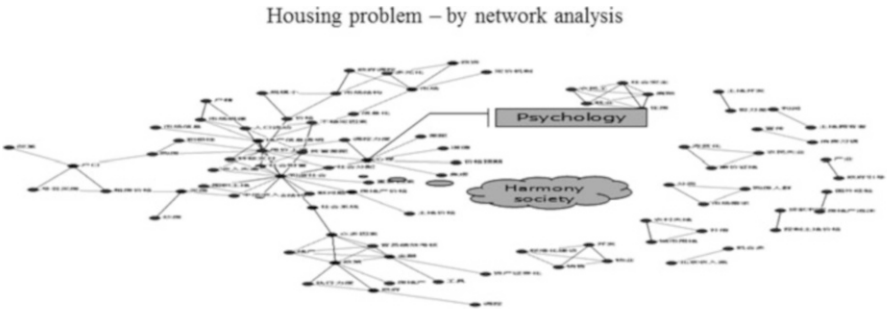

Fig. 13 Using network analysis to find the relationship within different subject words

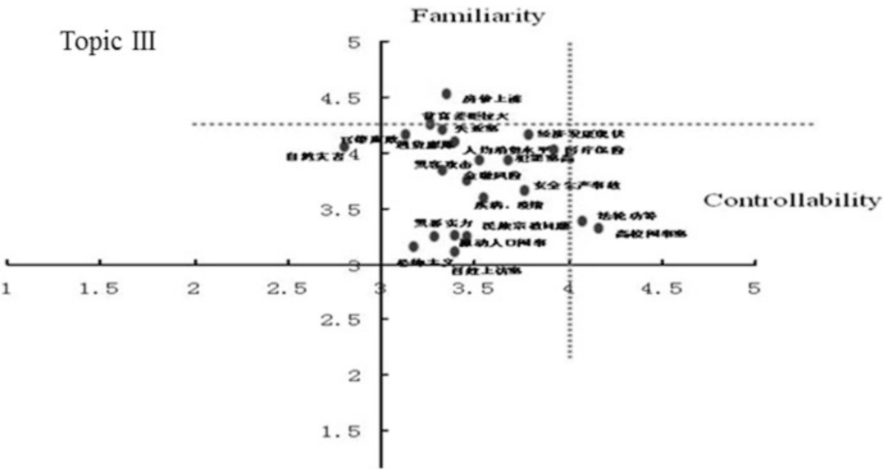

Fig. 14 Expressing opinions with psychology in total

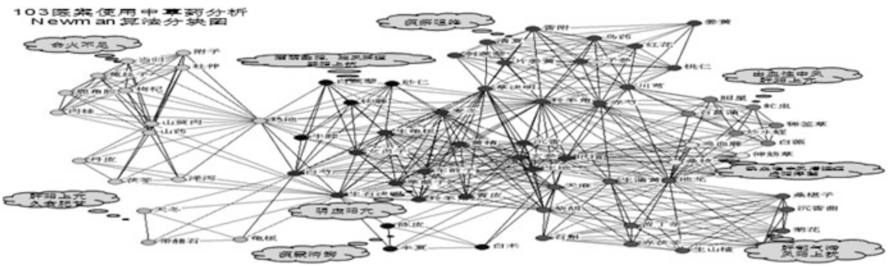

Fig. 15 Research framework for mining knowledge in TCM by Song

5 Conclusion

Since 1999 we have used an MSA approach to fulfill the main project which was supported by NSFC related to economic problems. From 2005 we were engaged in a project related to social system problems supported by the Chinese Academy of Sciences and the Ministry of Science and Technology. From 2006 we used it to solve some TCM inheritance problems in a project sponsored by the Ministry of Science and Technology, and from 2010 the author participated in the 973 plan sponsored by the Ministry of Science and Technology. Since all four projects belong to projects at a state level, the numbers of participants and organizations in the four projects amount to 20–40 and 5–10 respectively. The research backgrounds of the participants are quite different, and we were able to do wide interdisciplinary research – a perfect match for the requirements of the MSA approach.

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Problem Structuring Process by Qualitative Meta-synthesis Technologies

Xijin Tang

Abstract In this chapter, we first review some typical frameworks proposed for the so-called unstructured or wicked problem solving and the relevant computerized support development. Those include two decision-making models for decision support systems development (Simon's 3-phase model and Courtney's framework) and two problem structuring approaches in strategic decision-making (strategic assumption surfacing and testing – SAST by US scholars and Wisdom process proposed by UK researchers). Such an analysis aims to explain the working philosophy of meta-synthesis system approach, especially toward problem structuring where supporting technologies are needed to help distill visions from those original or first-hand on-site community opinions. Finally two technologies, CorMap and iView for qualitative meta-synthesis applied to idea or assumptions generation for further verification and validation, are briefly addressed, together with their practical applications on group discussion, social psychology mining and expert knowledge mining, etc.

Keywords Meta-synthesis • Decision support systems • Problem structuring • Creativity support • CorMap • iView • Wicked problems

1 Introduction

Despite the big success of systems engineering in aerospace and other big engineering projects since 1960s, limitations of mathematical modeling to unstructured messy problems, especially those problems involved with entangled socio-economic and environmental factors had been realized along with the system rethinking tide aroused in 1970s. Rittel and Webber (1973) formally proposed 10 properties typical of 'wicked problems', which referred to the numerous problems widely existed

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in planning, management, and policy making, and stood in sharp contrast to the problems of engineering and sciences: “it makes no sense to talk about optimal solutions ⋯.” Regarding structuredness of decision problems, Simon (1977) distinguished two extreme situations the programmed and the non-programmed while the latter was novel, non-current, of such poor structures and then difficult to be solved directly using a simple computer program without human intervention.

Many relevant studies from different perspectives were undertaken worldwide while some representative results were reported at a seminar at the International Institute of Applied Systems Analysis (IIASA) in the suburb of Vienna in August of 1980. The consequence of that meeting was later published as one book (Tomlison and Kiss, 1984) which showed “a coherent, interlocking, set of ideas considered as the foundations on which we may describe the subject as a science in its own right”, or could be regarded as new insights toward operational research (OR) and systems analysis. Among those thoughts, soft system methodology (SSM) proposed by Checkland (1981) where ‘issues’ instead of ‘problems’ were emphasized and preferred in systems practice and constructing a conceptual model instead of a mathematical model for desirable and feasible changes toward the real world situations reflected a distinguished advance of the soft system approaches or soft OR over the hard ones.

Till today ramifications of soft systems approaches for diverse situations (Flood and Jackson, 1991; Rosenhead and Mingers, 2001) have been spread worldwide except north America. In an editorial essay for celebrating the 40th anniversary of Rittel and Webber (1973), Xiang (2013) indicated that much of those researches on working with wicked problems “remains largely a repetitive description of the social reality of wickedness, rather than well-grounded theoretical explorations or empirical investigation” and “little has been reported on exactly how these ideas and proposed approaches ⋯ can be materialized on theoretical and/or empirical grounds” after a literature survey. Xiang referred some studies working with wicked problems from different perspectives. All of those referred studies were proposed by Western scholars while modern systems studies conducted by Oriental scholars were thoroughly ignored.

This chapter introduces some of the advances of qualitative-to-quantitative meta-synthesis systems approach originally proposed by the Chinese systems scientists Qian et al. (1990) to show the progress how to materialize the theoretical or empirical grounds in systems practice by Chinese scholars during the past two decades. Firstly some basic introductions about the approach are addressed.

2 Briefs on Meta-synthesis Systems Approach

Based on successful systems practice by Qian and Yu in national policy-making on financial subsidies policy of agricultural products by leverage of price and wages in the mid of 1980s as China was transferring from planning economy to market economy,[1] the meta-synthesis systems approach (MSA) was forwarded to emphasize right system methodology to deal with open complex giant system (OCGS) problems with which reductionism methods have difficulties to tackle. The new classification toward systems made by Qian et al. (1990) took the open complex giant system as the most difficult system and the social system was the most difficult OCGS.

"From confident *qualitative hypothesis* to rigorous *quantitative validation*" serves as a simplified working philosophy of MSA. In 1992 Qian proposed the term *Meta-synthetic Engineering*, as 'a development of systems engineering' for solving OCGS problems, and the 'Hall of Workshop for Meta-Synthetic Engineering' (HWMSE) as a platform to apply MSA (Qian, 2001; Wang et al., 1996). The concept of HWMSE reflects the emphasis of utilizing the breaking advances in information technologies to harness the *collective knowledge* and *creativity* of diverse technical groups of experts by synthesizing data, information, quantitative models, knowledge and experiences into an interdisciplinary problem-solving process from proposing hypothesis to quantitative validating. At that time, email, newsgroup, or those Web 1.0 technologies just started to spread worldwide.

After those MSA relevant concepts were put forward, studies have been taken to bring the concepts into operational unit for practical problem solving. Some initial demonstrations, mainly limited within military units for war-gaming, weapon system development, etc. had been tried in the 1990s. Most of those system demonstrations were not open for civil people. By Qian's original idea, HWMSE was composed of three systems: the human expert system, the machine system and the knowledge system. From the start Qian and his colleagues emphasized human beings played dominant roles during man-machine collaboration in MSA practice.

However, many studies, including those demos of HWMSE focused more on software engineering technologies and did not explain how the relevant three systems interact with each other to solve the OCGS problems clearly and logically, even those studies about the infrastructure of HWMSE by means of popular Web-enabled software engineering concepts and tools (Cao and Dai, 2003). Thus, those studies were not enough to show how to apply collective intelligence to complex problem solving process using MSA. Moreover, too many discussions into details of machine system development distorted the understandings of the capabilities of HWMSE and inevitably led to doubtful impressions toward HWMSE in practice, especially by those people who were expecting a breakthrough in systems studies by power of MSA via those demos over other methods in complex systems problems as systems engineering had been adopted into China as a discipline for only 20 years. Besides, international peers paid little attention to MSA as one systems approach.

Perplexed opinions toward MSA and HWMSE went with MSA studies since its birth and more concerns in complexity research also drew attentions to the approach itself (Gu and Tang, 2003). In 1999, Natural Science Foundation of China (NSFC) approved a 4-year major project on a pilot HWMSE prototype for macroeconomic

[1] Yu's talk at systematology seminar. In Jiang (2011).

decision making aroused in-depth research. By this project, practical progress on man-machine collaboration toward unstructured problem solving was started to be illustrated clearly.

Yu and Tu (2002) gave explicit explanations of MSA by addressing three types of meta-synthesis for the first time by their successful systems practice in macroeconomic policy making. The three types of meta-synthesis denote qualitative meta-synthesis, qualitative-quantitative meta-synthesis, and meta-synthesis from qualitative understanding to quantitative validation (also as qualitative-to-quantitative meta-synthesis), which actually indicates a working process of MSA to complex problem solving.

Gu and Tang (2005) discussed model integration and consensus making, the two fundamental issues along MSA practice and proposed six strategies toward meta-synthetic systems modeling together with a feasible working process. Yu et al. (2005) addressed knowledge creation during MSA to macroeconomic forecasting problems. New understandings achieved in many domains are catalysts to drive MSA studies as international scholars started to pay attention to MSA. A half-day special session on meta-synthesis was held just after the annual Complex System Modeling Workshop at IIASA in September of 2003.[2] That may be the second systems approach proposed by oriental scholars reported in IIASA. The first one is 'Shinayakana' approach proposed by Sawaragi and Nakamori (1989).

Next several typical approaches or frameworks for complex problem solving from different disciplines are briefly reviewed for easily explaining the working philosophy of MSA. The common grounds among those approaches infer to adopt or integrate those relevant methods and technologies into meta-synthetic engineering so as to develop a HWMSE is an effective way to show the power of MSA. And two qualitative meta-synthesis technologies, CorMap and iView for hypothesis generation during problem structuring process for further quantitative validation, are addressed to illustrate the integration of multiple technologies and their versatile applications.

3 Diverse Frameworks or Approaches for Unstructured or Complex Problem Solving from Decision-Making Perspective

In this section, some typical frameworks or approaches proposed for different objectives are briefly addressed to show their relevance to MSA and its practicing platform HWMSE. Those include two decision-making models for decision support systems (DSS) development (Simon's 3-phase model and Courtney's frame-

[2] http://www.iiasa.ac.at/~marek/wrksp/csm03/

work), two problem structuring approaches for strategic decision-making (strategic assumption surfacing and testing – SAST and Wisdom process). A simple summary is given to show their attributions to MSA.

3.1 Decision-Making Model by Simon and DSS

In late 1960s the term 'decision support system (DSS)' was proposed initially as one computer system to support semi-structured or unstructured problem solving during a decision making process as the *intelligence-design-choice* 3-phase process defined by Simon. Later *implementation* was added as the fourth phase. During the past decades, DSS is regarded as a big umbrella to include many computerized tools or systems to support different tasks during diverse decision making processes. The trends of DSS were sensed based on the advances achieved about those fundamental components of a DSS, i.e. data, model, knowledge and interface, as listed in Table 1 by Tang (2007).

The NSFC major project on MSA was composed of four sub projects, HWMSE platform, economic model, systems method, and data mining, where data mining sub project was for economic data base and knowledge discovery from economic data, economic model sub project for economic forecasting modeling, platform sub project for man-machine collaborative demonstration for economic forecasting with systems method sub project for fundamental problem exploration (Tang and Gu, 2002). Obviously the typical data-model-interface DSS framework adopted as the NSFC project scheme illustrates HWMSE's root from DSS.

Compared with much progress of the four components of DSS, the achievements of decision making model are unparalleled with the digital revolution. Actually among those problems faced along DSS development, 'people problems', which may refer to human's limited capacity in cognition, subjective prejudice and world views, and belief in experts, are key problems instead of those technology-related problems (Carlsson and Turban, 2001). The diversity of those human problems brings or increases uncertainties to decision making process, even those

Table 1 A glimpse of DSS development (Tang, 2007)

DSS components	Development highlight
Data system	Data warehouses, OLAP, data mining, Web-enabled DSS
Model system	Optimization-based, modeling paradigms
Interface/technology	Visualization, personalized/customized applications, intelligent agents, virtual reality
Knowledge system	Intelligent systems, knowledge management, knowledge creation
Decision-making models	Simon's model, multiple criteria decision analysis, problem structuring methods, systems approaches

uncertainties may enable a structured problem into ill or unstructured problem. Such a fact also indicates one main reason of those doubts toward HWMSE as people problems have not been reasonably studied or those IT people have not paid much attention into social and psychological topics; thus effectiveness of those so-called man-machine collaborative platform was doubted by systems engineering people in China.

Table 1 does not list another large category of DSS for group work, such as groupware, group DSS, CSCW, computer mediated communication (CMC) system and even those knowledge management tools, which support group activities on communication, collaboration and consensus building. Those tools may also be referred as collaborationware. The spectacular emergence of the Internet enables unprecedented supports for group work. Emails, instant messaging, BBS, chat rooms, blogs, microblogs, wikis, etc. enable rich information sharing so conveniently and timely, while the vast amount of information also increases information overload.

Simon differentiated rationality as substantive rationality and procedural rationality, and “opposed procedural rationality – the rationality that takes into account the limitations of the decision maker in terms of information, cognitive capacity and attention – to substantive rationality, which is not limited to satisfying, but rather aims at fully optimized solutions” (Pomerrol and Adam, 2006). Since the mid of 1990s, the term GSS has gradually replaced GDSS as more foci go to the group working process instead of only the final results of group decision-making, a reflection of emphasis of the procedural rationality, or support for argumentation and sense-making during problem structuring. Then another category of group supporting tools emerged based on different problem structuring methods illustrated as follows.

3.2 Frameworks for Strategic Problem Solving

Usually strategic problems are not regarded as structured problems. Many systems approaches together with working framework are oriented to strategic problem solving. Here two frameworks are reviewed, one is proposed by US scholars and another from UK.

3.2.1 Strategic Assumption Surfacing & Testing (SAST)

Developed by Mason and Mitroff (1981), SAST is a process which reveals the underlying assumptions of a policy or plan and helps create a map for exploring them. SAST incorporates the principles of *adversarial, participative, integrative*, and *managerial mind supporting* which are employed throughout the five phases of the SAST process, *group formulation, assumption surfacing and rating, within-group dialectic debate, between-groups dialectic debate*, and *final synthesis*. Then,

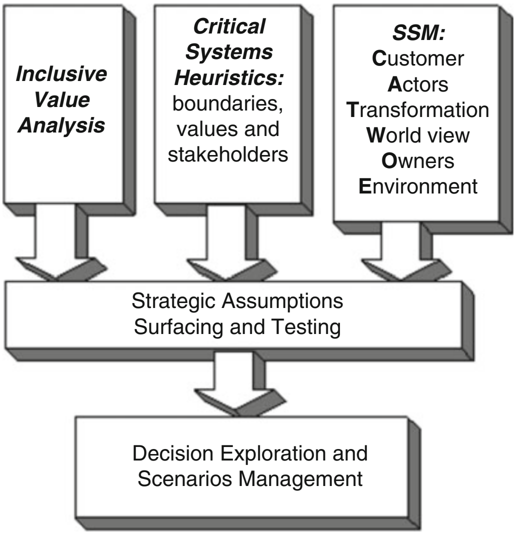

Fig. 1 A framework of multi-perspective for strategic decision-making

some other system approaches, such as SSM, critical systems heuristics, etc. can be adopted to enable or facilitate assumptions surfacing and dialectic debates for a multi-perspective modeling together with relevant tools (e.g. Decision Explorer) for comprehensive explorations (see Fig. 1).

Aforementioned soft system approaches including soft OR methods to deal with unstructured problems, especially those complex societal problems also provide rationales of DSS (Mackenzie et al., 2006; Tang, 2007). Lots of relevant tools had already been explored, such as QuestMap (IBIS based, now as Compendium) for dialogue mapping approach to deal with social complexity (Conklin et al., 2001), Decision Explorer and Group Explorer based on strategic options development and analysis (SODA) (Eden and Ackermann, 2001), etc. It is a trend to apply multiple methods on strategic decision making where new approaches emerge. Wisdom is such a result.

3.2.2 Wisdom Process

Proposed by scholars at University of Lancaster, Wisdom process as shown in Fig. 2 facilitates session includes brainstorming, cognitive mapping and dialogue mapping along the strategic problem solving process (Mackenzie et al., 2006). The cognitive mapping phase provides a macro view of the problem discussed by the group and the dialog mapping phase helps the group develop consistent micro views.

All those methods or tools actually are based on specific cognitive or mental models about group thinking or decision making. Recently computerized support to facilitate, expand, or enhance one's ability to work with one or more kinds of knowledge, from which to make some senses, distill insights or gain knowing, etc.

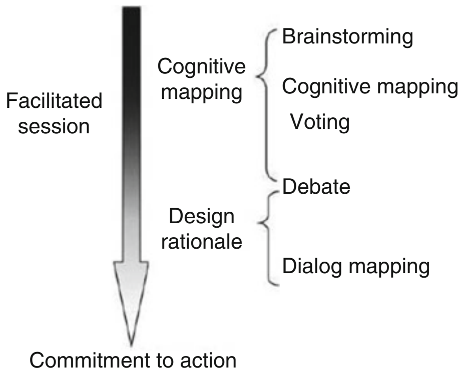

Fig. 2 Wisdom process (Mackenzie et al., 2006)

has been drawn more attentions, especially at Web 2.0 era and is expected for better job of harnessing the vast collective intelligence potentially available.

Klein and Iandol (2008) reported a study using Collaboratorium, with the same function as QuestMap. The researchers argued that current open-source/peer-production (OSPP) technology enabled large scale distributed participation but was not capable of collaborative deliberation, since the coverage of a topic was created bottom-up and then generally unsystematic. That kind of technology is more time-based, while collaborative deliberation requires logic-based postings. Such a study again tells the differences between two categories of support tools for group work addressed by Tang (2007). Those methods or relevant tools based on soft OR methods or IBIS-methodology for collaborative work help to obtain possible structures of the unstructured problems while sacrifice freedom of wild thinking and then may lead to loss of novel ideas, the typical disadvantages of consensus built top-down.

Obviously, the diversity of problem structuring methods cannot be explained well by Simon's normal 3-phase model. Courtney (2001) proposed an improved one.

3.2.3 Courtney's DSS Framework for Wicked Problem Solving

In comparison to traditional decision-making models at a DSS context, the salient feature of the Courtney's framework (see Fig. 3) lies the step of multiple perspectives development during problem formulation phases, where besides the technical (T), organizational (O) and personal (P) perspectives (Mitroff and Linstone, 1993), two other factors, ethical and aesthetic factors are referred to be considered.

Before actions, the procedure on perspective development and synthesis may be understood as divergence and convergence of individual/group thinking. From problem recognition to the perspective development, marked as (1) in Fig. 3, is a divergent thinking process for idea generation and creative perspectives toward the unstructured issues. The transfer to synthesis of perspectives, marked as (2) is a convergent process to acquire alternatives for choices or actions. The mental models

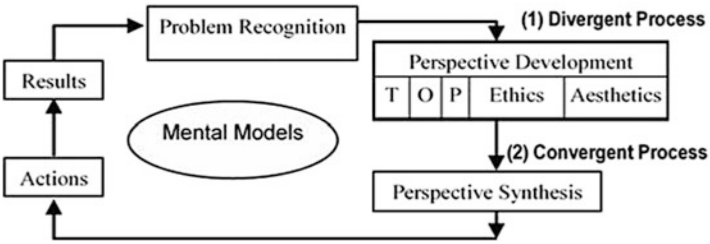

Fig. 3 Decision framework for DSS by Courtney (2001) with annotations by Tang (2007)

may be regarded as problem structuring methods or cognitive models of decision making. If such a process is a collective problem solving process, the mental models may refer to collective mental models. The transition from divergent to convergent process is defined by the mental model(s). Here (1) and (2) together with mental models explicitly illustrate the working process of MSA toward unstructured problem solving, while qualitative meta-synthesis usually happens to perspective development phase.

3.2.4 A Brief Summary

The 'wicked' problem term was adopted by Courtney (2001) when addressing DSS framework despite the term unstructured problem was more popular in traditional DSS studies. Even Rittel had already proposed IBIS to enable groups to decompose problems into questions, ideas and arguments to better deal with wicked problems, which illustrated problem structuring process for unstructured problems. The term 'wicked' problem has once been referred by the Advanced Concept Group (ACG) founded at the Sandia National Lab after the 911 crisis. The mission of ACG is to "harness the collective knowledge and creativity of a diverse group to solve perceived future problems of importance to the national security". There is a report on a summer experiment on computer-mediated group brain-storming at Sandia just shows those ACG scientists undertook serious experiments on the best way to solve wicked problems (Sandia, 2007).

By above discussions, especially on the central ideas of different approaches toward similar problematic situations, the terms unstructured problem, wicked problem and open complex giant system problems can be understood as of similar meanings and then those methodologies and tools originally proposed for one category of problems can be adopted by problem solving for another category. Table 2 lists a brief summary of above simple reviews.

In Table 2, HWMSE is regarded as an advanced state of a DSS while humans are elements of HWMSE and play primary roles even as machine systems (traditional DSS) provide intensive support. Next gives more details about MSA.

Table 2 Problems, disciplines and paradigms for problem solving

Terms for problems	Disciplines	Problem solving frameworks/methodologies	Support tools
Unstructured problems	Management science, OR	Simon's decision-making model, Soft OR methods or their synthesis, e.g. Wisdom process	DSS, GSS, etc.
Wicked problems	Social sciences	Courtney's framework, IBIS, etc.	DSS, GSS, etc.
Open complex giant systems	Systems science	Meta-synthesis system approach	HWMSE

4 More About MSA and HWMSE

Above discussions also show the study on MSA has already transferred from pure IT technology and system implementation to humans' recognition along the problem solving process and how to apply MSA to practical problem logically and feasibly. As more in-depth studies on MSA were carried out, explicit explanations of MSA, such as three types of meta-synthesis were clearly discussed by Yu and Tu (2002) with the case of policy making on macroeconomic problems.

4.1 A Working Process of MSA

The three types of meta-synthesis denote qualitative meta-synthesis, qualitative-quantitative meta-synthesis and meta-synthesis from qualitative understanding to quantitative validation, which actually indicate a working process of MSA to complex problem solving. Gu and Tang (2005) discussed how to achieve three types of meta-synthesis by a synchronous-asynchronous-synchronous (SAS) process while each type of meta-synthesis is achieved at different phase. Activities in Synchronous Stage I denote to achieve qualitative meta-synthesis, i.e. perspective development or hypothesis generation for meta-synthetic modeling. Divergent group thinking is the main theme at that stage. Methods oriented to acquire constructs or ideas toward the concerned problems are considered as qualitative meta-synthesis methods. Thus problem structuring methods can fulfill qualitative meta-synthesis. Those methods or the technologies such as IBIS define normative frameworks followed by the users. Then the output (such as ideas, options) are given directly by users; no further computational analysis is conducted toward those logic-based deliberation process such as Dialog Mapping or Cognitive Mapping.

The aforementioned problem structuring and relevant tools help to apply MSA and the construction of HWMSE. Next we try to understand HWMSE from creativity and its computerized support.

4.2 HWMSE: A Knowledge Creating 'Ba'

Meta-synthetic engineering aims to take the advantages of both the *human expert system* in qualitative intelligence and the *machine system* in quantitative intelligence to generate more (new) validated knowledge stored in the *knowledge system*. It reflects the emphasis on human's role in problem solving process, where resolutions about unstructured problems are captured via a series of structured approximation. For unknown or new issues, new ideas which may come from human's imaginary thinking; intuition and insight are often aspired. Supported by creativity software, sparkling ideas may drop into one's mind. Creative solutions are often associated with wisdom. Then HWMSE is expected to enable knowledge creation and wisdom emergence. Yu et al. (2005) studied the knowledge creation in macroeconomic problem solved in HWMSE.

Japanese Professor Ikujiro Nonaka proposed the theory about organizational knowledge creation where a right 'Ba' (a Japanese word) is emphasized (Nonaka and Takeuchi, 1995). 'Ba' is defined as a platform where knowledge is created, shared and exploited; the most important aspect of 'Ba' is interaction. The knowledge-creating process is also the process of creating 'Ba' (Nonaka et al., 2001). Considering the basic ideas of HWMSE, we suppose HWMSE is a right 'Ba' for idea generation and wisdom emergence for creative solutions of the complex issues (Tang, 2007). Table 3 lists some functions of HWMSE which may be achieved via the four different 'Ba's'.

The first column of Table 3 lists the activities related to different types of meta-synthesis; those activities may be carried out at different 'Ba's to enable knowledge

Table 3 Activities in HWMSE based on knowledge-creating 'Ba' (Tang, 2007)

Activities	Ba	Methods and resources	Supporting tools
Idea generation, confident hypothesizing, wisdom emergence	Originating Ba	Brainstorming, Soft OR methods	BBS, socialware, communityware, creativityware
Concept formulation, knowledge creation, scenario generation	Dialoguing Ba	Soft OR methods, problem structuring methods, KJ method, Delphi method, etc.	Creativityware, groupware, collaborationware, communityware, consensusware
Rigorous validation (qualitative-quantitative meta-synthesis)	Systematizing Ba	Domain modeling methods, analytical methods	Modelware, groupware
Qualitative-to-quantitative meta-synthesis	Exercising Ba	Consensus methods (nominal group technique, AHP, voting, etc.)	Modelware, consensusware, collaborationware

conversion by the methods or resources listed in Column 3. Possible supporting tools which can be elements of HWMSE are given in Column 4. Then to develop those supporting tools and enable their integration to fulfill those tasks or activities listed in Column 1 is a practical way to construct a HWMSE. Support for community or group work is a necessity. The technologies of HWMSE are a consensus of a variety of technologies for different tasks with different frameworks along the problem solving process.

A variety of explanations about human's creativity exist while 'creativityware' is usually developed based on the cognitive or social nature of creativity. Some extend their basis to knowledge creation model, such as SECI model, which actually indicates a qualitative meta-synthetic framework to develop the supporting tools. Shneiderman (2002) abstracted four activities: *collect*, *relate*, *create* and *donate* for a framework of creativity and proposed eight specific tasks: *searching*, *visualizing*, *consulting*, *thinking*, *exploring*, *composing*, *reviewing* and *disseminating* expected to be fulfilled by creativity software to accomplish those four activities. Those tasks may also be applicable to Simon's *intelligence-design-choice* decision making process. Therefore, those creativity supports can also be adopted into idea generation process. As a matter of fact, Japanese AI scholars made great contributions in creativity support systems (CSS) based on creative techniques or process invented in Japan (Gu et al., 2007).

Next two technologies CorMap and iView for qualitative meta-synthesis are briefly addressed. Each applies different computing mechanisms to fulfill some of the tasks identified by Shneiderman toward the ideas created bottom-up.

5 CorMap and iView: Qualitative Meta-synthesis Technologies

Both CorMap analysis and iView analysis aim to implement qualitative meta-synthesis for confident hypothesizing. The meta-data structure for both technologies is <*topic, userID, text, keywords, time*>. Such metadata indicate the corresponding *userID* submits one piece of *text* (e.g. one comment, one blog, the title of a paper, a reply to one question, etc.) with a set of *keywords* under the *topic* at the point of *time*. By word segmentation and filtered feature keywords used in text summarization, or even human's judgment, ideas and opinions can be transferred into a structured representation. Labels or tags of one blog can be the keywords for that blog. The keywords are articulated as attributes of the *userID* or the *text*.

5.1 Basic Ideas of CorMap and iView Technologies

Figure 4 shows the essential analytics of both technologies. Tang (2008a, 2009c) and Tang et al. (2008b) presented the mechanisms of both analytical technologies in details.

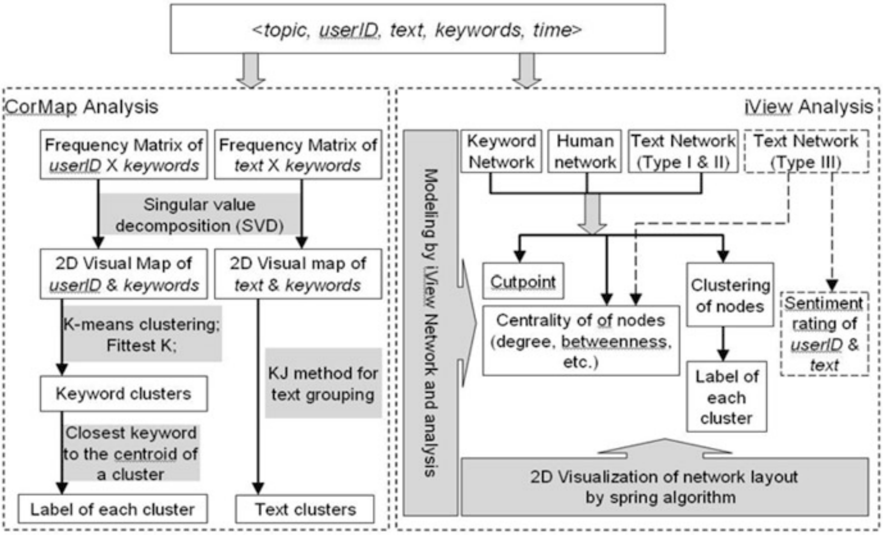

Fig. 4 The analytics of CorMap and iView

The CorMap analysis denotes a technology of exploratory analysis of textual data. By conducting a series of algorithms as listed in Fig. 4, CorMap analysis actually helps to expose the group thinking structure from one perspective. Such kind of analysis can be applied to any combination of the concerned participants and may help to 'drill down' into those community thoughts to detect some existing or emerging micro community. If applied to an individual human, CorMap analysis may help to unravel personal thinking structure. Luo and Tang (2010) adopted self-organizing map into idea clustering as another new perspective during idea structuring process in Japan (Gu et al., 2007).

The iView analysis exposes the group or individual thinking structure from another perspective. The central concept of iView analysis is the iView network which denotes three kinds of networks, *keyword network*, *human network* and *text network*. In a keyword network for iView analysis, the link between the vertices (keywords) denotes the co-occurrence of keywords among all *texts*. Such a network is referred as an *idea map* contributed by all participants. This topological network is a weighted undirected network where the weight of edge denotes the frequency of co-keywords. In a human network, the link between vertices denotes keywords sharing between participants. The strength between two participants indicates the number of the different keywords or the total frequencies of all the keywords they share.

Three types of text networks are built during the iView analysis. All are directed networks. The text network Type I denotes the directed link from text *j* to text *i* indicating text *j* cites one keyword originally referred in text *i*. In the text network Type II, the link denotes to cite the closest text including the concerned keyword. In the text network Type III, the semantic meaning of link expands to a variety of attitudes, e.g. oppose, support, etc. instead of keyword references in both Type I & II text networks. Text network may help to show how the ideas grow and spread. Different algorithms are applied to the text network Type III due to the different semantic meanings of the link. As a matter of fact, the iView network may be regarded as the different projections of a tripartite (text-user-keyword) network. After the projection, we get 1-mode network and apply graph theory and social network analysis (SNA) to exploratory analysis.

5.2 Features of CorMap and iView for Qualitative Meta-synthesis

Either CorMap or iView analysis shows different perspectives toward the same set of data based on different mechanisms to acquire constructs of the problems from those textual data for one topic. Both analytical technologies share common features:

- By a variety of transformations of original textural data to expose the hidden structure;
- Visualization of analyzing process to facilitate human's understanding;
- Adoption of a series of algorithms or methods instead of application of individual one;
- Support for a problem structuring process:

  1. Give a rough imagine of the issue;
  2. Draw a scenario of the issue using clustering analysis to detect the structure; meanwhile, one fit number of clusters is recommended; and
  3. Extract concepts from clusters of ideas.

  Thus, a category of concepts instead of a mess of diverse ideas is acquired step by step; and
- Facilitation of man-machine collaboration. Each step leaves rooms to facilitate analysts' direct manipulations and results' visualization.

Both technologies can be applied to qualitative meta-synthesis during problem structuring process. Due to different mechanisms of each technology, one may be more effective to human's understanding at one time. It is the human to make appropriate use of each technology during the discovery process.

5.3 Applications

Here a variety of applications are briefly addressed while also show the growing development of both technologies as exploited to a variety of mining in complex problem solving.

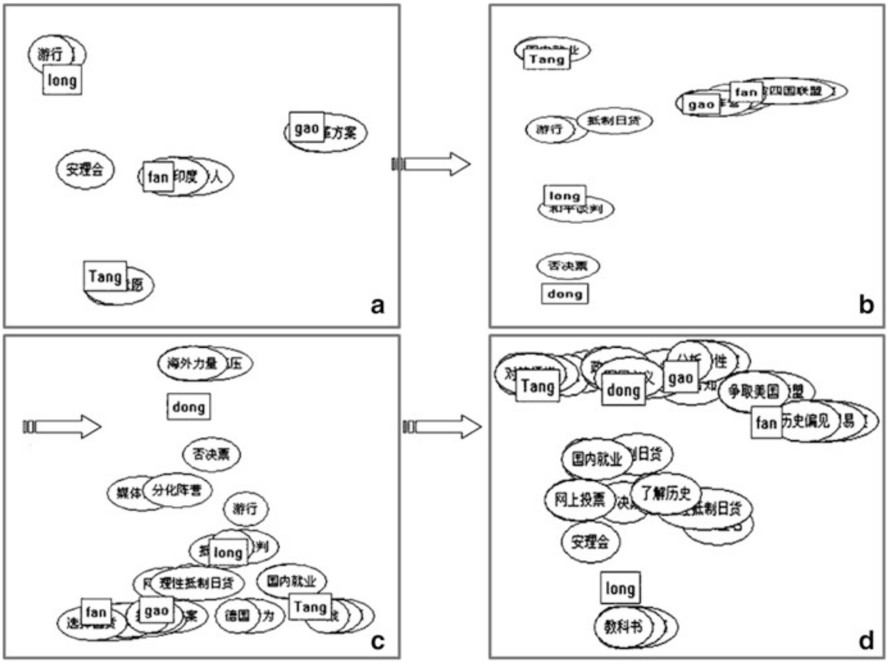

Fig. 5 The snapshots of one brainstorming session supported by GAE (*rectangular object* denotes participant ID while *oval object* denotes keyword) (Tang and Liu, 2007)

5.3.1 Group Thinking Process Mining

As a matter of fact, CorMap analysis was extracted from the design and development of group argumentation environment (GAE) as an embryonic system to support divergent group discussion (e.g. brainstorming) with visualized ideas represented by keywords and textual utterances at one 2D plot (Tang et al., 2005a; Tang and Liu, 2006) during the NSFC major project mentioned in Sect. 2.

Figure 5 shows four snapshots of one group discussion on "Japan's bid for one new permanent member of the Security Council of the United Nations" taken in an experiment on effectiveness of GAE supporting brainstorming held on April 25, 2005 (Tang and Liu, 2007). During that 50-min experiment, the group with five members ('Dong', 'Fan', 'Gao', 'Long' and 'Tang') supported by GAE produced 52 ideas (utterances) with 76 keywords while another 5-person group contributed 40 ideas at a face-to-face session with no computerized support.

The function of visualizing group discussion process in GAE is one principal idea adopted from augmented informative discussion environment (AIDE) by ATR scholars in Japan (Mase et al., 1998), while advanced analytical functions are implemented in GAE, such as different kinds of clustering of ideas, which is quite important during problem structuring process. Moreover, network based idea visualization does not exist in AIDE. Those functional changes between AIDE and

GAE also tell the biggest difference between CSS by Japanese researchers and GAE as the former put more study on technologies, especially adopting mobile appliances for information sharing while the later transfers to strengthen support sense-making and procedural rationality during group thinking process (Tang, 2007).

Other salient functions in GAE include: recording the first provider of each keyword and its references, which expects to reflect the psychological creativity addressed by Boden (2004); retrospective analysis of a finished session by time or by any combination of the involved participants to help identify some hidden psychological or social factors which may lead to different evolutions of the idea generation process. Those functions were driven by many experiments on a variety of topics, such as one consulting project on constructing national integrative transportation system by Chinese Academy of Engineering during 2003–2004 (Tang et al., 2005b).

A real enterprise version of the application of CorMap and iView or GAE, Expert Discuss System (EDS) were developed for State Power Economic Research Institute of State Grid of China during 2007–2008. EDS serves as support system for the human expert system in one HWMSE on power supply and demand studies. Figure 6 is one functional interface of iView analysis in EDS. Compared with GAE, both CorMap and iView analysis results are not pushed to the users automatically in EDS as previously done in GAE. Users need to pull those visualized results into

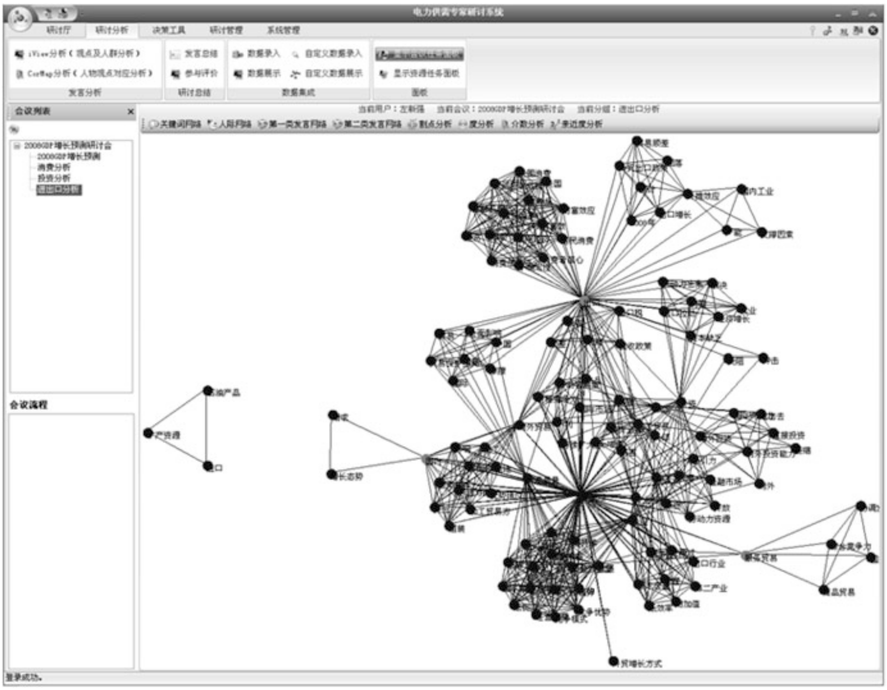

Fig. 6 The interface of iView analysis in Expert Discuss System for the HWMSE on power supply and demand studies

their workspace for the sake of system overload. Even with a lot of experiments of CorMap and iView toward group discussion process, there are not so many real applications of both technologies toward closed small group discussions. Instead, analytical results of both technologies on practical issues attract more attentions and lead to other practical applications, such as academic conference mining.

5.3.2 Conference Mining and On-line Conferencing 'Ba' (OLCB)

If conference presentations (papers) are regarded as those utterances during a group discussion session, analyses toward the whole set of presentations at one session, 1-day or whole conference by CorMap/iView technologies are actually the final results of group discussion on the specific topic, simply as one kind of conference mining. Tang and Zhang (2007) showed how to understand the topics of knowledge science based on KSS serial symposia, i.e. to get a rough image about what the knowledge science means, who are the principal investigators and the major special interested groups on specific topics. Tang et al. (2008a) illustrated the mining to a scientific forum in mainland China. The results were helpful to the forum organizers to explain why need to maintain the forum with high expenditure, a kind of support for decision makers.

Results of conference mining not only expose the main topics of the conferences, knowledge-sharing community, but also be helpful for paper review assignment to overcome limited rationality by considering both cognitive and social factors exposed by iView analysis (Tang and Zhang, 2008). Furthermore, to push such results to the authors may stimulate more active participation, friends-making, etc. The concept of on-line conferencing 'Ba' (OLCB) is then proposed and practiced at the international serial workshops on Meta-synthesis and Complex Systems since 2006 (Tang et al., 2007). Figure 7 shows the iView's keyword network of MCS'2007 where 13 cutpoints: *meta-synthesis, group argumentation, multi-agent system, hidden pattern, BPNN, knowledge management, simulation, complexity, complex system, SVM, knowledge transfer, complex network* and *chance discovery* are detected.

The term OLCB was firstly coined during the organizing the 7th International Symposium on Knowledge and Systems Sciences (KSS'2006) held in Beijing in September of 2006 to reflect new features not available in normal conference management system (CMS) for paper submission, paper review and news release. Publications or proceedings, conference rooms and auxiliary equipments are basic physical elements for one conference. Versatile organizing ways are soft elements for better communication among participants. Adoption of CorMap and iView analytical results into conference BBS may not only facilitate more exchanges between participants even before the convening time but also attract those who miss the conference get to know more about the conference from both the presentations and the academic and social relevance.

As a matter of fact, studies from both knowledge science and systems science bring new ideas to expand the CMS functions. That is why we name it as 'Ba',

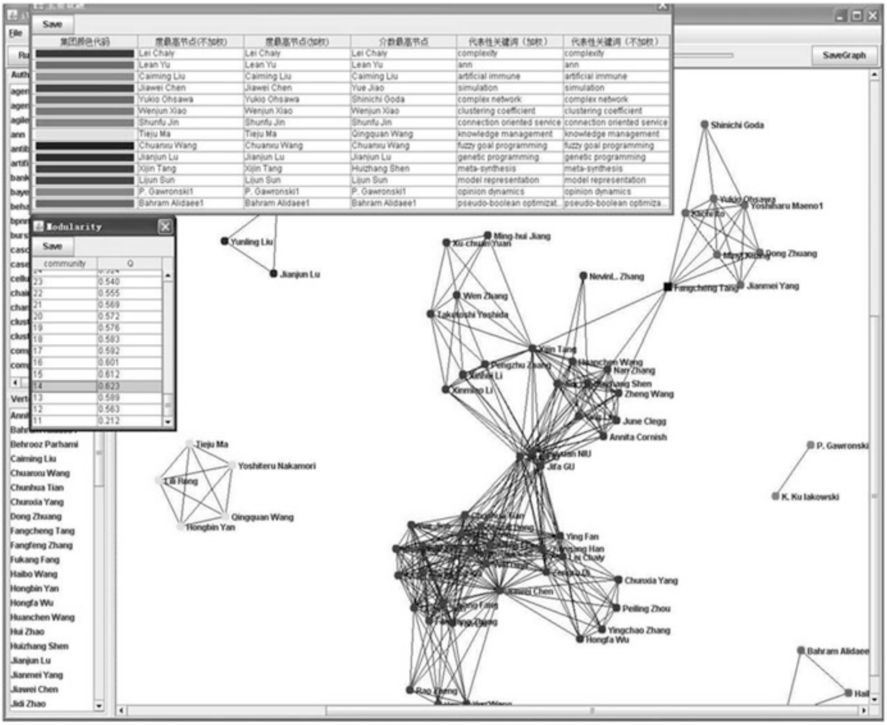

Fig. 7 The iView's idea map of MCS'2007 (keyword network; *black square node*: cutpoint) (Tang, 2008b)

instead of 'system' or 'platform', to emphasize the additional functions beyond traditional CMS as not only to record exchanges but also for knowledge creation.

OLCB is an interdisciplinary concept to reflect those enabling activities and relevant integrative supporting tools for various dynamic academic and social exchanges. Tang (2009b) discussed that OLCB was a kind of HWMSE.

5.3.3 Expert Knowledge Mining

Usually experts refer to senior specialists or authoritative persons in one domain. For a wicked problem, diverse specialists are expected for perspective development. One group of diverse experts on economics, management, sociology, psychology and history contributed their profound thoughts about emergent events for an efficient and effective emergency response system at a modern big city at a half-day meeting on June 6, 2013 just after the severe period of SARS in mainland China. That activity is a typical expert meeting in reality. Figure 8 shows the analytical results by GAE.

The left snapshot in Fig. 8 shows opinions from all participating experts while the right one visualizes opinions only from the experts when excluding one city official.

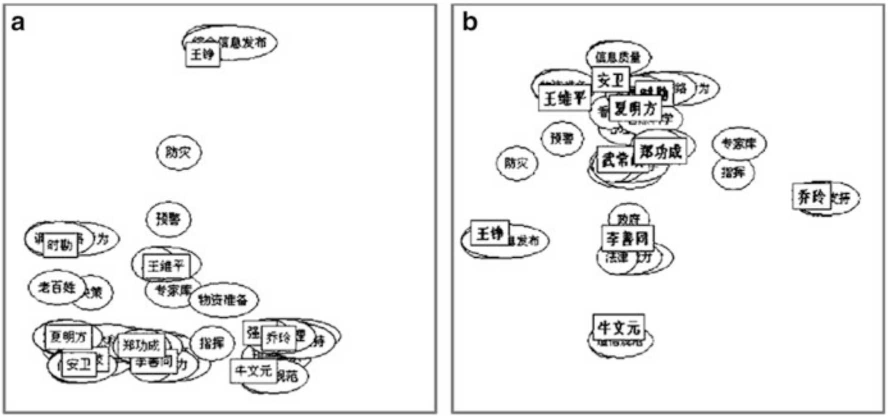

Fig. 8 Snapshots by GAE about authoritative experts opinions on impacts of SARS in June 6, 2003

CorMap/iView analysis is quite useful at such kind of situations where experts are mainly from a variety of domains and their opinions are just simple free speeches. At such kind of widely existing situations, experts usually prepare their speeches with time limit requirement before the meeting while on-site free discussions are also of time limits. The enlightenments from the other experts' opinions may not be quickly available till next round of meeting held later. Obviously the visualized analytical results may be useful for studies by Delphi method.

Another successful application is knowledge mining of the traditional Chinese medicine experts. A TCM Master Miner has been developed to expose the common grounds of diagnosis and treatment among the selected the traditional Chinese medicine experts to help find the schools among TCM masters (Tang et al., 2008b).

Figure 9 shows a global correspondence structure of the eight TCM masters. It is easily to find that at the center of the map lies the keyword 'K' (actually denotes the famous TCM book *Yellow Emperor's Inner Canon*) which is surrounded by names of some famous ancient TCM masters (keywords). This reveals the basic fact that all those alive TCM masters mainly got the fundamental concepts from both the Inner Canon written in the beginning of the first millennium and other ancient TCM masters. Moreover, the specialty of some masters could also be speculated, such as both 'A' and 'B' may be the experts on stomach and spleen disease according to their surrounding keywords. Here four experts, 'A' (in the center), 'B' (below the center), 'C' (at the bottom) and 'D' (left border), are selected and their group structure is as shown in Fig. 10.

The exact location of each TCM expert in Fig. 10 has changed compared of that in Fig. 9 while their relative spatial structure still remains, which may infer a somewhat stable joint knowledge structure among them. Further observation indicates those four experts all treat stomach and spleen disease. Moreover, those keywords at

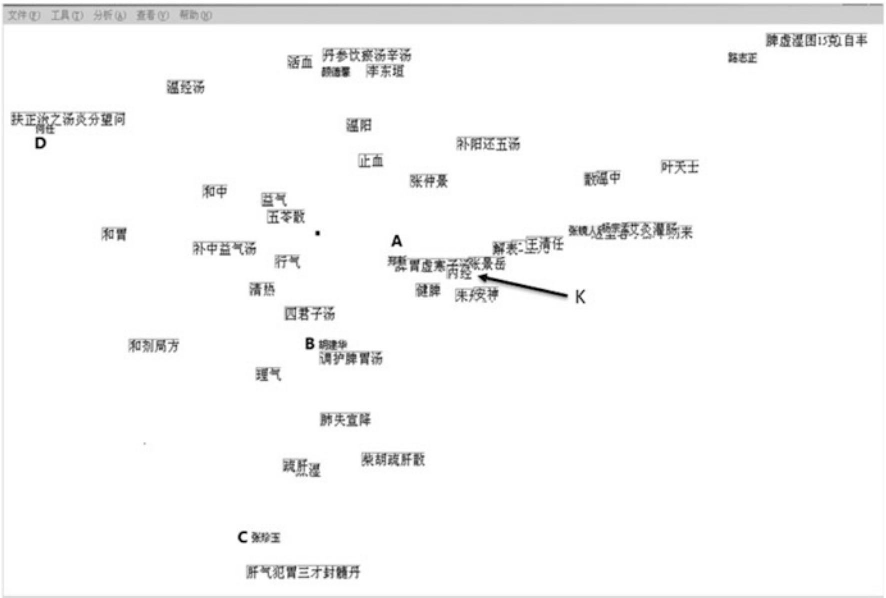

Fig. 9 Visualization of eight TCM masters' thought structure by CorMap analysis (Tang et al., 2008b)

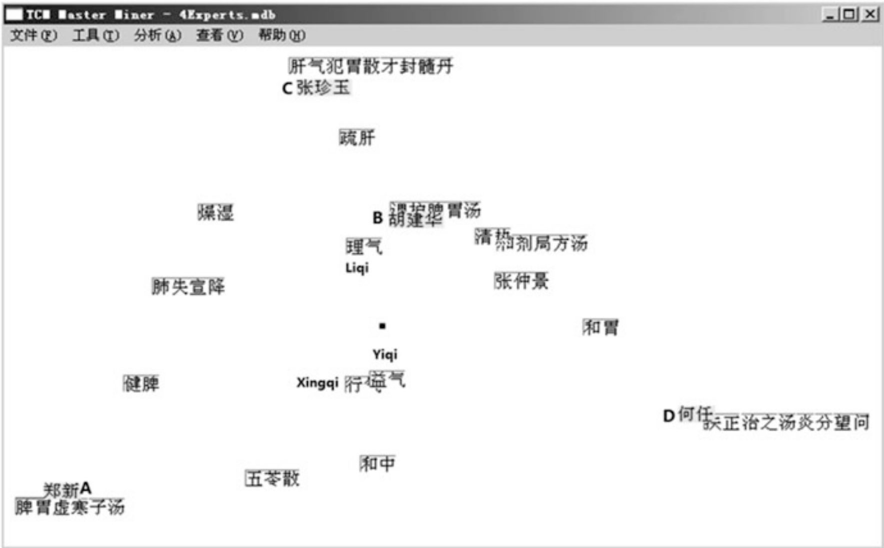

Fig. 10 CorMap visualization of the selected four TCM masters' thought structure (Tang et al., 2008b)

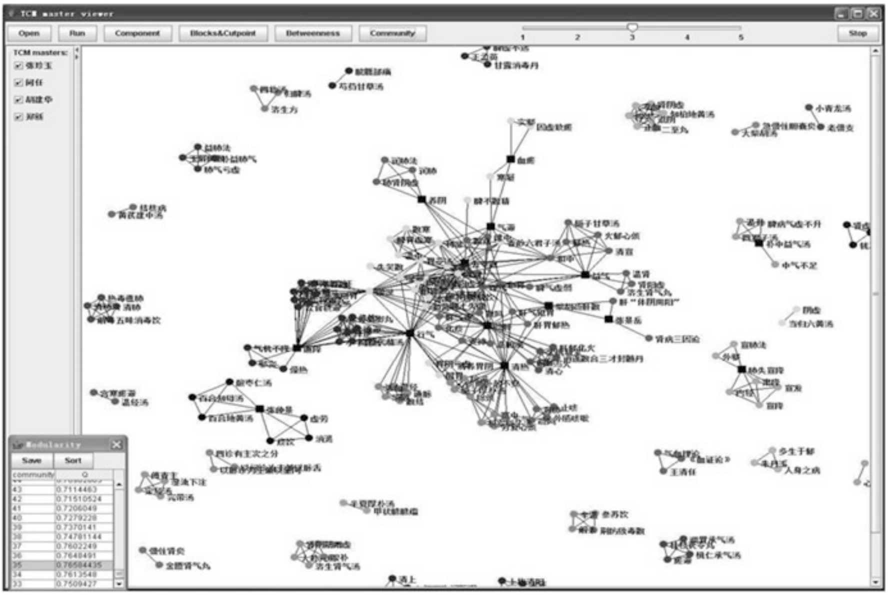

Fig. 11 Four TCM masters' thought map via iView's keyword network (cutpoint: *square node*) (Tang et al., 2008b)

the center of Fig. 10 are 'Xingqi', 'Yiqi' and 'Liqi', all related with 'qi' (the dynamic product of the orchestration of muscle action, or the invisible but observable force that carries food downward or upward in the digestive tract), also exposes the treatment principles applied by those TCM masters to stomach disease. With simple information, basic principles of those TCM experts' thoughts are easily acquired.

Figure 11 is the collective iView's keyword network of the selected four TCM masters whose knowledge correspondence is as shown in Fig. 10. Given such a network, more senses may be acquired by a variety of network analysis in detecting some features of the idea map, such as cutpoints, keyword structure, etc. For example, 'Xingqi' and 'Yiqi' are two cutpoints, which may reflect their principal roles in those four masters' knowledge. Together with Fig. 10, more senses could be acquired about the major treatment principles applied by those four experts.

5.3.4 Community Mind Mining

Tang (2009a) applied both technologies to one societal risk cognition study before Beijing Olympic Games.

When social psychologists study societal risks, initially they may carry out a small-scale word association test to acquire images and perceptions toward a set of impressive social concerns. Then they design questionnaires to carry out large-scale investigations and construct structure equations to reveal causality among risk factors. The processing of those word association tests is often taken manually to

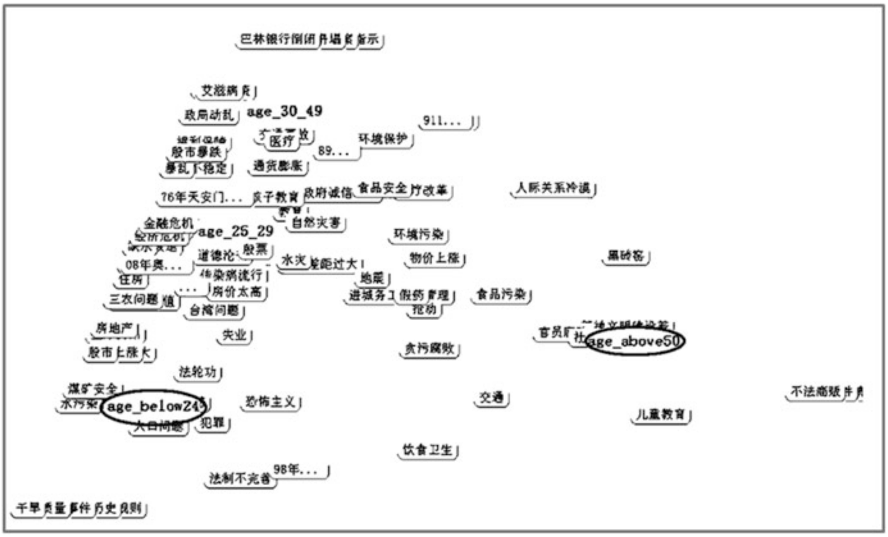

Fig. 12 CorMap of the subjects of 4-group ages and their encoded associated words on societal risks (Tang, 2009a)

encode those societal risk events. Some hypotheses have to be thought for design of questionnaire.

To facilitate their processing of word association test, both iView and CorMap analysis were conducted to a word association test on societal risk perception study in Beijing area by the social psychological researchers from the Institute of Psychology, Chinese Academy of Sciences in the Fall of 2007 (Zheng et al., 2009). The data with 321 valid subjects contributing 542 encoded societal risk events in the word associate test were processed. Figure 12 shows a CorMap of the subjects covering 4-group of ages and their encoded words about the societal risk.

Obviously the label ‘age_above50’ locates far away from the other three age labels in Fig. 12. As the mapping to 2D space accounts over 80 % of the total variation, 2D spatial relations are reliable and the distances between those different age categories suggest there are cognitive differences of perceptions toward societal risks between the public at different ages. The CorMap provides a basic or possible association between the subjects and their associative thoughts represented by those 542 words. Due to limited visualized spaces, many words are overlapped. As socio psychologists encoded those 542 events into 30-category of societal hazards, CorMap analysis was conducted by replacing those original 542 words with their category labels. The result is shown in Fig. 13. As only 30 keywords appear among all data records, the relevance mapping shown in Figs. 12 and 13 are different. However, ‘age_above50’ still locates far away from the other three groups. Labels of ‘age_30_39’ and ‘age_25_29’ come closer. As ‘age_below24’ and ‘age_above50’ separate in both CorMaps, the assumption of risk perception difference between ages is accepted for next round large scale investigation.

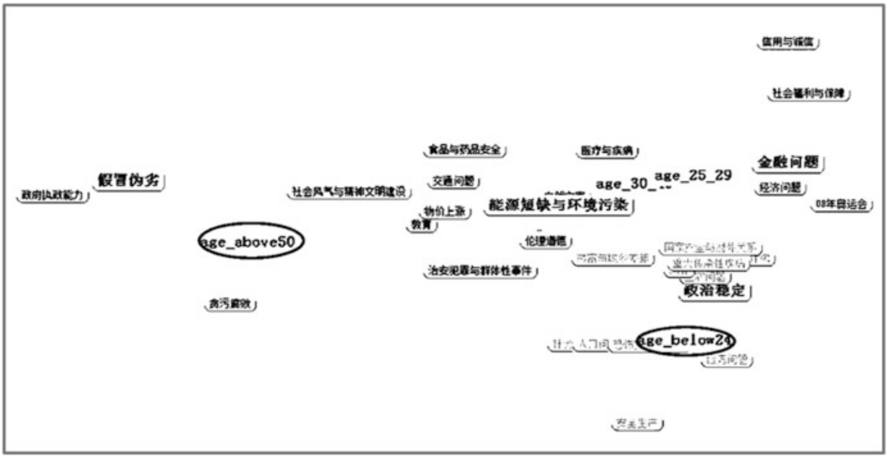

Fig. 13 CorMap of the people at different ages and their societal risk associated words (4 clusters of words while all words are of 30 categories) (Tang, 2009a)

Other CorMap analyses toward different topics such as words and people of different professions were also taken. Besides the iView analysis of those 542 words identified 58 cutpoint words which cover all those 30 categories, the shared words between those cutpoint words and the top 40 words with highest betweeness values account 21 words which also belong to those 30 categories. The iView analysis shows potentials to improve the efficiency of manual encoding for domain researchers.

Recent practical cases of CorMap/iView for mind mining are conducted on colleges students' word association tests on hot social events, such as Shanghai World Expo 2010 and the famous Foxconn Suicides (Tang and Luo, 2011). As a matter of fact, CorMap and iView are quite useful to transfer the first hand or on-site diverse community opinions into somewhat structured clusters. Consequently they may assist those studies by grounded theory (Urquhart et al., 2010).

6 Concluding Remarks

Perplexed opinions toward MSA and HWMSE have been getting along with MSA studies since its existence, especially the focus of many initial demonstrations of HWMSE is software engineering oriented and lack of explaining how the relevant three component systems interact with each other clearly and logically. Too many details about machine system distort the understandings of the capabilities of HWMSE to show the power of collective intelligence to complex problem solving. In this chapter, the meanings of MSA and HWMSE were explained by diverse paradigms relevant to unstructured or wicked problem solving and computerized creativity support. Moreover, the lengthy descriptions of those paradigms also exhibit the MSA practice itself for MSA research, which itself is an interdisciplinary job. From management science to systems thinking, from problem structuring to knowledge creation, from DSS to knowledge creating '*Ba*', the fundamentals and essentials of MSA are addressed for better understanding and acceptance by international peers. Technologies for HWMSE are a consensus of emergence of a variety of support for different tasks during problems-solving process based on different paradigms.

The digital revolution greatly decrease the distance between people. In recent years, technologies to facilitate group work, especially those open-source/peer-production technologies (e.g. chat rooms, wikis and blogs, etc.) enable an unprecedented explosion of information sharing while accompanying information overload. The community brainstorming sessions are of eruption with vast amount of wild ideas or topics created bottom-up even unsystematic. Then problem structuring methods, such as soft OR or IBIS methodology serve as design rationale to develop technologies for logic-based collaborative deliberation. Such kind of technologies heavily rely on the defined framework which somewhat hinders wider application.

The qualitative meta-synthesis technologies CorMap and iView take another way. Both conduct exploratory analysis toward those topics or ideas created bottom-up by textual computing and enable facilitation of human-machine interaction by visualizing the analytical process in accord to human cognitive process, which reflect the thinking of those 'people problems' instead of avoid of them in pursuit of advanced technologies. Four kinds of application are briefly addressed. Both technologies may be helpful to acquire useful information, such as options, which may be as the start point during a collaborative deliberation facilitated by the Web 2.0 tools.

The widely diffused Indian fable 'blind men and an elephant' may be a useful metaphor to explain the MSA essence. The parable has already been effectively implies humans one-sided cognition from their subjective experiences. The mission of MSA is to overcome individual's limitation or 'people problems' for a real or more closely image of the concerned system 'the elephant' while employing CorMap and iView analysis helps to reveal the perspectives diversity along the collective cognitive and problem solving process.

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Knowledge Systems Engineering: A Complex System View

Zhongtuo Wang and Jiangning Wu

Abstract In this chapter, a new discipline: Knowledge Systems Engineering (KSE) is proposed to establish for the organization and management of knowledge systems. The main features of KSE are systematic and integrative thinking and investigations not only for knowledge management but also for the knowledge enabling (or knowledge facilitating) to innovation. The goal, function, architectures of knowledge system and the contents of the discipline are outlined.

Keywords Knowledge systems engineering • Knowledge management • Knowledge enabling • Knowledge system

1 Introduction

Stepping into the post-industrial age, many concepts have been coined, such as globalization, the new economy, the information economy, the knowledge economy, the experience economy, and the creative economy. Of them, the knowledge economy is seen as the latest stage of development in global economic restructuring. This latest stage has been marked by the upheavals in technological innovations and the globally competitive need for innovation with new products and processes.

Within the past 20 years, we have witnessed the rise of knowledge economy as main driver of global and local economic development. The knowledge economy (1995 to date) creates the possibility for a totally new global paradigm, which brings billions of minds together to create wealth. The explosion of knowledge results in an acceleration of innovation, aimed at making life better and more fulfilling.

Although knowledge has always been central to economic development, only over the last 20 years has its relative importance been recognized, just as that importance is growing. The OECD economies are more strongly dependent on the production, distribution and use of knowledge than ever before. This is because with the earth's depleting natural resources, the need for green infrastructure, logistics

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industry forced into just-in-time deliveries, growing global demand, regulatory policy governed by performance results, and a host of other items high priority is put on knowledge. Knowledge now has become the key economic resource and the dominant – and perhaps even the only – source of comparative advantage (Drucker, 1995).

Comparing with the traditional economy, the knowledge economy has the following key respects:

- The economics are not of scarcity, but rather of abundance. Unlike most resources that become depleted when used, information and knowledge can be shared, and actually grow through application.
- The effect of location is either diminished, in some economic activities: using appropriate technology and methods, virtual marketplaces and virtual organizations that offer benefits of speed, agility, round the clock operation and global reach can be created.
- Laws, barriers, taxes and ways to measure are difficult to apply solely on a national basis. Knowledge and information 'leak' to where demand is highest and the barriers are lowest.
- Knowledge enhanced products or services can command price premiums over comparable products with low embedded knowledge or knowledge intensity.
- Pricing and value depend heavily on context. Thus the same information or knowledge can have vastly different value to different people, or even to the same person at different times.
- Knowledge when locked into systems or processes has higher inherent value than when it can "walk out of the door" in people's heads.
- Human capital – competencies – are a key component of value in a knowledge-based company, yet few companies report competency levels in annual reports. In contrast, downsizing is often seen as a positive 'cost cutting' measure.
- Communication is increasingly being seen as fundamental to knowledge flows. Social structures, cultural context and other factors influencing social relations are therefore of fundamental importance to knowledge economies.

These characteristics of the knowledge-based economy require new ideas and approaches from policy makers, managers and knowledge workers.

Related to the concept of knowledge economy, the term 'creative economy' appeared in 2001 in John Howkins' book about the relationship between creativity and economics. For Howkins (2001), "creativity is not new and neither is economics, but what is new is the nature and the extent of the relationship between them and how they combine to create extraordinary value and wealth". The creative economy resets old borders, by allowing businesses to flourish by means of their own defined business cultures. Through this process the creative economy prompts new perspectives on value creation thus leading the transformation of creative ideas into the tangible production of products and services. Such process can be related to social innovation, i.e., the creative economy can generate new ideas bringing positive impact on the quality and/or quantity of life of members of society. The creative economy can be regarded as social innovation insofar overall creativity, culture, and knowledge start to be seen as fundamental to economic and social development.

Knowledge as an intangible resource, as factor of production and as capital, must be managed effectively. Knowledge management (KM) is often defined as the ability to get the right information to the right people at the right time. It refers to the systematic process by which knowledge needed for an organization to succeed is created, captured, shared and leveraged. In KM process, producing new knowledge to fulfill the increasing demand is very important.

Some people think the concept of knowledge management itself is limited. In fact, the term management implies control, but knowledge (especially in human brains) is inherently uncontrollable. Hence, the important thing is how to make the knowledge enable to promote development of human endeavor. So the concept of knowledge enabling or knowledge facilitating is more appropriate for the understanding the role of knowledge in real life. No matter how to define KM, the core issue of knowledge management is to place knowledge under guidance in order to get value from it.

2 Knowledge Systems Engineering

Since knowledge management is a complex task, each of the approaches has its own limitations and we must have a systems point of view. Systems sciences have an important role to play in providing methodology and techniques for knowledge management. There exists a need to systematically and actively manage knowledge which resides in the different sources of an organization.

2.1 Knowledge Systems and Knowledge Networks

From the knowledge management standpoint, knowledge processes (KP) play a predominant role in business processes of companies, which strongly depend on human specialized expertise and judgment, continual learning, and implicit or explicit information transformation by knowledge workers. KP often couple with the business process, in which KP support the effective and efficient execution of business activities. In that sense, there is an increasing need for systems that seamlessly support knowledge-intensive business processes to support knowledge work and improve knowledge worker productivity.

In knowledge processes, there exist a series of knowledge processing cycles including the capture, analysis, creation, and application of knowledge within an organization. Some of these processes are realized by a given kind of technological systems and tools. These systems constitute the knowledge processing systems (KPS), a portion of knowledge systems (KS). KPS typically involve creating/generating, storing/representing, accessing/using/re-using, and disseminating/transferring knowledge processes, which provide an information and communication technology platform to realize knowledge sharing.

Knowledge systems to some extent are seen as enabling technologies for effective and efficient KM, but they are different from the general information systems (IS). In KS, the coordination of information and collaborative work are paid more attention, which implies that collaboration and knowledge sharing can be realized by providing a range of knowledge services to their users. The primary goal of these systems is to increase organizational effectiveness by using knowledge from the past to bear on present activities.

From the cost-efficiency perspective, IS are often dealing with pre-set value objective in minimum or maximum, whereas KS have moving targets since they involve high degrees of contribution from knowledge workers and involved parties. Every system needs goals. But the knowledge system needs different 'specificity' in defining goals. More ambiguity and slacks are needed in knowledge systems which are different from that of information systems. Reductionism involved in IS may not be applied to KS profitably. KS need to focus on people since they are the source of knowledge generation and application.

Knowledge systems are different from information systems mainly in that they embed or presuppose communication capabilities inside the system. Table 1 shows the differences between IS and KS in different aspects (Choi and Choi, 2007).

Table 1 Comparisons between IS and KS

	Information systems	Knowledge systems
Management issues	Artificial system as an asset User as a problem	Knowledge as an asset Sharing as a problem
Organizational issues	Engrafting IS into organizations	Business process to knowledge process
IPO-based features	Accurate input Efficient process Compatible output	Explicit or tacit input Sense-making process Extensible output
Problem-related feature	Problem-solving	Problem- or Opportunity-finding
Organizational learning perspective	Learning bounded to business process	Learning diversified & utilized
Focus of learning (characteristics)	Optimization of what is already learned (preserving and refreshing learning)	New learning & empowerment (innovative)
Locus of value	Business process Efficient design and implementation Reductionism Compatibility/inter-operability	Collaboration Knowledge sharing Utilizing systematic ambiguity Personal expertise

Beside technological systems, there are some other components in knowledge systems including personal systems, organizational systems, business systems, cultural systems, etc.

It's worth mentioning that the knowledge community has much to offer in knowledge systems, since it involves interactions and collaborations among the related parties. Collaboration is key in knowledge creation and sharing. Collaboration within and across organizations can create new value. The word 'collaborate' nowadays is equivalent to 'networking', which in a knowledge-driven organization does not simply mean using ICT networks to communicate, but means paying attention to 'knowledge-worker support network'. IT networks have proved to be a limited mean for disseminating tacit knowledge. Instead, human networks and networking to enable knowledge diffusion and integration in knowledge intensive organizations are important mechanisms that can support product development and innovation as they enable cross-fertilization of tacit knowledge between individuals.

The positive aspects of knowledge networks relate to knowledge processes like improved knowledge transfer and learning. Negative aspects found relate to network size. Communication efficiency is reduced in large networks where network paths are too long. In large networks that require information and communication technology (ICT) social ties are weakened and the possibility to develop common language is limited.

A knowledge network can either be limited to one company or have members from several companies. Networks that have members from several firms are superior to a single firm network in innovation as they represent a greater diversity of knowledge. Global companies with many subsidiaries and geographically distributed units can gain from creating knowledge networks in which experts from different units can communicate and share ideas across unit boundaries.

2.2 Composition, Structure and Function of the Knowledge System

The main components of the knowledge system are the knowledge elements, and the knowledge sources (or retainers). The knowledge elements are the individual components of knowledge (e.g., a particular piece of knowledge that an employee may have about a process within the organization). The knowledge retainers are the repositories of knowledge elements of the domain. These repositories can be both codified knowledge retainers (i.e., knowledge bases) as well as personalized knowledge retainers (i.e., the human knowledge resource of the organization). Once the relevant retainer has been identified, either the knowledge can be retrieved automatically (i.e., when the knowledge is stored in a knowledge base) or manually (i.e., if the knowledge belongs to a human then he/she will be consulted).

Due to the abstractness and intangibility of knowledge, people are prone to accrue knowledge from its carriers such as books, newspapers, electronic media, and so on. But in nature, people or organizations themselves are the real carrier of knowledge. They compose the fundamental elements of KS.

It is well known that any system is a set of interacting or interdependent elements forming an integrated whole. Each system can be delineated by its spatial and temporal boundaries, surrounded and influenced by its environment, described by its structure and purpose and expressed in its functioning. Likewise, knowledge system composes diverse knowledge elements which form a stable structure by their mutual relations, constraints and restrictions. The structure of KS is often in forms of networks, some of which are tangible like information network, and some of which are intangible like interpersonal network. The essential aim of KS is to provide all knowledge requested by knowledge workers. To meet KS's goals, functions of KS in general must include:

- acquiring and organizing knowledge effectively and efficiently;
- retaining and protecting knowledge intentionally;
- transfer knowledge timely to right person in right place at right time;
- facilitating new product or service development;
- operating and managing knowledge asset by market rules;
- building organizational culture to promote knowledge creation, knowledge transfer and knowledge application.

As mentioned above, KS is not only a kind of IT-based system which has predefined goals and tasks. Instead it is a complex system which consists of social system, information system, and knowledge content system. The complexity lies in the subjectivity of knowledge embedded in human brains or organizational memory as well as the uncertainty of environment for knowledge creation. KS is also a kind of complex self-organization system, which implies that new knowledge is an emergence of the system. Therefore, we can study such human-computer system in a systematic way based on systems science theory.

2.3 Categorization of Knowledge

The knowledge element in KS has different types. According to OECD (1996), knowledge can be classified as know-what, know-why, know-how, and know-who four types.

- *Know-what* refers to knowledge about 'facts'. How many people live in New York? What are the ingredients in pancakes? And when was the battle of Waterloo? are examples of this kind of knowledge. Here, knowledge is close to what is normally called information – it can be broken down into bits. In some complex areas, experts must have a lot of this kind of knowledge in order to fulfill their jobs.

- *Know-why* refers to scientific knowledge of the principles and laws of nature. This kind of knowledge underlies technological development and product and process advances in most industries. The production and reproduction of know-why is often organized in specialized organizations, such as research laboratories and universities. To get access to this kind of knowledge, firms have to interact with these organizations either through recruiting scientifically-trained labor or directly through contacts and joint activities.
- *Know-how* refers to skills or the capability to do something. Businessmen judging market prospects for a new product or a personnel manager selecting and training staff have to use their know-how. The same is true for the skilled worker operating complicated machine tools. Know-how is typically a kind of knowledge developed and kept within the border of an individual firm. One of the most important reasons for the formation of industrial networks is the need for firms to be able to share and combine elements of know-how.
- *Know-who* becomes increasingly important. Know-who involves information about who knows what and who knows how to do what. It involves the formation of special social relationships which make it possible to get access to experts and use their knowledge efficiently. It is significant in economies where skills are widely dispersed because of a highly developed division of labor among organizations and experts. For the modern manager and organization, it is important to use this kind of knowledge in response to the acceleration in the rate of change. The knowledge of know-who is internal to the organization to a higher degree than any other kind of knowledge.

Learning to master the four kinds of knowledge takes place through different channels. While know-what and know-why can be obtained through reading books, attending lectures and accessing databases, the other two kinds of knowledge are rooted primarily in practical experience. Know-how will typically be learned in situations where an apprentice follows a master and relies upon him as the authority. Know-who is learned in social practice and sometimes in specialized educational environments. It is socially embedded knowledge which cannot easily be transferred through formal channels of information.

The above four types of knowledge can also be divided into two categories according to accessibility – *explicit* or *tacit*. The former two are of explicit knowledge, and the latter two are of tacit knowledge. Explicit knowledge can be articulated in a written or verbal form including grammatical statements, mathematical expressions, specifications, manuals, and so forth. Hence, explicit knowledge is codified and communicated. While tacit knowledge is hard to articulate with formal language. According to Polanyi (1966), tacit knowledge is knowledge that is difficult to externalize, since tacit knowledge resides in the individual's experience and action. He described tacit knowledge with the idiom "we can know more than we can tell". Polanyi (1966) also emphasized that tacit knowledge is learned by way of know-how and is retained at the unconscious or semi-conscious level. More than 2500 years before, Chinese scholars began to aware of the nature of different kinds of knowledge. A textbook named 'Yi Zhuan' for explanation of 'Yi

Ching (philosophy of Change)' had said: "Writing could not fully describe what the people want to say; speech could not express what the people want to think". This implies that Chinese people in earlier days began to recognize the difference between explicit and tacit knowledge.

Tacit knowledge is personal and context-specific knowledge embedded in individual experience and involves intangible factors such as personal belief, perspective, and the value system (Nonaka and Takeuchi, 1995).

All knowledge has a tacit and explicit component and the degree varies along a continuum. The greater the tacit knowledge dimension the more difficult its transfer and sharing will be. The connection between tacit and explicit knowledge has been recognized in which "tacit knowledge is the means by which explicit knowledge is captured, assimilated, created and disseminated" and where tacit knowledge forms the background necessary for assigning the structure to develop and interpret explicit knowledge. Viewing tacit to explicit knowledge as a continuum hints at a process in which tacit knowledge is converted or transformed into explicit knowledge. This middle ground of knowledge between tacit and explicit is where the domain of implicit knowledge exists. The implicitness enables the possibility of transforming what was originally tacit knowledge into explicit knowledge.

Additionally, knowledge can be categorized into individual knowledge and organizational knowledge. Knowledge is created in human brain. The individual knowledge is the origin of all knowledge. Organization also has its own knowledge, including explicit as patents, design and handbooks and tacit as teamwork experience, working habits etc. Organizational knowledge is created through the collaborative work and crystallized in the organizational knowledge network. The organizational tacit knowledge has its unique characteristics and cannot be bought from outside.

Knowledge can also be categorized into:

1. Encoded knowledge,
2. Embedded knowledge,
3. Embrained knowledge,
4. Embodied knowledge, and
5. Encultured knowledge.

2.4 Knowledge as a Thing, as a Process and as Capability

To more fully understand knowledge, it is beneficial to segregate how knowledge is viewed.

From a static standpoint, knowledge is thought as a thing, owned by somebody as property. Knowledge as an object leads people to focus on databases and other storage devices on identifying, organizing and collecting knowledge. The knowledge-as-a-thing-driven KM model adopts the view of knowledge as an object that can be captured, stored and reused. Thereby, KM is often perceived as merely a technological solution, consequently a significant amount of attention is placed on implementing platforms and repositories to capture, store, control, manage and reuse structured knowledge.

Knowledge is not only a thing or substance, but is far more part of a process. Based on the dynamic view, knowledge is regarded as a process which focuses more on dynamic aspects of knowledge, such as acquiring, communicating, sharing, creating, adapting, learning, and applying. The knowledge-as-a-process-driven KM model regards knowledge as a flow rather than an object and focuses on knowledge creation, collaboration and practice.

Idea describing the movement of knowledge begins to depict knowledge as a fluid and in dynamic realm. The famous physicist D. Bohm explored the movement of knowledge as thought and consciousness using the analogy of particle physics. He suggests, the whole movement of thought from individual awareness to communication between people is a continual cycle, as an unbroken totality of movement, not belong to any particular person, place, time or group of people.

Both of these ways of thinking about knowledge are useful for understanding different qualities. The question of whether knowledge is a thing or a process is like the wave-particle duality in quantum physics. There are two equally valid experimental processes regarding the properties of light.

Both views are correct from different vantage points. Another related perspective is that of a knowledge value chain. The starting process is knowledge identification or creation, then the knowledge collection and codification. The knowledge repository is followed. The next is knowledge diffusion and utilization. Flow of knowledge along the value chain can add the value.

Knowledge is a human capability rather than a property of an inanimate object such as a book or computer record. Such capability like skill, experience, or intelligence can be used to do or to judge something, now or in the future. Knowledge as a capability can be acquired by an individual as a result of reading, seeing, listening to, or feeling (physically or emotionally) and doing something. Knowledge about work can be best acquired (learned) through work itself.

2.5 Knowledge Systems Engineering

The field of knowledge management has drawn insights, ideas, theories, metaphors, and approaches from diverse disciplines including organizational science and human resource management, computer science and information system, management science, and psychology and sociology, among others. Research on KM in sum can be organized into two different streams, one is IT focused and another is human focused. Both streams have the limitations to KM, therefore a systematic and integrative thinking for KM is required. Accordingly, a new discipline namely knowledge systems engineering (KSE) is proposed in terms of the thought of systems engineering.

Before introducing KSE, let's have a brief review on systems engineering (SE). Systems engineering is an interdisciplinary field of engineering that focuses on how to design and manage complex engineering systems over their life cycles. Issues such as reliability, logistics, coordination of different teams (requirements management), evaluation measurements, and other disciplines become more difficult when dealing with large or complex projects. SE deals with work-processes, optimization methods, and risk management tools in such projects. It overlaps technical and human-centered disciplines such as control engineering, industrial engineering, organizational studies, and project management. SE ensures that all likely aspects of a system are considered, and integrated into a whole.

In the period of more than half a century since the foundation of SE field, it has many successful applications. In the energy industry, the energy systems engineering investigates the energy exploration, transmission and utilization problems from a unified and systemic view, no matter what kind of the resource and end-user are. In the IT industry, information systems engineering investigates the information generation, processing, transmission and utilization in a unified and systemic view, no matter the information are in telecommunication system, computer network or bio-technological system. In KM field, why not investigate knowledge acquisition, manipulation, dissemination and creation from a unified and systemic view?

Upon this point, we suggest to establish a new branch of systems engineering: '*Knowledge Systems Engineering* (KSE)'. It can be defined as the discipline of organization and management of knowledge systems in accordance with the definition of SE.

KSE as an application-oriented discipline, integrates both the technology-centered and human-centered approaches, integrates the knowledge management and knowledge enabling, and can be acceptable by people with science-technology background and with humanity background. For KM issues, any single approach like IT based or human based will fail to fulfill knowledge tasks. This is because IT based approach mainly focuses on explicit knowledge, whereas human based approach more focuses on tacit knowledge. However, both explicit and tacit knowledge are vital for knowledge creation and application.

Therefore, we need to rethink how to design and build a coherent model by means of systems thinking for KM that can leverage knowledge involves a combination of both explicit and tacit knowledge. The major challenge is to properly address the tacit dimension of knowledge. At the heart of KM lie people. Consequently, traditional technology-push models of KM have to be replaced with new models that reflect the human side of knowledge. This requires a radical shift in emphasis from a focus on know-what to a focus on know-how and know-who. From a complexity perspective, in new KM models, knowledge should be regarded as a living entity rather than managed as a static object or a predetermined process.

KSE differs from the Knowledge Engineering in Artificial Intelligence at its area of investigation not only limited to the technological aspect like the existing Knowledge Engineering. Also from the dimensions of research it differs from traditional Human Resource Management and Information Management.

2.6 Complexity of Knowledge Systems

Knowledge is inherently personal, social, distributed, and complex. A knowledge system is a complex adaptive system (CAS) comprising many interacting identities in which cause and effect relationships are intertwined and cannot be distinguished. It is open and adaptive without outside intervene in a changing environment. Complexity of the knowledge system is characterized by adaptation, emergence, self-organization, openness and decentralization.

- *Adaptation*: A knowledge system is a kind of complex adaptive system. A knowledge system is complex in that it is diverse and made up of multiple interconnected knowledge elements and adaptive in that it has the capacity to change and learn from experience. A knowledge system has a non-deterministic character; it can evolve in ways that we may not expect or predict. Knowledge development in a knowledge system is continuous and fluid, with no clearly defined beginning or end.
- *Emergence and self-organization*: Knowledge is complex in nature. And emergence and self-organization are the effective ways to cope with complex systems. As an example of a complex adaptive system, a knowledge system holds emergent properties and includes self-organized entities. A knowledge system is co-constructed and maintained by individuals. It emerges naturally and is derived from the bottom-up connection of multiple personal knowledge networks. A knowledge system houses the learning that occurs in a bottom-up and emergent manner, rather than learning that functions within top-down and hierarchical structures under the control mechanisms of outside forces. A knowledge system has a non-deterministic character and can evolve in inherently non-linear and unpredictable ways.
- *Openness and decentralization*: As with complex systems, knowledge systems are open and their boundaries are difficult to be determined. And, knowledge is decentralized and ubiquitous in nature. Hence, openness and decentralization are central attributes in knowledge systems.

From CAS perspective, the characteristics of the knowledge system respect seven basics maintained by Holland (1996). According to Holland, there are four properties that are in common – aggregation, nonlinearity, flows and diversity. The three mechanisms are tagging, internal models and building blocks. These seven basic characteristics can be used as an effective tool in knowledge management. They offer a way to understand how self-organization emerges from lower-level or local interactions. Self-organization can be seen, at least in some cases, as an effective way of organizing and creating enabling infrastructures for creative work.

The four properties among seven basic characteristics are:

1. *Aggregation*: In a knowledge system, especially for personnel system, agents with some knowledge spontaneously aggregate together on the basis of similar purpose, interest, profession, emotions and benefit. Such agent can be a person, a group or an organization. They constitute a multi-level structure through

aggregation. Agents at the low level are individuals who can aggregate to form the higher level of agents (group or team), and then form the highest level of agents (department or organization). This is the aggregative feature of the knowledge system. Holland points out the formation of complex agents called meta-agents in social systems (whether natural or artificial) based on complex behavior of smaller, simpler agents.

2. *Nonlinearity*: Nonlinear interactions are the norm in CAS and are one of the reasons in the emergent global behaviors which indicate that the system is a CAS. In knowledge systems, knowledge exchange and creation are nonlinear interactive activities. This leads to the fact that the team creativity can be much more than the sum of individual creativity.
3. *Flows*: Another property of CAS is the formation of dynamic networks and flows. Collaboration within and across organizations spurs the formation of interpersonal network. When agents share their own knowledge on the network, a flow of knowledge occurs. Additional behavioral property that can be observed in flows is the recycling effect where knowledge resources are recycled over the flows via the network nodes (agents) thus enriching the emergent behavior.
4. *Diversity*: Diversity refers to agents with different traits in aspects of personality, social status, expertise, etc. The difference between knowledge namely knowledge distance is the precondition of knowledge transfer and sharing among agents. Keeping certain diversity in a team or organization will promote new knowledge generation.

The three mechanisms among seven basic characteristics are:

5. *Tagging*: Tagging is a mechanism which is frequently observed in knowledge systems. Take the transactive memory system (TMS) as an example. In the process of formation of TMS, tagging as an identification mechanism plays an important role. Team members can make ‘flags’ to tag other persons’ knowledge and skills during cooperation. These‘flags’ then help teammates get to know who knows what and who can do what which are the main contents of the TMS.
6. *Internal Models*: Internal models are a mechanism by which each agent inside a KS has its own internal mechanism and has evolved its model with the style of its own. All of these models form the whole system model with multi-layer structure.
7. *Building Blocks*: Complex system is organized by a lot of small systems as ‘building blocks’ by different manner of combination. The main feature of the complex system lies in the varieties of combination rather than the number of building blocks.

2.7 System-of-Systems Engineering

We have known that knowledge system is a complex system which comprises personnel system, organization system, technology system, business system and cultural system. Different systems have their own functionalities to support knowledge work which essentially means the activities of knowledge creation, dissemination, storage and utilization. In this regard, well-defined and implemented KS should satisfy all functions required by the organization.

In twentieth century most systems were developed to satisfy specific functional objectives. The objectives were typically focused on the requirements in a single functional area resulting in a number of vertically independent systems within an organization. By the turn of the century, a new type of system began to emerge. It is the super-system, the meta-system, the system-of-systems (SoS) which is made up of components which are large-scale systems themselves and can be called member system to differ from subsystem. Although its components are widely distributed and loosely related and work independently, the system-of-systems (SoS) can function as an integrated whole with larger capability.

So far there is no widely accepted definition of system-of-systems. The following distinguishing characteristics may help us to understand this notion.

- *Independence of the individual systems*: A system-of-systems is composed of systems that are independent and useful in their own right. If a system-of-systems is disassembled into the member systems, these member systems are capable of independently performing useful operations independently of one another.
- *Mutual influences between member systems*: Different members may influence each other through the network that links them, in which they may work collaboratively within a SoS or counteractively between two SoSs.
- *Geographic distribution*: Different member systems are not only widely distributed spatially and mutually independent in their development temporally, but also workable autonomously. Often, these systems can readily exchange only information and knowledge with one another, and not substantial quantities of physical mass or energy.
- *Organizational factor involved*: SoS is an integration of human, soft elements and hardware system, in which human and soft elements play a large role in making the SoS a flexible 'machine'.
- *Shared mission*: Guided by a common objective, various member systems interact with each other and gradually integrate into a whole, consequently wholeness effect emerges. The shared mission drives the component systems as well as the SoS itself to evolve continuously.
- *Emergent behavior*: The system-of-systems performs functions and carries out purposes that do not reside in any member system. These behaviors are emergent properties of the entire system-of-systems and not the behavior of any member system. The principal purposes supporting engineering of these systems are fulfilled by these emergent behaviors.
- *Evolutionary development*: A system-of-systems is never fully formed or complete. Development of these systems is evolutionary over time and with structure, function and purpose added, removed, and modified as experience with the system grows and evolves over time.

As stated earlier, the knowledge system is a complex system which is composed by organization, technical tools and knowledge carrier, etc. Normally, it cannot be built up in a single leap, but be integrated with the existing systems and new systems. From this point of view, the knowledge system can be considered as 'system of systems (SoS)', which is a composition of member systems. In knowledge management area, there are many systems like SoS. For example, in a research institution, there are some independent systems including personnel systems, information technology systems, knowledge content system, and interpersonal relationship systems. Such member systems already exist with their own structures and functions, which are different from the sub-systems of the general systems. Another example, studying water supply systems often requires knowledge generated in a number of systems. One system is weather prediction. Another is the study of runoffs and storage of water. A third is the delivery system. Each of these systems often follows their own process in capturing and processing knowledge and usually building a model to study behavior in their area of interest. Provision of intelligent services is also composed of a number of systems. One for example is focusing on customer relationship management (CRM), another getting the resources by knowledge discovery tools to provide the service and still a third is provision of the actual service by accomplished professionals.

SoS aims to let emergence happen to generate SoS growth. It is an ultimate goal for the SoS to achieve the wholeness effect through collaboration and interaction of various member systems and coordination of various soft elements. Occurring in the course of SoS dynamic evolution rather that its stationary state, emergence is the unique innovative quality of SoS in its structure, behavior and state, representing a promotion in SoS capability.

3 Architecture of Knowledge Systems

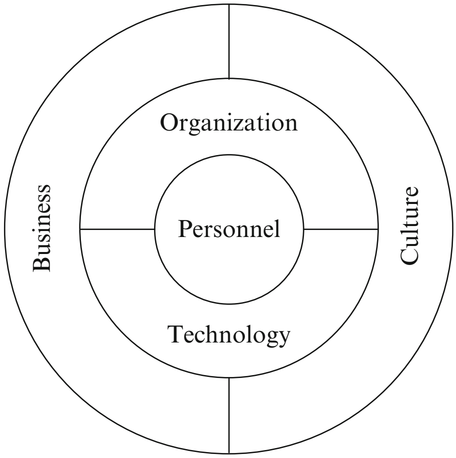
The knowledge system is a complex system with high abstractness. In order to build up a framework of KSE, we will start to set up the architectures of KS.

3.1 Architecture Model

The designed architecture of KS should facilitate the capture, codification, validation and reuse of knowledge. A complete and well-defined system must be tied to the organization's strategic goals. The complete system can effectively improve the innovation and efficiency within the organization. The proposed architecture includes components of personnel, organization, technology, business and culture, of which people are at the heart of the architecture, as shown in Fig. 1.

In the diagram, the core represents innovative subjects including individuals, teams or groups, organizations, or a population of organizations. Next circle consists of organization and technology, defined as "the place and tool used by people to coordinate their actions to obtain something they desire or value – that is, to achieve

Fig. 1 Architecture of the proposed knowledge system



their goals". The outer circle contains business and culture depicting the conditions for realizing effective and efficient KM in the organization.

All five of components in the KS architecture are necessary and inter-dependent. Personnel are working together by means of technologies to produce knowledge products or provide knowledge-based services. Organizational culture supports a strategic positioning for KM within the organization. In short, it is people who shape the culture, manage the content, deliver the process, work with the technology, and create the value in the KS.

3.2 Personnel Architecture

In the personnel architecture, the main components are knowledge workers. In the knowledge economy, cheap labor is not an advantage, and professional labors with high adaptability to the environment become very important since they are the source of creativity. This makes employees a major asset. Just as Drucker (1999) said: "the most valuable asset of a 21st century institution, whether business or non-business, will be its knowledge workers and their productivity".

Half a century ago, visionary Peter Drucker coined the term 'knowledge worker' to describe a new class of workers who would shape the future of business in an economy driven by information and knowledge as opposed to the production of goods. Knowledge workers are workers who can drive organizational performance and success through the effective use of the knowledge they possess. Typical examples may include engineer, doctor, lawyer, senior manager, architects, scientists, and public accountants, etc. Normally, knowledge workers are requested to have T-shaped expertise. The vertical bar on the T represents the depth of related skills and expertise in a single field, whereas the horizontal bar is the ability to collaborate across disciplines with experts in other areas and to apply knowledge in areas of expertise other than one's own. T-shaped expertise enables individual specialists to have synergistic conversations with one another. In modern society, the compound workers with π-shaped skills are called for, which implies knowledge workers not only have skills and expertise in one field but also have the knowledge in the other fields.

Knowledge workers bring benefits to organizations in a variety of important ways. These include:

- analyzing data to establish relationships;
- assessing input in order to evaluate complex or conflicting priorities;
- identifying and understanding trends;
- making connections;
- understanding cause and effect;
- ability to brainstorm, thinking broadly (divergent thinking);
- ability to drill down, creating more focus (convergent thinking);
- producing a new capability;
- constructing or modifying a strategy.

The roles of knowledge workers across the workforce are incredibly diverse. Knowledge workers play different roles in their work as controller, helper, learner, linker, networker, organizer, retriever, sharer, solver, and tracker suggested by Reinhardt et al. (2011). Table 2 displays roles and typical knowledge actions of knowledge workers.

For knowledge worker productivity, Drucker (1999) outlines the following six factors.

1. Knowledge worker productivity demands that we ask the question: "What is the task?"
2. It demands that we impose the responsibility for their productivity on the individual knowledge workers themselves. Knowledge workers have to manage themselves.
3. Continuing innovation has to be part of the work, the task and the responsibility of knowledge workers.
4. Knowledge work requires continuous learning on the part of the knowledge worker, but equally continuous teaching on the part of the knowledge worker.
5. Productivity of the knowledge worker is not – at least not primarily – a matter of the quantity of output. Quality is at least as important.
6. Finally, knowledge worker productivity requires that the knowledge worker is both seen and treated as an 'asset' rather than a 'cost'. It requires that knowledge workers want to work for the organization in preference to all other opportunities.

It is the knowledge worker that is the core element of the KS because without the worker, there is no knowledge exchange. Therefore, to be successful, the firm must encourage its employees to reach their maximum potential. This includes employees building their confidence as knowledge workers, realizing the importance of the

Table 2 Different roles of knowledge workers as well as their actions

Role	Description	Typical knowledge actions (expected)
Controller	People who monitor the organizational performance based on raw information	Analyze, dissemination, information Authoring, analyze, dissemination, feedback, information search, learning, networking
Helper	People who transfer information to teach others, once they passed a problem	Authoring, analyze, dissemination, feedback, information search, learning, networking
Learner	People use information and practices to improve personal skills and competence	Acquisition, analyze, expert search, information search, learning, service search
Linker	People who associate and mash up information from different sources to generate new information	Analyze, dissemination, information search, information organization, networking
Networker	People who create personal or project related connections with people involved in the same kind of work, to share information and support each other	Analyze, dissemination, expert search, monitoring, networking, service search
Organizer	People who are involved in personal or organizational planning of activities, e.g. to-do lists and scheduling	Analyze, information organization, monitoring, networking
Retriever	People who search and collect information on a given topic	Acquisition, analyze, expert search, information search, information organization, monitoring
Sharer	People who disseminate information in a community	Authoring, co-authoring, dissemination, networking
Solver	People who find or provide a way to deal with a problem	Acquisition, analyze, dissemination, information search, learning, service search
Tracker	People who monitor and react on personal and organizational actions that may become problems	Analyze, information search, monitoring, networking

knowledge they possess, and encouraging employees to share their knowledge assets among co-workers. To be clear, all workers have knowledge to contribute to the firm. A well-defined and implemented personnel system should provide the mechanism to encourage knowledge workers to participate in the knowledge sharing activities, which enhances the potential for the firm to operate at peak efficiency.

The personnel architecture is closely related to the organizational architecture. They must be planned and designed simultaneously.

3.3 Organizational Architecture

When we transit from an industrial society to a knowledge society, the knowledge-based organization (KBO) has emerged as the dominant structure of both public and private organizations. In the KS, KBO is the main form of organizational structure. The KBO is a management idea, describing an organization in which people use systems and processes to generate, transform, manage, use, and transfer knowledge-based products and services to achieve organizational goals.

KBOs are very different from bureaucratic organizations in terms of organization and leadership. The former organizations emphasize the use of ideas and capabilities of employees to improve decision making and organizational effectiveness, while in contrast, bureaucracies are run with autocratic decision making by senior leadership with unquestioned execution by employees. KBOs are therefore flexible and customer-centric, while bureaucracies are focused on stability and the accuracy of repetitive internal processes. The autocratic leader flourishes in a bureaucracy while charismatic and transformational leadership is important to the knowledge-based organization's effectiveness, and motivating employees towards a collective goal set, mission, or vision.

The KBO lives and breathes knowledge. From day-to-day operations to long-term strategy, creating and applying knowledge is always in the forefront. Any organization can be knowledge-based, regardless of the product or service it produces as long as it takes knowledge seriously. This requires managing its knowledge creation and sharing processes, formulating its competitive strategy with knowledge in mind, and regarding knowledge in every decision it makes.

To model the KBO, it can be regarded as an intelligent complex adaptive system which composes of a large number of self-organizing components that seek to maximize their own goals but operate according to rules in the context of relationships with other components. In an intelligent complex adaptive system the agents are people. The systems (organizations) are frequently composed of hierarchical levels of self-organizing agents (or knowledge workers), which can take the forms of teams, divisions or other infrastructures that have common bonds. Thus while the components (knowledge workers) are self-organizing, they are not independent from the system they comprise (the professional organization).

Real KBO is a learning organization (LO). A learning organization is a kind of knowledge-based organization, where people continuously expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning how to learn together (Senge, 1990). Normally the phrases knowledge organization and learning organization are used to describe service organizations. This is because most of the value of these organizations comes from how well their professionals learn from the environment, diagnose problems, and then work with clients or customers to improve their situations. The problems with which they work are frequently ambiguous and unstructured. The information, skills, and experience needed to address these problems vary with work cases. The LO can learn successfully and repeatedly change itself for improved management and use of knowledge; empower people in and out of the organization to learn as they work; and make use of technology to take full advantage of learning.

In LOs, they are increasingly using knowledge-worker team namely knowledge-based team (KBT) to streamline difficult tasks, resolve complicated problem-solving activities, develop new innovative products, and perform a number of other critical tasks that could not be completed in a timely manner by any one individual. Work required by organizations today has become more complex, requiring the capabilities of teams in order to collaborate and work effectively toward solving complex problems. Organizations use teams when faced with complex and difficult tasks. Additionally, as tasks become too complex for any one individual, organizations have to rely on teams.

KBTs often engage in non-routine tasks to produce creative outputs. Therefore, such teams need to consist of a well-balanced diverse group of employees that have the proper knowledge, skills, and abilities to resolve the complicated problems and adapt to the changing requirements. Knowledge-workers need to possess both technical skills and team human resource skills in order to deal effectively in that environment. Shared leadership can effectively lead teams based upon the area of knowledge, skills, or abilities that are required at any given time. This collaborative leadership is not based upon authority but rather responsibility and expertise.

Some teams are designed out of necessity rather than convenience, such as virtual teams. A virtual team is normally a temporary, culturally diverse, geographically dispersed, electronically communicating work group. Members of virtual teams could come from different places located in different geographical locations, or from different units of the same organization. Virtual teams are required to work across boundaries of time and space, relying on IT-based technologies and information systems. Virtual teams provide an extra level of complexity in which knowledge sharing and knowledge transfer must be conveyed between geographically dispersed team members and between organizational units. Here, team members have to adjust for the lack of conveniences that face-to-face teams typically provide, such as relying partially on non-verbal cues. Due to the importance of communication placed on virtual teams, computer-mediated communication tools play a critical role in knowledge sharing and knowledge transfer between team members and organizational units. Some technology tools utilized by virtual teams include: instant messaging and chat, groupware/shared services, remote access and control, Web conferencing, file transfer, e-mail, and telephone.

Virtual teams present unique leadership challenges as their members are geographically dispersed, and usually engage in complex projects that necessitate members to coordinate their inputs and contributions. Leaders of virtual teams have to develop practices that ensure that their members benefit from participating in these virtual teams and that the competencies and diversity in experience or insight of members are understood and leveraged. Understanding how members identify each other's competencies and consult each other, builds a map of the emerging social networks within a virtual team.

An extension of virtual teams is the ‘far-flung team’, which is described as globally distributed multi-disciplinary virtual teams. Far-flung teams are becoming critical to managing knowledge resources for global organizations. Technology required for far-flung teams to communicate and share knowledge takes two forms: electronic spaces that provide “same time, different place” communication (synchronous), and technology providing “different-time, different place” methods for communication (asynchronous). Some of these technologies utilized for far-flung teams include: audio conferencing, video-conferencing, application sharing, electronic white boarding, threaded discussions, shared document repositories, and workflow organization (Malhotra and Majchrzak, 2004).

With the development of ICTs and the prevalence of the Internet, the world-wide virtual communities evolve rapidly. A virtual community can be recognized as a valuable and effective system for facilitating knowledge sharing, which has all of the following characteristics: an aggregation of people; rational utility; interpersonal interactions in cyberspace without physical co-location; social-exchange processes; and a shared property/identity, objective, or interest. A virtual community is a technology-supported cyberspace, centered upon the communication and interaction of participants to generate member-driven information and knowledge, resulting in the building of interpersonal relationships. A virtual community can be viewed from two perspectives. From a sociological perspective virtual communities can be classified into four types: interest, transaction, fantasy, and relationship. ‘Wikipedia’ is the most well-known and successful example of a virtual community. ‘Wikipedia’ is an open knowledge platform which allows anyone with the Internet access to contribute their knowledge by adding new content or editing the existing content shared by other users. From a business perspective virtual communities are driven by four primary motivations: purpose, practice, circumstance, and interest.

3.4 Technological Architecture

The technological architecture of the KS includes all the techniques and tools. KM technology can be divided into the following general categories: groupware, workflow, content/document management, enterprise portals, e-learning, scheduling and planning, telepresence.

- *Groupware* refers to technologies that facilitate collaboration and sharing of organizational information. One of the earliest very successful products in this category was ‘Lotus Notes’. Notes provided tools for threaded discussions, sharing of documents, organization wide uniform email, etc.
- *Workflow* tools allow the representation of processes associated with the creation, use, and maintenance of organizational knowledge, such as the process to create and utilize forms and documents within an organization. For example, a workflow system can do things such as send notifications to appropriate supervisors when a new document has been produced and is waiting their approval.

- *Content/Document Management* systems are systems designed to automate the process of creating Web content and/or documents within an organization. The various roles required such as editors, graphic designers, writers, and producers can be explicitly modeled along with the various tasks in the process and validation criteria for moving from one step to another. All this information can be used to automate and control the process.
- *Enterprise Portals* are web sites that aggregate information across the entire organization or for groups within the organization such as project teams.
- Technology of *e-learning* enables organizations to create customized training and education software. This can include lesson plans, monitoring progress against learning goals, online classes, etc. E-learning technology enables organizations to significantly reduce the cost of training and educating their members. As with most KM technology in the business world this was most useful for companies that employ knowledge workers; highly trained staff with areas of deep expertise such as the staff of a consulting firm. Such firms spend a significant amount on the continuing education of their employees and even have their own internal full-time schools and internal education staff.
- *Scheduling and planning* tools automate the creation and maintenance of an organization's schedule: scheduling meetings, notifying people of a meeting, etc. An example of a well-known scheduling tool is 'Microsoft Outlook'. The planning aspect can integrate with project management tools such as 'Microsoft Projec't. Some of the earliest successful uses of KM technology in the business world were the development of these types of tools, for example online versions of corporate 'yellow pages' with listing of contact info and relevant knowledge and work history.
- *Telepresence* technology enables individuals to have virtual meetings rather than having to be in the same place. Videoconferencing is the most obvious example.

These categories are neither rigidly defined nor exhaustive. Workflow for example is a significant aspect of content or document management system and most content and document management systems have tools for developing enterprise portals.

The above technologies can help people complete knowledge-oriented tasks. But as the amount of such tasks increases, the need for automation becomes more and more urgent. In this sense, the notion of intelligent agent is a useful tool for the automation of specialized knowledge intensive tasks. Agents are considered intelligent if they pursue their goals and optimize their performance according to some metrics. An agent should be capable of interacting with other agents (human or software) and are designed in such a way that the system of which they are a part achieves a set of global objectives through the interaction of the various types of agents. An arrangement of agents is called a Multi-agent System (MAS).

Nowadays, Web 2.0 tools become more and more powerful to build and sustain relationships in disperse social communities, to create and extend networks, and to produce synergy effects through aggregated interaction patterns of users. Web 2.0-based enterprise platforms support dynamic knowledge exchange and the emergence of a corporate information structure, which represents the genuine interests and competence domains of employees. In particular, Web 2.0 technologies include blogs, wikis, podcasts/vodcasts, social networks, social bookmarking, multimedia sharing tools, RSS (Real Simple Syndication), etc.

1. *Blogs and microblogs*: Blogs are rich sources of information that support tacit knowledge sharing by establishing a space that gives everyone a voice, enabling people to have discussions, immediately annotate and document their thoughts, and to capture or share personal knowledge and insights in a friendly environment. Allowing people to talk about their personal experiences is one of the main mechanisms for sharing tacit knowledge. Blogs provide such a space for storytelling, which might be their most important benefit for the externalization of tacit knowledge. Immediate feedback on blog posts is also helpful for transferring tacit knowledge. The other potential of blogs in facilitating tacit knowledge is that they enable users to support their ideas and stories by embedding multimedia files (such as images and audio-video presentations) for further explanation of something or for the demonstration of a practical skill. Microblogs such as Twitter and Yammer also provide opportunities for broadcasting as well as keeping up-to-date with new advancements, trends, and publications. They are also helpful in networking and strengthening socialization within and across organizations, which are essential for tacit knowledge creation and sharing.
2. *Wikis*: Wikis can be used to create an informally structured body of knowledge. They can facilitate the knowledge conversion from tacit to explicit and thus increase knowledge dissemination. Wikis affect both the externalization (writing down personal knowledge) and the internalization (processing the information offered by a wiki and integrating it into the individual's knowledge) of tacit knowledge. Wikis assist the sharing of tacit knowledge by providing a field for collaborative knowledge capturing and sharing accompanied with social interactions. Wikis can also be used as a community building exercise where people can contribute in their area of expertise. This will also create a social network driven by expertise, enabling tacit-to-tacit knowledge transfer using the socialization process. Contributions to the Wiki can be recognized and rewarded thus incentivizing the sharing of knowledge.
3. *Social networks (SNs)*: Social networks will help create relationships and connect individuals who may have expertise. Well-developed SNs could leverage crowd opinion and incorporate rewards into the KM system. The main role of SNs in sustaining tacit knowledge flow is in building voluntarily based social communities of practice (CoPs), which is essential for sharing tacit knowledge. SNs enable experts to be located, foster peer-to-peer relationships, promote technical discussions, and provide areas for socializing and the sharing of personal knowledge. Embedded instant messaging and discussion forums support concurrency and the co-presence of users in SNs environments, which helps in trading tacit practical knowledge among participants. In addition, SNs increase the level of interpersonal trust through establishing closer and more

frequent communication among members, which are both necessary for the effective transfer of tacit knowledge.

4. *Multimedia sharing tools (podcasts/vodcasts)*: These tools are particularly useful in the internalization process of knowledge sharing, which can enhance the learning and conceptualizing of existing knowledge. In addition, they are useful in demonstrating technical know-how and transferring hands-on experiences that may not be expressible by verbalization or through other formal documentation methods. The ability to comment, rate, and develop a meaningful discussion about multimedia files shared via social media channels is another advantage of these channels in facilitating the sharing of tacit knowledge.
5. *RSS (Real Simple Syndication)*: RSS seems to be more appropriate for sharing explicit knowledge. It usually gathers and distributes already published knowledge in different places (e.g., blogs). However, it increases the visibility of information published in other places, which in turn helps indirectly to disseminate tacit knowledge widely.
6. *Social bookmarking*: Although social tagging plays an indexing role in structured knowledge sharing, it can also help tacit knowledge sharing by connecting people with common interests and harnessing individuals' collective intelligence as they allocate, organize, and share personalized tags with each other. In addition, it can be used as an annotation tool by adding new tags for specific content. Sometimes, tagging can resemble highlighting key ideas in a book with a marker, enabling the transfer of underlying logic and key information. Another effect of social tagging on the sharing of tacit knowledge is to locate experts with similar interests by following their personalized tags.

3.5 Business Architecture

In the knowledge economy, knowledge is a resource for value creation in a firm which is replacing or perhaps supplementing land, labor, and capital and becomes a new driver to firm development. Like most resources, knowledge is only valuable if it can be transmuted in goods and services that people will pay for. Knowledge (especially in science and technology and management areas) directly involves in the production process and is increasingly becoming the most important factors of production. In today's market, knowledge intensive products (such as computer chips, fine chemical products, etc.) are very popular, whose value most come from the knowledge itself rather than material or scale of production in many cases. Knowledge economization can be found not only in modern service industries but also in traditional industries including manufacturing, forestry, agriculture, and mining.

Knowledge products as the output of knowledge working process can either be tangible or intangible. The so called tangible knowledge products refer to books, drawings, and designs in which knowledge is isolated with its producer or consumer. On the contrast, for intangible knowledge products, knowledge involved cannot be separated from its carrier and has to be attached to its production behavior and process. Knowledge has the explicit value and can be purchased more or less directly. Skill teaching and technology consulting are the examples.

Knowledge products can be classified into the following four categories in general.

1. *Scientific theory knowledge* including works, academic papers, online documents, etc. Such knowledge is generated by one-time production. With the protection of property right, this kind of knowledge can be printed in a large scale or transmitted through the Internet widely.
2. *Technical knowledge* including technology principles, methods, technical routes, formulations, designs, computer programs, etc. Similar to the first kind of knowledge, it is also created by one-time production and can be sold for many times. The difference is such knowledge can directly create value.
3. *Knowledge service* including consulting service, etc. It is often performed by knowledge intensive organizations, such as accounting firms, audit firms, asset appraisal firms and the like.
4. *Physical products with embedded knowledge* including high-tech products like hybrid rice, integrated circuit chips, smart phones, robots and so on.

Knowledge products not only have the use value, but also have the value under the market economic circumstances. Knowledge market is different from the traditional commodity market, it emphasizes on places or activities related to knowledge exchange like science and technology exchange center, academic conference, technology practice group.

Various knowledge embedded products or services are kinds of physical capital, whereas knowledge itself is a kind of intellectual capital which is seen as the main driver of value creation in today's knowledge-based economy. Both physical capital and intellectual capital are organizational resources from the resource-based view (RBV) which contribute to firm's competitive advantages and consequently facilitate the firm to produce supernormal performance over a sustained period of time.

From human resources or knowledge assets to intellectual capital of a firm, there is a need to conduct a business process by which intellectual resources can be transformed into the value of the firm.

Knowledge asset refers to the accumulated intellectual resources of an organization. It is the knowledge possessed by the organization and its workforce in the form of information, ideas, learning, understanding, memory, insights, cognitive and technical skills, and capabilities. Workforce, databases, documents, guides, policies and procedures, software, and patents are repositories of organization's knowledge assets. Knowledge assets are held not only by an organization but reside within its customers, suppliers, and partners as well.

Knowledge assets are the 'know how' that the organization has available to use, to invest, and to grow. Building and managing intangible knowledge assets are key components for the organization to create value for stakeholders and to help sustain overall organizational performance success.

Measuring the knowledge asset means putting a value on people, both as individuals and more importantly on their collective capability, and other factors such as the embedded intelligence in an organization's computer systems.

As to intellectual capital (IC), it is combination of intangible knowledge assets. IC is knowledge that can be exploited for some money-making or other useful purpose. This term combines the idea of the intellect or brain-power with the economic concept of capital, the saving of entitled benefits so that they can be invested in producing more goods and services. IC in general include the skills and knowledge that a firm has developed about how to make its goods or services; individual employees or groups of employees whose knowledge is deemed critical to a firm's continued success; and its aggregation of documents about processes, customers, research results, and other information that might have value for a competitor that is not common knowledge. In short, IC can create a competitive advantage for a firm, and efficiently organize the firm's information. IC in the production context is an intellectual material including knowledge, information, intellectual property, and experience that can be put to use to create wealth for the firm.

Intellectual capital is normally classified as follows (Edvinsson and Malone, 1997):

- *Human capital*: The value that the employees of a firm provide through the application of skills, know-how and expertise. Human capital is an organization's combined human capability for solving business problems and exploiting its intellectual property. Human capital as the knowledge created by and stored in a firm's human resources namely employees is inherent in people and cannot be owned by an organization. Therefore, human capital can leave an organization when people leave, and if management has failed to provide a setting where others can pick up their know-how. Human capital also encompasses how effectively an organization uses its people resources as measured by creativity and innovation.
- *Structural capital*: The embodiment, empowerment, and supportive non-physical infrastructure, processes and databases of the organization that enable human capital to function. Structural capital includes processes, patents, and trademarks, as well as the organization's image, organization, information system, and proprietary software and databases. Because of its diverse components, structural capital can be classified further into organization, process and innovation capital. Organizational capital includes the organization philosophy and systems for leveraging the organization's capability. Process capital includes the techniques, procedures, and programs that implement and enhance the delivery of goods and services. Innovation capital includes intellectual property such as patents, trademarks and copyrights, and intangible assets. Intellectual properties are protected commercial rights such as patents, trade secrets, copyrights and trademarks. Intangible assets are all of the other talents and theory by which an organization is run.

- *Relational capital*: The relations between an organization and its customers consisting of customer relationships, supplier relationships, trademarks and trade names (which have value only by virtue of customer relationships) licenses, and franchises. The notion that customer capital is separate from human and structural capital indicates its central importance to an organization's worth. The value of the relationships a firm maintains with its customers and suppliers is also referred as goodwill, but often poorly booked in corporate accounts, because of accounting rules. Compared to human and structural capital, customer capital as an essential part of intellectual capital has an incremental importance and influences the realization of organizational values.

Intellectual capital includes many intangible factors and items, and as a result, it is difficult to evaluate IC performance using only traditional crisp values. To evaluate the performance of intellectual capital more appropriately, not only quantitative indexes but also qualitative dimensions or factors that are evaluated by experts should be taken into account.

3.6 Cultural Architecture

Culture plays a predominant role in KM success, particularly in processes related to effective knowledge creation, transfer and sharing. Culture enhances coordination, internal control, a focus on common goals, motivation, and identification with the company and therefore positively influences the company performance.

A knowledge culture is one particular variety of culture. It can be regarded as the basic values, norms and practices followed and learned by knowledge workers collectively, that govern knowledge works' perception, thoughts, feelings and actions. Values are deeply embedded, which implies that they are difficult to talk about and even more difficult to change. Norms and practices, on the other hand, are more directly observable and easier for employees to identify. Knowledge culture enables knowledge workers to interpret their experience in similar ways and behave according to agreed upon norms.

Knowledge culture can influence the knowledge-related behaviors of individuals, teams, organizations and overall organizations. As knowledge workers may belong to different groups at the same time, they carry several layers of cultures within themselves, i.e. national, regional, ethnic, gender, organizational level, etc.

3.6.1 National Culture

Hofstede (2001) defines national culture as a 'collective phenomenon', because it is at least partly shared with people who have lived within the same social environment where it was learned. National culture is the collective programming of the mind that distinguishes the members of one group or category of people from another.

It is the manner in which members of a society habitually deal with those issues that varies among societies, thus forming different cultures. Taking China as an example, ‘mianzi’, ‘guanxi’ and ‘quanzi’ are all Chinese cultures which differentiate from other countries. People who are inside the ‘quanzi’ will share information and knowledge. If not in the ‘quanzi’ but having ‘guanxi’ or ‘mianzi’ with some people they can get access to knowledge but may have to pay a price (in ‘guanxi’ or ‘mianzi’). Some people who are outside the ‘quanzi’ may have little idea that it exists much less who the members are.

Different national cultures can influence KM actions in different ways. High power-distance societies, where power disparity and specialization are favored, may foster a focused knowledge acquisition; individualistic societies, where the interests of the individual lie ahead of those of the group, may promote private knowledge storage; masculine societies, where decisive and aggressive management is preferred over intuition and consensus, may encourage prescribed knowledge diffusion; and high uncertainty-avoidance societies, where tolerance for risk and uncertainty is low, may support exploitative knowledge application.

3.6.2 Organizational Culture

At the organizational level, culture is typically defined as shared beliefs, values, and practices within the organization that guide the behaviors of organizational members. Organizational culture impacts the knowledge exchange, the combinative interaction, and the perceived value of organizational members. It is thought to be one of important factors for successful KM. So organizations should establish an appropriate culture that encourages people to create and share knowledge within the organization.

According to Cameron and Quinn (2006), fourfold organizational cultures i.e. clan, adhocracy, market and hierarchy, can be formed based on two main dimensions. One dimension reflects dynamism which is typified with special focus on flexibility and discretion, and the other reflects stability and control which is characterized in stressing on control and predictability. Clan culture is a warm and friendly workplace where people share with each other like an extended family. In contrast, adhocracy culture is a dynamic, entrepreneurial and creative workplace, which encourages individual initiative and provides freedom for people who are willing to stick their necks out and dare to take risks. Market culture is a workplace with hard-driving competitiveness, a results-oriented organization led by tough and demanding leaders who are hard drivers, producers and competitors. Hierarchy culture is a workplace with formalized and structured procedures that govern what people do. Leaders in particular see themselves as being highly capable coordinators and organizers.

Another segmentation of organizational culture comes from Harrison (1995). He called them power, role, achievement, and support. In power culture, leaders are expected to be all knowing and forceful, still, they should display justice and be paternalistic. Role culture has a pyramid shape with clearly defined rules and expectations. There will be less direct supervision, and performance is monitored through well-established information systems. The values of the role culture are order, dependability, rationality, and consistency. Achievement culture assumes that employees enjoy challenging jobs and prefer tasks that are intrinsically satisfying. Top management trusts employees and gives them the freedom to make decisions and act to meet goals. It relies on self-motivating strategies and is based on competence. It also creates a high-energy environment by using the mission to attract and release its members' energy in pursuit of the common goals. Finally support culture assumes that people derive satisfaction from relationships, mutual respect, trust, and support.

Teams are primary organizational mechanisms for leveraging the diverse specialized knowledge of individuals toward a common goal. Since teams are typically focused on a single objective and may be short-lived, the concept of climate is more appropriate at the team level than is that of culture. Team climate can be thought of as the social-psychological attitudes shared among members toward decision-making, task understanding, and reward structures. Team climate may either promote or inhibit a team's knowledge sharing behaviors.

In the KS, knowledge culture should be seriously taken into consideration. That is to say appropriate knowledge culture that is required to foster KM activities should be developed. 'Good' culture will lead to 'good' KM behaviors and outcomes. Vice versa, successful knowledge processes can influence the knowledge culture. If employees regard the introduction of a knowledge system as advantageous, they might collectively change their perception, thoughts, feelings and actions towards knowledge processes. Or when a new knowledge practice is found to be especially useful, it is embedded in the organizational climate, and perhaps, eventually in culture. In this sense, we can say the knowledge culture brings a positive impact on knowledge activities.

3.6.3 Cultural Barriers to KM Processes

Knowledge culture is one of the key success factors of KM because it affects learning, acquisition, sharing and other related areas of knowledge. In contrast, knowledge culture is also identified as the main barrier to the success of KM in organizations. Different cultures may introduce different barriers to an organization's KM efforts. The following are some of barriers to KM processes.

1. *Selfish culture*: According to Hofstede (2001), in highly individualistic cultures, it is believed that employees perform best as individuals and the decisions made by individuals are of higher quality than decision-making by groups. Highly individualistic cultures believe that withholding information or knowledge and avoiding alliances will lead to greater success. On the other end, collectivistic cultures attribute organizational success to knowledge sharing and openly committing oneself.

2. *Hierarchical culture*: High power distance cultures are often tradition driven. In terms of work culture, employees from high power distance cultures often experience and accept inequality in distribution of power. In such cultures, organizational structure is cross-cultural barriers to KM often a pyramid and there is a lot of supervision. Bosses tightly control employees and people fear speaking openly. High level of inequality between individuals in such culture will result in low sharing of knowledge. This will impact the knowledge process of externalization and internalization. Hierarchical structure and inequality will lead to reduced flow of knowledge and lower chances for knowledge conversion processes to succeed. Thus, for high power distance cultures, knowledge sharing as well as creation will be harder than cultures with lower power distance.
3. *Uncertainty avoidance culture*: Individuals from low uncertainty avoidance cultures prefer clearer instructions and are generally relationship oriented. In contrast in high uncertainty avoidance cultures, individuals accept diversity and are open to change and innovation. High uncertainty avoidance cultures often have a higher tolerance for ambiguity. In organizational settings, employees from high uncertainty avoidance cultures are appealed by technological innovations. They are task oriented and believe in relying on specialists with expertise. Low uncertainty avoidance cultures believe in common sense rather than expertise. As a result low uncertainty avoidance cultures will resist seeking and sharing knowledge as compared to high uncertainty avoidance cultures.
4. *Masculine culture*: Highly masculine cultures differentiate between genders and the roles defined for them in society. In terms of work environment, highly masculine cultures stress on competition and performance while low masculine cultures value relationships. Highly masculine cultures resolve conflict by fighting till one person gives up while low masculine cultures use compromise and negotiation. Highly masculine cultures emphasize competitiveness which can lead to knowledge hoarding. As a result, knowledge sharing and seeking will be discouraged. This will directly lead to lower knowledge creation due to barriers to the process of externalization as well as internalization.
5. *Long-term orientation culture*: In cultures with long-term orientation, individuals value perseverance and keep future rewards in sight. In contrast, short-term orientation cultures are concerned with traditions and primarily look to past as well as present. In terms of work environment, employees from long-term orientation are given resources as well as time to make their contributions. On the other hand, short-term oriented cultures constantly judge managers. Employees from short-term oriented culture also feel the need to protect their 'face' and believe in following traditions. This fear of apprehension may lead to lower sharing of opinions and knowledge. This will lead to lower externalization of tacit knowledge, impacting knowledge sharing as well as knowledge creation processes.

4 Working Processes in Knowledge Systems

KM has been studied in the past 20 years at the individual, group, organizational, inter-organizational, city, country and international levels, with a particular focus on people, processes, technology and learning. KM can be defined as a process in which both explicit and tacit knowledge inside and outside the organization's boundaries are involved. The KM process essentially facilitates:

- generating new knowledge, accessing valuable knowledge from outside sources (a generating and accessing process);
- improving knowledge growth through culture and incentive and representing knowledge in documents, databases, and software (a facilitating and representing process);
- embedding knowledge in processes, products, and/or services and using accessible knowledge in decision making (an embedding and usage process); and
- transferring existing knowledge into other parts of the organization and measuring the value of knowledge assets and/or impact of knowledge management (a transferring and measuring process).

The working processes of KS can be divided into two levels including knowledge operation level and knowledge management level respectively. These two processes form a two-layer structure, as shown in Fig. 2. Knowledge operation process is the knowledge collection process and/or new knowledge generation process in which people collect, share and use knowledge to accomplish their work. Whereas knowledge management process is to manage the knowledge operation process to

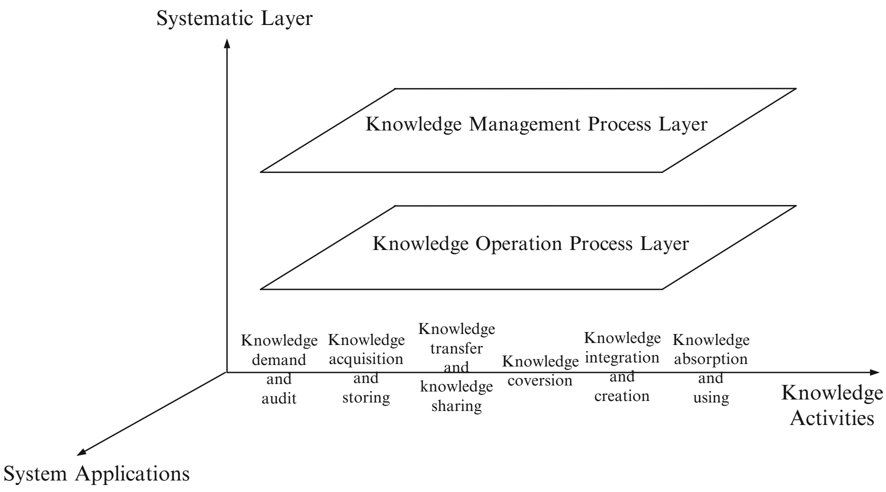


Fig. 2 Working processes of knowledge systems

provide a better knowledge application and innovation environment. Both of the processes have close connection and clear difference.

Knowledge operation process contains a group of systematically related actions directed to meet a specified result or end. Where many activities are involved, they are, not necessarily sequential, knowledge demand analysis, knowledge acquisition, knowledge storing, knowledge transfer, knowledge sharing, knowledge conversion, knowledge integration and creation, knowledge assimilation, knowledge application, and so on.

4.1 Knowledge Demand and Audit

Knowledge demand analysis and knowledge audit are the starting point for knowledge operation processes of knowledge systems. They are used to provide a sound investigation into the company or organization's knowledge needs and 'health'.

Knowledge demand analysis is to know what kind of knowledge is needed for the work or activities within the organization. Knowledge demands in organizations cover many aspects including individual or collective demands, object-driven or general demands, formal or informal demands, internal or external demands, etc.

To identify the different knowledge demands and status by a person and organization, the knowledge auditor plays an important role since he/she can give an organization a comprehensive picture of its strengths and weakness, allowing it to focus its efforts in the right direction.

Every so often, a company may hold a knowledge audit. By auditing, the company can know what knowledge exists, where knowledge is stored and who knows what, and see whether the existing knowledge is being properly managed. Knowledge audit is essential in the development of an effective KM system. Knowledge audits not only disclose what knowledge the company has and who within the company holds that knowledge but can also highlight redundant knowledge. If each individual employee in a company has knowledge which is outdated or no longer applicable to current needs, and this is multiplied by the number of employees in a company, and compounded by outdated knowledge held in central files, the magnitude of the problem soon becomes clear. A knowledge audit can act like a long overdue spring clean and eliminate knowledge which is no longer needed. The purpose of the audit, and the job of the auditor, is to reassure the company and the shareholders that the intangible asset that is knowledge is being properly looked after, much as a financial audit provides reassurance that money is being properly managed.

Some of the questions addressed during a knowledge audit are as follows:

- What are the organization's knowledge needs?
- What knowledge assets or resources does it have and where are they?
- What gaps exist in its knowledge?
- How does knowledge flow around the organization?

- What are the blockages that prevent knowledge from flowing across the organization (people, procedures, technology)?

Once you start asking these questions, a clear picture of your organizations knowledge structure will start emerging, and using these results can help you establish processes and systems to tackle certain shortcomings.

Some of the key benefits of a knowledge audit are as follows:

- It helps the organization clearly identify what knowledge is needed to support overall organizational goals and individual and team activities.
- It provides evidence of the extent to which knowledge is being effectively managed and indicates where improvements are required.
- It provides an evidence-based account of the knowledge that exists in an organization, how that knowledge moves around in, and is used by, that organization.
- It provides a map of what knowledge exists in the organization and where it exists, as well as revealing gaps.
- It reveals pockets of untapped knowledge.
- It provides a map of knowledge and communication flows and networks.
- It provides an inventory of knowledge assets, giving a clearer understanding of the contribution of knowledge to organizational performance.
- It provides vital information for the development of effective knowledge management programs and initiatives that are directly relevant to the organization's specific knowledge needs and current situation.

Most often, the deliverable for a knowledge audit is a detailed report documenting the current state of knowledge management within an organization, an analysis and summary of themes from conversations with staff, and a presentation to management and/or a project team summarizing findings.

Knowledge audits are usually conducted as part of the planning phase to develop and implement knowledge management initiatives. Within this framework, a completed knowledge audit should be used to inform decision makers about how/where to proceed and which areas should be prioritized.

4.2 Knowledge Acquisition and Storing

Knowledge audit reveals the knowledge needed by firm, the next step is to identify knowledge sources and acquire the knowledge accordingly. Firm's knowledge ranging from technology knowledge and organizing knowledge to product knowledge and market knowledge, in general, may come from either internal source or external source. Internal knowledge is the knowledge located within the internal source, which is associated with the internal staff, technical information, database, business processes, the daily work process, system and organization culture. The external knowledge is the knowledge from the outside which might be generated through interactions with customers, suppliers, competitors, and personal or professional networks. Acquired knowledge from the internal resource is favorably to form the competitive advantage of the enterprise and cannot be imitated by competitors easily although it may spend much time and high cost.

Knowledge acquisition is a process by which knowledge is obtained through widely scanning of the internal and external sources. It details how people experience new knowledge, how that knowledge is stored in the brain, and how that knowledge can be recalled for later use.

The firms' knowledge can be gained in various ways depending on which type of knowledge is needed, such as:

- Through staff training to acquire internal knowledge. Staff training can be conducted in some ways, such as sending people outside for training, hiring outsiders for internal training and education, establishing regular knowledge teaching and communication system.
- Through leasing, joint venture, licensing trade, purchase, talent introduction and knowledge alliance to obtain the external knowledge.
- Through books, journals, intranet postings and social media to acquire codified knowledge.
- Through the internet to gather related knowledge.
- Through data mining techniques to discover new knowledge.

Along two dimensions of knowledge nature (experiential or objective) vs. knowledge sources (internal or external), knowledge acquisition can be divided into four types, i.e. direct experience, indirect experience, external search, and internal information (Fletcher and Harris, 2012).

Direct experience concerns experiential knowledge that is developed by the firm. The indirect experiential knowledge refers to learning from the others. Firms can acquire indirect experiential knowledge by incorporating other units into the organization as well as imitating the behavior of other, established firms which has the potential to improve firm operations. Likewise, firms can gain objective knowledge that is external and internal to the organization. Objective knowledge refers to knowledge that is explicit or codified. External information concerns focused search for objective knowledge from external sources such as chambers of commerce, trade publications, newspapers etc. Internal information, on the other hand, refers to codified explicit experiential knowledge that is made accessible in the firm's internal systems for knowledge sharing.

For some knowledge on the basic theory as well as the knowledge related to the public interest, they are the common wealth of humankind which belong to the whole society. Such knowledge can be acquired without much payment or with little cost for knowledge carriers.

For the Internet knowledge, 'Witkey' is a new way to collect such knowledge. The so called 'Witkey' is a web-based system whereby users can exchange and purchase services and information, share knowledge and experience in order to save time and money. By using 'Witkey', people can obtain their required knowledge with a little pay.

Acquired knowledge should be stored in organization memory (OM). Memory as a long-term repository is defined as a system of knowledge and skills that preserves and stores perceptions and experiences beyond the moment when they occur, so that they can be retrieved at a later time. One form of OM in a team setting is the transactive memory system (TMS). TMS is a collective system that is used by individuals in close relationships to encode, store, and retrieve knowledge in different domains (Wegner, 1987). In a TMS, individual knowledge is shared with other team members, which can be retained and recalled collectively. Individual knowledge is embedded into the collective knowledge of the team through a TMS, providing a repository of knowledge for team members. As Wegner indicated a TMS has two components: a structural component, which shows how TM links individual memories to a collective knowledge network; and three transactive processes that can occur during the encoding, storing, and retrieval of information in the team memory. The structural component in the TMS, just as many researchers suggested, is a cognitive structures built upon a shared conception of one another's expertise which is developed in the team in order to integrate members' distributed skills and expertise. The computer network metaphor is often used to identify three processes related to the development and application of TMSs as directory updating, information allocation, and retrieval coordination.

For codified knowledge, it can be retained in the knowledge repository of the firm. Knowledge repository is an online computer-based system which is used to store professional knowledge, experiences and documents. Knowledge structure in the knowledge repository may take one of the following forms:

- Dictionary including definition, concept and vocabulary of nouns in the knowledge domain.
- Image database including digitalized image and video files.
- Textual database including books, journals, manuals and instructions, etc.
- Database including various kinds of databases.
- Case base including typical cases on decision-making and problem-solving.
- Rule base including definitive knowledge as well as rules on decision-making and problem-solving.
- Script library including events, processes and typical behaviors.
- Object base including concepts, entities, and objects.
- Process base including working processes.
- Model base including causality model, etc.

4.3 Knowledge Transfer and Knowledge Sharing

Knowledge in the repository of the organization should be activated by a number of ways for its future use and value creation. Knowledge transfer and sharing among employees can enable the firm to make the best use of its knowledge.

Knowledge transfer (KT) is regarded as the process by which an organization makes available knowledge about routines to its members, and is a common phenomenon that can be an effective way for organizations to extend knowledge bases and leverage unique skills in a relatively cost-effective manner. The transfer of knowledge is a multifaceted and dynamic process. It encompasses the more overt structured knowledge transfer as well as the more difficult to observe but equally crucial absorption and building of tacit knowledge in unstructured knowledge transfer. There are two types of KT processes (Chen and McQueen, 2010): structured knowledge transfer and unstructured knowledge transfer. Structured knowledge transfer is a formal, planned and intentional transfer process, such as trainees in a classroom listening to an expert giving a presentation. Unstructured knowledge transfer is an informal, unplanned and spontaneous transfer process, which occurs during daily work.

Persons from different institutions often communicate at a deep level and transfer knowledge. Knowledge flows are essential when knowledge is transferred to a person or to an organization. The flow of knowledge is an important concept for understanding collaborative innovation. People often understand knowledge as a process, and the knowledge management is based on knowledge flows and the processes of creating, sharing, and distributing knowledge.

Knowledge transfer occurs at various levels: between individuals, from individuals to explicit sources, from individuals to groups, within groups, between groups, and from the group to the whole organization. Communication processes and information flows together build up those knowledge flows for transferring knowledge from one place or format to another. The receiver relates it to his/her own mental model and creates his/her own interpretation of the original knowledge that he/she received.

New knowledge is formed when the receiver relates the received knowledge to his/her own understanding – his/her mental model – and forms his/her own interpretations from this knowledge.

The nature of the transferred knowledge is often addressed as an important factor. For instance, the more tacit and complex, the more difficult it becomes to accomplish transfer. The more ambiguous the causes and effects of the knowledge, the more difficult it is to transfer. Besides the knowledge transferred itself, the cognitive abilities of both the source of knowledge and the recipient are key factors. Absorptive and retentive capacity of the recipient, i.e. how well equipped they are to take in, absorb, and apply the knowledge, is of course central in transfer situations. Furthermore, the value of the stocks of knowledge at the source is a potential factor. The more valuable it is, the more likely it is that the recipient will attempt to use it. The absorptive capacity will determine whether it will work or not. Another factor, related to competitive advantage, is the uniqueness and inimitability of the knowledge. If knowledge transferred internally can also be transferred externally to competitors, for instance through personnel migration or intelligence activities, there is a risk that the effects, say on costs, can be duplicated by competitors. This can lead to cost reductions across the industry, meaning there is a risk that price and profit levels are reduced overall. Here, the commonalty of knowledge across actors will determine the risks of failure. Another risk refers to drawbacks that result from the articulation of knowledge necessary in order to be able to transfer it. Articulation requires simplification, which means that finer aspects of the knowledge might have to be removed or be unintentionally lost. Some argue that the risks associated with articulating and transferring tacit knowledge are so high that it is more effective to avoid transferring such knowledge and accept the higher costs associated with coordinating a diverse set of organizational skills. However, it has also been argued that organizations must try to diffuse knowledge, otherwise it will be difficult to reap the leveraged benefits of knowledge.

During knowledge transfer, there is another issue addressing transfer will. Given that it is people who actually create, share, and use knowledge, an organization cannot effectively exploit knowledge unless its employees are willing and able to share their own knowledge and assimilate the knowledge of others. It implies a voluntary act by individuals who participate in the exchange of knowledge even though there are no compulsory pressures.

Knowledge sharing (KS) involves at least two persons, groups, or organizations: the sender, who is willing and able to share knowledge, and the receiver, who is willing and able to combine this new knowledge with his or her existing knowledge and use it. KS can be people-oriented which emphasizes the importance of tacit knowledge, the social infrastructure and the business performance, or technology oriented, i.e. concentrating on the technology infrastructure and the ways, in which explicit knowledge is codified, stored and interrogated.

KS is a critical activity for managing knowledge in organizations, as it improves the knowledge asset by adding to the organizational knowledge, since individuals' knowledge becomes part of organizational knowledge. KS can occur among individuals, among groups, among organizational units, and among organizations. KS in organizations occurs in two channels, one inside the organization and the other between the organization and its environment. Knowledge-sharing forums are examples of KS inside the organization. These sharing forums provide an environment where both explicit and sticky tacit knowledge can be shared. Sharing does not mean that one person's knowledge is transferred to another, but rather it provides an environment where different actors contribute within a context and, based on the absorptive capacity of the recipients, a flow of knowledge occurs. Barriers to KS include the absorptive capacity, relationships between employees, time, cultural differences, etc.

4.4 Knowledge Conversion

Shared knowledge in a firm contains both tacit and explicit knowledge. One of the challenges is what to convert to explicit knowledge, so that it more easily transferable. Nonaka and Takeuchi (1995) defined four types of conversion processes which they describe as 'fundamental to creating value'. There are four combinations of conversion of explicit and tacit knowledge:

1. Tacit-to-tacit (socialization) – individuals acquire knowledge from others through dialogue and observation;
2. Tacit-to-explicit (externalization) – the articulation of knowledge into tangible form through elicitation and documentation;
3. Explicit-to-explicit (combination) – combining different forms of explicit knowledge, such as that in documents or databases; and
4. Explicit-to-tacit (internalization) – such as learning by doing, where individuals internalize knowledge into their own mental models from documents.

The above four processes form the SECI (Socialization – Externalization – Combination – Internalization) spiral. The SECI spiral is the interplay between tacit and explicit knowledge starting at the individual level. Individuals' knowledge is the basis of organizational knowledge creation. The dynamic interaction between individuals and their environment facilitates the four modes of knowledge conversion.

- *Socialization* is the process of transferring tacit knowledge to another through shared experience. The tacit knowledge is acquired through building a field of interaction to share experiences and mental models, such as spending time together or living in the same environment, or informal social meetings outside of the workplace. Mental models refer to deeply held internal images of how the world works, which have a powerful influence on what we do because they also affect what we see.
- *Externalization* is a process of concept building involving the conversion of tacit knowledge into explicit knowledge. In other words, tacit knowledge is articulated into explicit concepts. Tacit knowledge is shared by a self-organizing group through dialog and reflection. Using appropriate metaphors or analogies the group members articulate their hidden tacit knowledge. Tacit knowledge is converted to explicit knowledge in the form of a new concept.
- *Combination* is a process of systemizing concepts into a knowledge system, by combining it with external knowledge. This involves combining various forms of explicit knowledge such as documents, meetings, telephone conversations, or messages on computerized communication networks by sorting, adding, combining and categorizing them into new knowledge, a new product or new service.
- *Internalization* is a process of embodying explicit knowledge into tacit knowledge. The knowledge conversion process of 'learning by doing' triggers internalization. New concepts created by individuals or the group need to be justified through bodily experience.

Nonaka and Takeuchi (1995) emphasizes that organizational knowledge building is a spiral process, starting at the individual level and moving up through expanding communities of interaction that cross group, departmental, divisional, and organizational boundaries. At the same time, there is the feedback of organizational level of knowledge to the group level and then back to the individual level. The four modes of knowledge conversion enable organizational knowledge to become externalized and amplified, and organizational knowledge building to become larger in scale and faster in speed.

The foundation of the above four basic processes is ‘Ba’, a rather fuzzy concept proposed by the Japanese philosopher Kitaro Nishida, and further developed by Shimizu. ‘Ba’ is defined “as a context in which knowledge is shared, created, and utilized, in recognition of the fact that knowledge needs a context in order to exist” (Nonaka et al., 2001). This context can be tangible, intangible or any combination of tangible and intangible elements. In this perspective, the concept of knowledge is strongly related to a given material and cultural context, beyond the fact that it is has been considered a personal belief. Knowledge belonging to given person may be shared, recreated or amplified when that person is an active actor in ‘Ba’. To make things even more confused, Nonaka et al. (2001) consider that “‘Ba’ as an interaction means that ‘Ba’ itself is knowledge rather than a physical space containing knowledge or individuals who have knowledge”. In our understanding, ‘Ba’ is suitable to create an innovative atmosphere.

According to Nonaka and Takeuchi (1995), the four ‘Ba’ phases correspond to the four phases of the SECI spiral:

1. *Originating ‘Ba’* corresponds to the *Socialization* phase of SECI spiral. People share feelings, emotions, and mental models in it.
2. *Interacting ‘Ba’* corresponds to the *Externalization* phase. Here individual ‘know how’ and mental models are converted into common terms and concepts.
3. *Cyber ‘Ba’* corresponds to the *Combination* phase and technology which is used to present the explicit knowledge.
4. *Exercising ‘Ba’* corresponds to the *Internalization* phase. In this phase, explicit knowledge is converted into tacit knowledge.

Although the SECI spiral model has been widely used in knowledge management research, it has some limitations. Glisby and Holden (2003) have argued that all four modes of knowledge conversion are culture-dependent, where Japan-specific cultural factors are tacitly embedded in the model. They, however, suggest that understanding Japanese social and organizational cultures and related value systems might enable this model to be used successfully in Western or other cultural settings.

The Japanese organization style is rooted in the tradition of groupism (Hayashi, 1990). Groupism is the individual identity with a group to the extent that their individuality is not completely repressed, but it is submissive to the group (Graham, 2003). The group in Japanese organization is the foundation for loyalty, belonging, and family. The Japanese employee has a deep cultural system that defines their altitude toward the head of the group and to the members of the group. It is quite natural that SECI spiral is relevant to the Japanese organizational system. On the other side, the culture of some Western developed countries like Unite States itself is rooted on individualism in contrast to Japanese. The American employees were less loyal to the organization and more focused on their individual need. The Japanese culture capture group knowledge and Americans capture individual knowledge.

There are some dissenting theories refuting the SECI spiral as a foundation and tool for understanding knowledge conversion (Gourlay et al., 2003). But the overwhelming consensus shows that Nonaka’s SECI spiral is useful and relevant for the conversion of tacit knowledge to explicit.

4.5 Knowledge Integration and Creation

As knowledge is transferred and shared from one to another, the knowledge is then combined and creates new knowledge. This process of transferring and combining knowledge is known as knowledge integration (KI). KI is a process of transferring knowledge, both tacit and explicit, across organizational boundaries and sharing it with individuals and teams at recipient sites.

Knowledge integration can be thought of the integration of specialist knowledge to perform a discrete productive task. Where this description emphasizes the output, others focus on the knowledge component, e.g., the integration of different types of component knowledge. Other descriptions focus on the integration component, e.g., the synthesis of individuals' specialized knowledge into situation-specific systemic knowledge; or the integration of complementary assets and knowledge. In some cases, the integration component is presented as a social process, e.g., an ongoing collective process of constructing, articulating and redefining shared beliefs through the social interaction of organizational members.

The term 'Integration' now is one of the most often used words in the industry and academia. It is a universally accepted necessary process in the constitution and development whatever integration is. The essential feature of innovation is knowledge integration and creation. The function of innovation system is production, diffusion and use of new and economically useful knowledge to value-creation.

The industry academia government relations are emerging from different institutional starting points of knowledge integration, which perform different knowledge functions.

In the epistemological dimension, there are two kinds of knowledge: explicit and tacit. The explicit knowledge can be codified, stored and easy to excess. On the other hand, tacit knowledge is knowledge that people possess but cannot be easily codified.

Recently scholars of knowledge management in different countries pay more attention to the tacit knowledge and its role in the innovation process. One of the important factors in the learning, absorption and innovation is the crucial effects of tacit knowledge. In knowledge application and creation the emphasis is on tacit knowledge, which is in the form of know-how, skills, common knowledge, and practical knowledge of organizational members and closely associated with real life. The tacit knowledge is acquired by and stored within individuals.

In the ontological dimension, there are two kinds of knowledge: individual and organizational (collective). Innovation is a kind of social activities and organizational knowledge is necessary. The collaborative innovations are based on the knowledge integration and knowledge sharing. Academia, enterprise, and government share information and knowledge across institutional spheres to generate new innovation opportunities. The most important and difficult tasks are communication and interaction of tacit knowledge for the knowledge integration since they are on the base of mutual empathy and understanding.

Knowledge integration is the process of synthesizing multiple knowledge modules from different sources into a common knowledge module. It focuses more on synthesizing the understanding of a given subject from different perspectives. Integration of knowledge includes integrating the knowledge of:

1. Technology and business;
2. Explicit and tacit;
3. Individual and organizational, etc.

From the strategic view, knowledge integration of collaborative innovation refers to the integration of knowledge (intellectual) assets including human assets, structural assets and social assets.

It is widely accepted that knowledge integration improves firm performance. High knowledge integration creates superior product innovation performance in industry networks and across functional boundaries. One knowledge integration activity, co-development with customers, directly improves product performance.

Knowledge creation (KC) refers to how new knowledge is created in organizations. This new knowledge could be generated at each level:

- job/individual;
- team;
- organization; and
- industry.

The goal of any knowledge management and knowledge enabling program is to link its newly created knowledge to other people even other generations of people. The act of knowledge creation is dynamic and includes what individuals possess through their experiences, learning, and talents. All this forms the basis of tacit knowledge. Once it is expressed in any form (such as words, and sounds), the knowledge becomes static and explicit (Conway and Sligar, 2002). For example if you have a new idea of design a business mode, your creation remains a dynamic one until you write it down. This is the key to knowledge generation and innovation The knowledge worker might come up with a solution to a problem and have moved knowledge from the dynamic state to static state, thus becoming an author of new ideas.

Within knowledge creation process, knowledge created by an individual is shared by team members, which is then transferred to the team and codified into written or digital format, and finally becomes part of the organization's knowledge system, supporting the knowledge processing and management process.

The organization can increase the members' participation in this authorship process by motivating them. If the organization requires knowledge workers to become authors, allocate time in the schedule so that authoring is a priority. The more empowered a knowledge worker feels to publish authored materials, the more likely he or she will do it. If a knowledge worker comes up with an idea to solve a particular problem in the group, a committee can be formed to collaboratively discuss and come up with even more solution to the problem. If the organization's author participation is low, the culture or the infrastructure should be changed to improve it.

4.6 Knowledge Absorption and Using

In the present competitive and dynamic business environment, organizations strive to identify and assimilate new knowledge in order to gain first mover advantage and enhance their performance and profitability. Thus, the ability to absorb new knowledge has become crucial for organizations willing to achieve sustainable competitive advantage.

Absorptive capacity (ACAP) as an organizational capability enables the firm to benefit from external knowledge. ACAP is defined as one of the firm's key learning processes with regard to identifying, assimilating, and exploiting knowledge available in the environment. Organizational ACAP builds on the individual ACAP of its members, although it is not the sum of these individual capabilities. ACAP uses external knowledge to foster internal innovation. It is widely accepted that ACAP develops cumulatively, is path-dependent, and builds on existing knowledge. ACAP requires an understanding of how to work with other specialists. This is referred to as shared understanding, or complementarity between the recipient and source knowledge.

ACAP is a dynamic capability pertaining to knowledge creation and utilization. This is what causes the differences in a firm's ability to ensure a competitive advantage: According to the dynamic capability theory, ACAP is an ability that requires investments in order to be advanced.

With high ACAP, the firm could timely response to technological change by utilizing the knowledge and technology generated into new products and processes.

When the organization has assessed the potential value that a knowledge project can create for itself and seen the framework, the leader needs to evaluate whether the organization is ready for such a change. He may do it by weighing the value that the knowledge management solution brings against it risks (Conway and Sligar, 2002). A team that is considering starting a KM effort should take into consideration the potential areas of risk. There are nine main areas that might influence even impair the success of KM solution:

1. *Cost of solution*: A new solution places considerable risk and financial strain on the organization. The cost contains two parts, the upfront investment (hardware, software, and people costs for development, etc.) and operating cost (technical and non-technical).
2. *Organizational competencies*: Organizations need to balance their KM programs across three competencies: customer satisfaction, product leadership, and organizational operations. Outstanding performance in one dimension might lead to prosperity, but falling short in another dimension might threaten the organization's survival.
3. *Proving success*: The organization need to align the objectives of the knowledge management program with business success criteria, to develop a set of evaluations reflecting this alignment.
4. *KM adoption*: KM solutions involve two groups of persons: knowledge creators and knowledge users. Knowledge creators view KM as a threat to their prestige,

perhaps even their livelihood. As the only person who truly understands how to solve particular technical issues, why should he be interested in sharing this knowledge? Knowledge users may also lack enthusiasm. To address this risk, the true innovative problem solvers must appreciate that not only does their worth to the organization increase the more they share their knowledge of existing problems and move on to solve new issues, but equally important, their managers understand their value. Likewise, the knowledge user can be given new challenges that don't rely on repeating known solutions to problems.

5. *Executive sponsorship*: The role of sponsor involves much more than authorizing the expenditure for the initiative. Executive sponsorship for a new KM project is critical if the program is to be a success. Special challenges arise if the KM sponsor leaves the organization or moves to a new position. If the KM initiative was founded on a clear business case that was aligned with the key business goals, the new sponsor can rapidly appreciate the initiative's value.
6. *KM tools*: KM systems typically make life easier either or for the contributor or the knowledge re-user, but not both. It involves the responsibility for indexing and metadata. The contributor would prefer to simply submit material into the system without codifying metadata, entering keywords, and so on. On the other hand, knowledge users need to be able to find the most appropriate information as rapid as possible, so they want to enter the minimum amount of information necessary to retrieve the most appropriate knowledge. The solution to this problem may put more work on the contributor or on the knowledge user. It may introduce a third party to codify the knowledge or use the automated tools to help.
7. *Culture change*: When organization introduces a system-based approach, the group dynamics that made a community-based approach viable may be destroyed. Organizations fail when they adopt a KM strategy that straddles both a document-centric strategy and a collaboration strategy.
8. *Inflexibility*: Although a disciplined approach to understanding the goals and performance metrics of a KM initiative can reduce the uncertainty of creation value, KM remains inherently unpredictable. In addition to the uncertainties of the business environment and the capabilities of the technology itself, which affect all IT applications, KM depends on a change in working behavior. As a result, few KM initiatives are likely to follow their original plan exactly.
9. *Solution delivery process*: The final implementation risk involves the methods used to deliver the IT solutions. Implementation teams should look closely at the methods that their technology solution uses, whether in-house or external, to see how well they support the specific needs of this type of work.

Since there are such a wide range of risks, a disciplined approach to risk management becomes essential. But overspending on the managing uncertainties will reduce the value created by the initiative and underspending may threaten the ability to achieve the goal.

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A Practical Case of Knowledge-Based Archive Management System

Jiangning Wu

Abstract To preserve historical documents and mine precious knowledge involved, a knowledge-based archive management system (KB-AMS) is introduced in this chapter. From a socio-technical perspective, the system is designed as a both human centered and IT-based system which not only provides access to archives but also facilitates knowledge sharing and creation and therefore enhancement of knowledge services. Based on the conceptual model, people, resources, processes, and technologies within the system are described and analyzed by introducing a practical case in the context of historical archive preservation.

Keywords Historical documents • Knowledge-based archive management system • Knowledge sharing and creation

1 Background

Historical documents carry the civilization achievements in ancient society, which record many aspects on development of society. Many ancient documents are now suffering progressive degradation and consequently are threatened of a real danger of disappearance, which makes it difficult to consult them in physical environment. Currently in China, except very few extremely valuable rare books, most ancient books or materials are not preserved in appropriate conditions (Li and Niu, 2010).

To safeguard historical documents and mine precious knowledge involved, one of the better ways is to handle them in digital format for most cultural institutions. Nowadays, numerous digital archive projects have been conducted worldwide to preserve and sustain such cultural heritage. These projects aim to preserve cultural heritage and collections; popularize fine cultural landmarks; encourage information/knowledge sharing; invigorating cultural content and value-added services, and improve literacy, creativity and quality of life. They are considered as the prerequisite and foundation for developing digital archives from which an archive's

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conventional functions in academic research, exhibition, and education can be extended and developed through information technologies.

Recent technological developments (development of the Internet, communications with high output, important storage capacities, and algorithms of compression of images) and the policy of digitization on a large scale of the patrimonial archives make it possible to place at our disposal enormous databases of digitized documents. The digitization process and the use of standard formats to set up image database ensure the long-term preservation of the historical documents. As a result a defined community or set of communities can access, consult and further study these documents easily and publicly.

Digitization of historical documents involves *a large amount of knowledge-intensive activities*. It is believed that digital archives and knowledge management process are closely related to each other. The application of theories and methods of knowledge management in building knowledge based digital archives can better strengthen their services, enrich their managing methods, and improve their adaptability in a constantly changing digital environment.

Ancient documents have a historical value not only for their physical appearance but also for their contents. That means just browsing through the mass of digitized document images is not enough. Instead, mining the contained contents and unlocking the wealth of information in these ancient resources are called for. Manually typing all the information and recording into databases are tedious and slow processes, requiring a lot of resources. Moreover, there are many challenges in transforming paper documents to useful information, especially when documents are handwritten and are degraded due to the ageing impact. Crowdsourcing is a good choice for tedious work, in which a large group of people can make their efforts to fulfill tasks solely.

This chapter addresses an archive digitalization project called 'Historical Document Digitalization (HDD)' which is sponsored by Ministries of Chinese central government. The collection of historical documents on the old Canton custom is provided by Guangdong provincial archive in China, most of which are in English. Through digitization, the archive not only provides access to its historical documents but also allows for the preservation of rare, fragile, and unique materials. With the contents of historical documents, new knowledge can be extracted by which the archive is able to provide knowledge-based services. For these purposes, a knowledge-based archive management system (KB-AMS) is built by introducing related people, technologies, and other resources. Regarding the KB-AMS, its main tasks, concept model, technological infrastructure are described in detail, and the other issues like work team setting and system development and implementation are just outlined in the following sections.

2 Three Main Tasks

Creating the digital copy of the historical document can generate a surrogate which can then be accessed and used instead of the original, thereby assisting in the preservation of the original. To preserve historical documents and hereafter discover the knowledge from them, three main tasks have to be carried out, i.e. transforming original paper materials into images, transforming content of image into text, and transforming textual data into knowledge.

2.1 Transforming Original Paper Materials to Images

The digitization of the historical documentary collection has undeniable advantages, permitting a reliable and well-structured filing by putting together the images with textual data. Such digitization depends on the choice of the scanner, the digitization mode and the storage format. After selecting the high-quality scanners, they can then be used to get scanner images taking resolution which have to be well-chosen in order to preserve the maximum useful information for the rest of the treatment. But a high scanner resolution may generate an image file of a big size which poses a storage problem of such files.

In the HDD project, all the paper materials for digitization come from the collections of the Guangdong provincial archive. Those source files are scanned by the high-quality scanner and the scanner images are stocked in genuine color on 24 bits in the non-compressed TIF format in the image database. Such images named as the original data are of high quality and lossless compression, but with large storage space which leads to difficulties for frequent operations. Therefore there is a need to compress the images by using the most adapted methods and techniques like digitization and compression, in order to minimize the storage costs and to make their access easily and remote loading fast. The reprocessed images are called the secondary data. Both the original data and the secondary data are stored in the image database. Later they are treated by optical character recognition (OCR) techniques for further use.

2.2 Transforming Content of Image into Text

Nowadays, just offering the scanned images of pages to users is not an option. Instead, full text access is called for. If one wants to deliver digital images that replicate the appearance of the original materials and use full text for searching, the digitization approaches would have to include both scanning and text conversion. Text conversion is a transcription process in which OCR produces machine-readable and fully searchable characters.

In this stage, OCR tool selection is crucial. Commercial OCR tools focus mainly on modern documents and are geared to recognize a wide variety of relatively short documents printed with modern fonts. In most archives, symbolization is often being applied to a completely different type of material, often printed with old-fashioned fonts or handwritten styles that are very different to contemporary styles. Except for the fonts, historical documents suffer the other serious problems including degradation and presence of folds and tears in the documents; deformations due to the natural curve of the pages; generated shade of the interior of the binding; text appears in the form of waves; text of the back shows through due to the acidity of the ink; presence of humidity mark making illegible for the original; variability of page-setting and the styles of writings etc. All these problems lead to OCR tools to produce unsatisfying results for historical documents. As a result, the recognition rate becomes poor or even useless. In this case, post-correction is needed which is a professional and knowledge-based job.

2.3 Transforming Textual Data into Knowledge

Various defects mentioned above generate a loss of structural information of the documents, and the difficulties increase thus to reach the structure and consequently information. To rebuild the logic structure of the document starting from its physical structure, we have to segment the text in paragraphs to detect titles, paragraphs, columns, headings and footers and to separate the various components located on pages. These activities constitute dull work in the manual case. Techniques like text mining tools can take the burden of such work especially for large-scale texts. Through text mining, new information/knowledge can be discovered and the evolution of cultural phenomena can be traced.

Another challenge is the language barrier. Currently, most existing lexica for historical language is not adequate. Whereas the historical documents in the HDD project are all in handwritten English, this brings many challenging tasks for identifying and translating their contents.

3 Presenting a Conceptual Model

Considering that modern archives perform many knowledge-based activities, and by nature, knowledge management (KM) process is embedded in archive management system (AMS), therefore, there is a necessary to develop an integrated knowledge-based archive management system (KB-AMS). The reason why both knowledge management system (KMS) and AMS can be integrated into the whole lies in their common traits (Roknuzzaman et al., 2009).

- *Objectives*: The main objective of both AMS and KMS is as same as to provide users with access to knowledge resources. Focusing the information management function, an AMS is largely technical and service-oriented while KMS is mostly people-oriented.
- *Content/resources*: Data, information and knowledge are the main resources in AMS as well as in KMS. Concerning content, a digitalized AMS emphasizes digitally coded explicit knowledge, while KMS focuses on both tacit and explicit knowledge, either in digital or physical form. The tacit dimension of KMS can contribute to AMS in developing a mechanism for converting, storing and sharing knowledge.
- *People/workforce*: People are the key actors in the organizational processes and the main users of AMS or KMS. People with the proper blend of technical, managerial, behavioral, cognitive and interpersonal skills can play significant role in designing, operating, and maintaining an AMS and a KMS system. End users need to be trained and skilled in both the cases.
- *Process*: Both AMS and KMS can share almost the same mechanism of life cycle process of information/knowledge. They follow the same procedure of acquisition, processing, organization, storage, retrieval and dissemination of information and/or knowledge for its proper utilization.
- *Technology*: AMS integrates a wide range of computing and communication technologies including more advanced and fast processing digital technologies, digital repositories, information retrieval engines, document management system, electronic publishing system, web-based technologies like the Internet, Intranets, Extranets etc. These technologies are more or less concerned to KMS along with groupware, collaborative tools, knowledge portals, knowledge creation technologies etc. Some important tools and techniques like indexing, taxonomies, codification, metadata, data mining, database management, knowledge mapping techniques etc. are being used in AMS and in KMS for the management of contents and their retrieval.

In fact, both AMS and KMS are content-centric as well as technology oriented, but KMS emphasizes more human aspects. However, they should not compete with one another; rather they complement each other. It is believed that if an AMS applies the knowledge process, it can provide more knowledge-based services and hence satisfy users' needs.

Based on this understanding and following the idea of knowledge systems engineering presented in chapter "Knowledge Systems Engineering: A Complex System View", an integrated KB-AMS is proposed whose conceptual model is shown in Fig. 1.

In general, a digital AMS may contain four main components: digital resources, technologies, a digital community, and services. Digital resources refer to the collections in digital or electronic forms including items like text, graphics, images, audio, video, catalogues etc. as well as contents generated from original materials. Technologies involved in AMS may include electronic document management system, full text search engines, relational databases, online public access catalogue

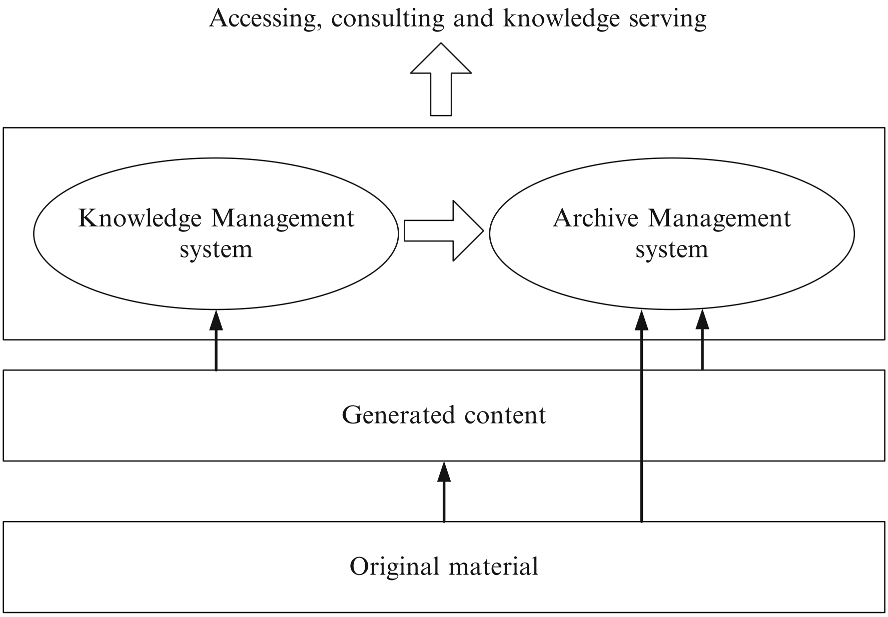

Fig. 1 The conceptual model of KB-AMS

(OPAC), digital multimedia technologies, web-based hyper media and hypertext, the Internet/Intranet, user and system interface etc. Technology promotes the KB-AMS functions like knowledge acquisition, conversion, processing, storing and providing universal access to digital information. Regarding the digital community, it is constituted by a set of well-structured personnel who are able to deal with digital contents, digital technologies, system designs and service promotion. In the KB-AMS, people, process and technology work together to satisfy end user's need for information or knowledge anytime, anywhere. KB-AMS services interact with digital resources, knowledge management systems and users.

Not only KMS can be integrated with the existing AMS to become a KB-AMS, but AMS itself is working as a KM system since a well-planned and well-designed AMS can provide AMS community with access to digital knowledge resources. In a question of how KMS can be integrated into AMS, a pragmatic and systematic approach is adoption of existing AMS including its knowledge resources, technologies, people and the process. Therefore, considering the broad perspective and potential benefits of KM, it is suggested the incorporation of KM process into AMS, which ultimately would upgrade the existing AMS framework consisting of five elements, i.e. digital resources, technologies, a digital community, services and KM.

The KM life cycle process contains six main steps: acquisition, organization, storage and retrieval, dissemination, creation of knowledge and receiving appropriate feedback from AMS community (Roknuzzaman et al., 2009).

1. *Acquisition of knowledge*: Acquisition of knowledge is the starting point of KM in AMS for building digital collections. It refers to the process of acquiring AMS knowledge resources including knowledge extracted from historical documents, technologies, human expertise and services for AMS community. The task of acquisition includes: identification of AMS knowledge resources-both explicit and tacit, conversion of knowledge from traditional to digital format, gathering resources from the web etc. As a continuous process, capturing of knowledge involves the gathering significant knowledge from original archives, published books, internal and external reports; from professionals working in the digital environment; and from other valuable sources.
2. *Organization of knowledge*: Knowledge organizing in the digital environment includes archives and content management systems, classification and categorization schemes, taxonomies, thesauri, abstracting and indexing databases, semantic networks, ontologies, OPAC, institutional and subject repositories, web search engines, web tools like wikis and blogs etc. The organization of knowledge eventually builds the knowledge base of AMS by converting information or unobvious knowledge to explicit knowledge in a usable form, and by providing means of codifying, categorizing, indexing and accessing explicit knowledge.
3. *Storage and retrieval of knowledge*: The organized knowledge is stored in the repositories for preservation as well as multiple uses. For the purpose of knowledge distribution and sharing, a number of tools and techniques are used to facilitating the retrieval process. Taxonomies, knowledge mapping, data mining, metadata, browsing, searching etc. are some of the popular tools used in KM. These tools are also familiar in AMS for structuring and retrieval of digital information, mainly explicit in nature. Therefore, the application of KM in AMS can support a storage and retrieval process not only for explicit knowledge but also tacit knowledge. KM may share various computational techniques including linguistics analysis, machine learning, knowledge repositories, and human-computer interaction with AMS to support AMS people with access to digital knowledge resources. While explicit or documented knowledge can simply be converted into digital form and can best be kept in digital files and databases, tacit knowledge might need to be packaged in a more indirect form like a story telling video etc. Since the tacit knowledge is hard to articulate, agent-based retrieval systems may be used to capture the interests and or knowledge of AMS community.
4. *Dissemination of knowledge*: This step directs the dissemination of right knowledge to the right people at right time. The dissemination of knowledge refers to those activities and processes associated with the flow of artifacts from one agent to another. The transferred knowledge is then practiced, shared, applied, utilized and used to attain archivists' ultimate goals of satisfying users' needs, developing research activities, creating new knowledge, promoting archive functions, and building up a knowledge culture. In a digital environment, knowledge can be transferred in the form of a number of knowledge-based services and

products including e-mail, electronic publications, presentations, websites, on-line discussion forums, video-conferencing and collaboration tools etc.

5. *Creation and discovery of new knowledge*: Knowledge in nature has two types: tacit and explicit. For tacit knowledge creation, it deeply depends on the communication among people. Frequent meetings can facilitate exchanging and transferring tacit knowledge face-to-face. As to explicit knowledge, data mining ad hoc text mining methods and tools can help finding the hidden and unknown information/knowledge from the databases.
6. *Feedback*: The final step of KM process is to receive responses or feedbacks from the end users as regard to the extent of satisfying their knowledge needs. Feedbacks may also take the form of comments or suggestions on a particular service or system. Users' feedbacks or responses can be obtained through e-mail, web-enabled digital forms etc. The received feedbacks are then analyzed and evaluated to refine, readjust or redesign the system or service, if necessary. The value of feedback for KM could be derived by its proper integration and implication in the AMS. Some of the important functions of feedback system are as follows:

   - the assessment of existing knowledge resources and services;
   - identification of knowledge needs;
   - integration of new knowledge and services;
   - modification of existing system;
   - replacing outdated knowledge;
   - evaluation of knowledge;
   - continuous improvement; and
   - providing knowledge in a best possible way to satisfy AMS community.

By integrating KMS with AMS, the benefits are apparent in terms of strategic planning, KM culture formation, intellectual assets management, and knowledge sharing and innovation activities.

Developing a KB-AMS requires a strategic and business plan based on an effective group decision making process. The strategic plan for KM initiatives would contribute to make strategies and decisions on information or knowledge resource allocation and organization, execute strategies and business process analysis including strengths, weakness, opportunities and threats. KM strategic plan for AMS may include the development of database tools for supporting KM initiatives, coordination and distribution of digital knowledge construction, human resources development, financial asset management, intellectual property rights management, socio-economic political and technological issues.

KM process in AMS can contribute to the development of knowledge warehouses of the archive by acquiring, capturing and creating appropriate knowledge resources. KM establishes a unified knowledge framework in the archive within which the knowledge currently available in multiple formats can be collected, converted, organized and disseminated, and thus making them available to those who need these, where and when they need these.

Intellectual capital involves human capital, customer capital, structural capital and business intelligence capital. The archive possesses a number of human resources having experience and expertise in the field. The expert knowledge, skills and experiences can be transformed into intellectual capital or assets of archive which should be managed and utilized for the benefit of the users, and for internal operation and future use of archive. Practicing KM assists in developing an organizational culture and environment for capturing, managing, and updating the intellectual assets, and making them easily accessible for sharing and utilizing.

The archive has its own strategy and process of disseminating and transferring articulated knowledge items to its user community, and some people perceive this process as knowledge sharing. Knowledge sharing is seen as a central concept of KM, which focuses more attention on tacit knowledge. The tacit knowledge can be communicated through interaction, collaboration and conversations in communities/networks of practice. The introduction of KM provides archive an opportunity to promote a collaborative, innovative and knowledge-sharing culture. The experience and expertise of other archivists can be shared under the existing archive cooperation, networking and resources sharing programs. The dynamic growth of knowledge resources and increasing individual demands for specific knowledge item have raised challenges for an archive in providing innovative and efficient knowledge services. An effective KM practice would help archive to plan and design its services tailored to the interest and need for specific knowledge of end users.

In short, only if we combine the knowledge involved in historical archives and the tacit knowledge of individuals, we can truly realize the wide functions of the AMS and show the advantages of KM.

4 Processing Knowledge Contents

To mine the knowledge from historical documents and further satisfy the needs of knowledge specialists and users, a standard process should be followed by which knowledge content with well-defined knowledge content structures can be created and maintained autonomously. These knowledge content processes can be regarded as a life cycle that comprises knowledge content collecting, digitizing, editing, organizing, publishing, and accessing phases (Hsu et al., 2006). The major tasks of each phase are summarized as follows:

1. *Collecting stage*:
   - To express the knowledge concepts for a particular application and user group, the variety of knowledge element must be decided in advance; and
   - To collect original materials such as documents, photographs, audio, or video for the target content type and prepared under a standard knowledge content structure.

2. *Digitizing stage*:
    - To digitize the original materials into digital objects using standard formats; and
    - To assign a meaningful and unique object identifier for each digital object.
3. *Editing stage*:
    - To interpret each digital object with semantic metadata to make it a core knowledge element; and
    - To store core knowledge elements in the core knowledge element repository for further organization and reuse.
4. *Organizing stage*:
    - To reuse and organize core knowledge elements into advanced knowledge elements, which can be a multimedia document, knowledge unit, knowledge group, and knowledge network;
    - To use a multimedia document composed of a set of digital objects for interpreting a subject relating to an artifact;
    - To organize a set of multimedia documents into a knowledge unit for interpreting an artifact;
    - To arrange a set of knowledge units to create a knowledge group with the same characteristics for a particular exhibition topic;
    - To link the above elements to other related elements to form a knowledge network; and
    - To store multimedia documents, knowledge units and knowledge groups in advanced knowledge repositories with their semantic metadata to be reused and shared among specialists and applications.
5. *Publishing stage*:
    - To justify knowledge content before delivering to users;
    - To convert each knowledge element into XML-based content structure by the system;
    - To allow specialists to assign a presentation template to each knowledge element; and
    - To generate web pages from combining the XML-based content and the specified presentation template.
6. *Accessing stage*
    - To allow users to access knowledge content through an integrated semantic classification hierarchy-based browsing interface to share the common knowledge concepts with specialists;
    - To design a metadata query interface for each knowledge repository for each domain; and
    - To publish knowledge content from various domains through a unified knowledge portal.

By using the generated contents, KS-AMS can realize its knowledge based functions, such as knowledge retrieval, knowledge analysis, knowledge visualization, and so on.

5 Setting Up a Work Team

Digitizing and analyzing historical documents in KM context are extremely complex knowledge intensive work, which usually could not be done within one institution. There is a need for professionals from different domains to collaborate with each other across organizational boundaries and contribute their skills and expertise to the predefined jobs. Moreover, new knowledge is rarely generated by an individual, instead it frequently occurs in situations in which a number of people work together to create something new in a mutual exchange.

The work team can be formed of individuals that have been chosen for the skills, experience, knowledge and networks they bring to the project. Under the HDD project, along with sound technological infrastructure, human factors are also given priority in designing, developing, organizing, managing, maintaining, and operating KB-AMS. Experts involved in the project coming from two universities in China, local government in Guangzhou and Guangdong provincial archive form a team, in which each member plays a different role according to his/her contributions to the project. For example, academics in the project focus on research jobs like model and algorithm development, information technology personnel conduct technical work like system building, software selection etc., and archivists are in charge of handling digitization tasks.

No matter what roles and positions experts hold, their work has the same features summarized as below.

- *Autonomy*: Degree of control of the worker on how a task is done.
- *Structure*: Degree of established rules, policies, or procedures on how a task is done.
- *Tangibility*: Degree to which a task is capable of being easily perceived using the five senses; especially by the sense of touch and sight.
- *Knowledge*: Degree to which having previous knowledge, executing cognitive actions and executing cognitive processes are part of the task.
- *Creativity and innovation*: Degree to which cognitive processes are used to lead to the production or creation of something that is both original and worthwhile.
- *Complexity*: Degree to which a task offers great difficulty in understanding or has confusing interrelated sub-tasks.
- *Routine and repetitiveness*: Degree to which a task is part of a regular or established procedure characterized by habitual or mechanical performance of tasks.
- *Physical effort*: Degree to which a task requires body strength, coordination, and skill in order to be performed; the use of physical power.

Except for experts in the project, there should be a special person who is clear about the whole working process and has both the technical and the organizational capabilities to manage and coordinate team members (Mendelsson et al., 2014). In this regard, it suggests that a team can have two project leaders – one who is a technical expert and another one who has capabilities to identify the needed capabilities and knowledge for the project, generate enthusiasm and commitment, integrate the activities of the group members and anticipate conflicts and minimize their potential impact on the success of the project in advance.

6 Building the Technological Infrastructure

The proposed KB-AMS is an advanced archive management system in KM context. Within the system, there are many knowledge resources involved including professionals from different institutions, various technologies as well as huge amount of historical documents. If being well behaved, they should be managed in an integrated system. Such a system should be both human centered and IT-based. In other words, it should be a kind of knowledge-based system rather than only a computer-based information or document system. What distinguishes knowledge from information is the way in which knowledge empowers people with the capacity for intellectual or physical activity. Knowledge is a matter of cognitive capability and enables people to do and reflect. Information, by contrast, is passive and meaningless to those without suitable knowledge. In this sense, KB-AMS is a socio-technical system which not only provides access to archives but also facilitates knowledge sharing and creation and therefore enhancement of knowledge services.

As a socio-technical system, KB-AMS is a living, complex and dynamic system that encompasses a complex combination of elements such as technological infrastructure, organizational infrastructure, corporate culture, knowledge, people etc. This section only pays a close attention to its technological infrastructure. When framing the KB-AMS design space, four dimensions i.e. people, technology, content and service should be taken into account. The structure of the framework for KB-AMS is designed as a four-layered structure as shown in Fig. 2 since the layered structure is popular in information/KM system design. Four layers include presentation layer, application layer, function layer, and data layer from the top down.

Four structural layers support different kinds of functionalities including digitization, large repositories, process and collaboration management, data transfer and access, knowledge retrieval, knowledge analysis and visualization etc.

6.1 Presentation Layer

The presentation layer generates web pages and provides user interface. The knowledge portal (KP) is located in this layer. The basic function of KP is to facilitate the access of digitalized historical documents. The other functionalities related to KM activities cover different aspects including communication (supporting internal and

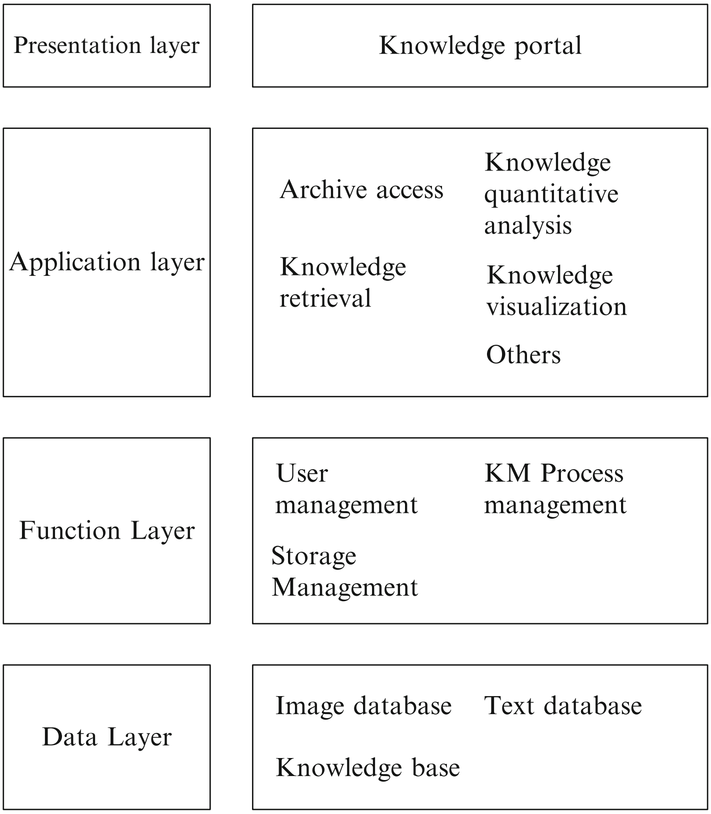

Fig. 2 Framework of four-layered KB-AMS

external communication among members for sharing and transferring knowledge), collaboration (technologies are used for sharing ideas, sharing creation, and sharing a work space), contents (organizing and structuring knowledge to enhance its use and to guide users to available knowledge resources), coordination (managing dependencies between activities), customization (searching knowledge and delivery of more relevant knowledge to users), community (building and managing communities to activate communication and sharing among researchers), and connection (creating and managing knowledge networks, and finding relevant experts).

6.2 *Application Layer*

The application layer directly determines the capability of the whole system. It consists of archive access module, knowledge retrieval module, knowledge quantitative analysis module, knowledge visualization module and others.

- *Archive access module*: This module supports the construction of online services including integrated access to on-line information sources; on-line retrieval of information: accessing, browsing and searching facilities; electronic access to digitalized image database (both in-house and external); electronic access to full-text historical documents; networking and resources sharing; electronic publishing etc.
- *Knowledge retrieval module*: Knowledge retrieval (KR) refers to getting information in a structured form on the basis of retrieving knowledge from the repository. Different from data retrieval and information retrieval, KR focuses on the knowledge level. Data retrieval and information retrieval organize the data and documents by indexing, while knowledge retrieval organizes the knowledge structure by using concepts and their relationships extracted from contents of documents. Knowledge structure can be built based on the hierarchical structure of concepts which is often a tree-like graph. The hierarchical concept graph is the so-called ontology which is a formal representation of knowledge within a domain. Ontology, as a metadata structure, provides a controlled dictionary where each concept is clearly defined and possesses machine handling semantics. Ontology-based knowledge organization can contribute to express the contents of information elements and semantic relations between them. With the help of ontology, semantic reasoning and knowledge retrieval can be realized. Figure 3 demonstrates a 'tea' ontology which is generated from the digitalized historical documents on the old Canton custom.

  Through ontology, knowledge retrieval module can standardize and improve the knowledge search and discovery mechanisms, and consequently provide the retrieval results in a knowledgeable way.
- *Knowledge quantitative analysis module*: Knowledge quantitative analysis can be conducted in a computational way. Computational analysis of digitized books enables us to observe cultural trends and subject them to quantitative investigation (Michel et al., 2011). Michel et al. declared that 'culturomics' extends the boundaries of scientific inquiry to a wide array of new phenomena. Word frequency is often used to quantitatively analyze the knowledge. In Michel's work, for example, they compare the frequency of 'the Great War' to the

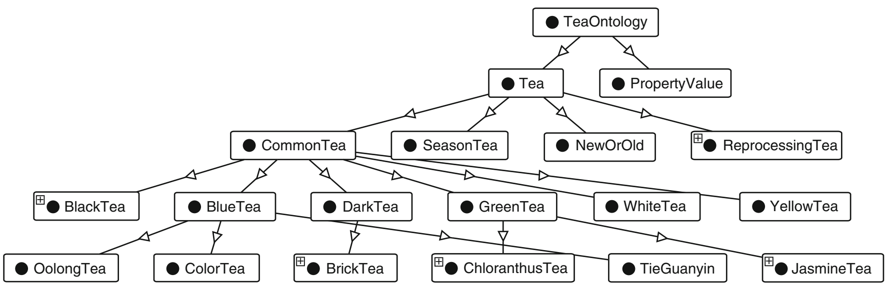

Fig. 3 Ontology for the concept 'tea'

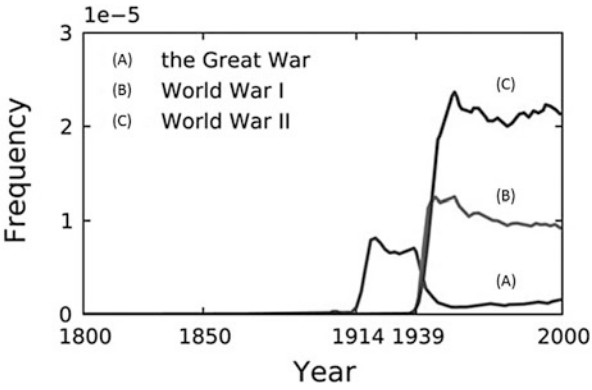

Fig. 4 Culturomic analysis – Usage frequency over time for 'the Great War' (*A*), 'World War I' (*B*), and 'World War II' (*C*) (Source: http://www.sciencemag.org/content/331/6014/176.full.html)

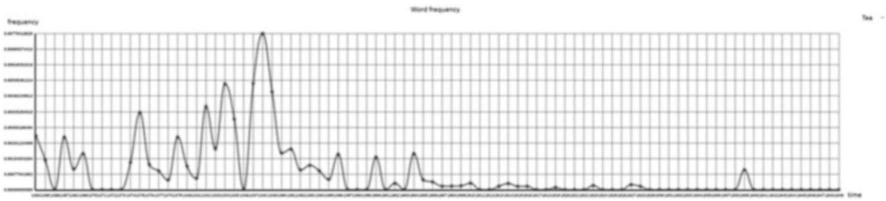

Fig. 5 Culturomic analysis for the term 'tea'

frequencies of 'World War I' and 'World War II' based the corpus they created which contains 5,195,769 digitized books. References to 'the Great War' peak between 1915 and 1941. But although its frequency drops thereafter, interest in the underlying events had not disappeared; instead, they are referred to as 'World War I (see Fig. 4).

The example highlights the central factor that contributes to culturomic trend. Cultural change guides the concept under discussion such as 'Great War'.

Computational analysis can also be used to study language, lexicography, and grammar. Linguistic change, which, of course, has cultural roots, affects the words we use for those concepts ('the Great War' versus 'World War').

In the same way, the knowledge quantitative analysis is applied to historical documents on the old Canton custom, frequency changes of the term 'tea' reflect a cultural phenomena at that time (see Fig. 5). In fact, knowledge statistics function provides more convenience for system users and researchers.

- *Knowledge visualization*: Visualization is an effective way to communicate abstract data and information through the use of interactive visual interfaces. Knowledge visualization tools have a great potential as they allow knowledge, usually coded in a rigorous but not intuitive formalism, to be visually presented and therefore easily perceived. Of visualization tools, word clouds have emerged as a straightforward and visually appealing visualization method for text. They are used in various contexts as a means to provide an overview by distilling text down to those words that appear with highest frequency. In a typical word

Fig. 6 An example of keyword clouds referring to documents on the old Canton custom in China

cloud, words from a document are packed into a rectangular region in which font size indicates word frequency and font color indicates other useful information. Figure 6 shows a word cloud picture portraying the contents of the given document collection which are selected from published books in Chinese on the old Canton custom.

It is notable that knowledge visualization should not be only limited to computer-based images, but it should focus on supporting the (inherently social) processes of creating and sharing knowledge with others.

6.3 Function Layer

The function layer is between application layer and data layer. It does not take part in application operations directly, and therefore it has no user interface. This layer provides a platform to support user usage and application development. Generally, user management module, KM process management module, and storage management module comprise the function layer.

- *User management module*: This module builds a directory to save users' personal information and their affiliations as well as their roles and authorities for information/knowledge accessing. Once logged in, users are managed by a unified identification. They are divided into different groups and each group owns different access authorization. Through user management module, corresponding functions are provided, such as add new user, delete user account, modify users' information, and so forth. Besides, the module can help form and expand the social networks of users according to their registered identities.

- *KM process management module*: Knowledge in nature has two basic types: tacit and explicit. Managing such knowledge is a systematic process including knowledge capturing, knowledge organizing, knowledge retaining, knowledge sharing, knowledge using, new knowledge creating etc. The KM process management module takes charge of connecting knowledge processes and making them play the role synergistically. To get more knowledge from the outside, the module may introduce the crowdsourcing mechanism for this purpose. Crowdsourcing is a type of participative on-line activity in which an individual, an institution, a non-profit organization, or company proposes to a group of individuals of varying knowledge, heterogeneity, and number, via a flexible open call, the voluntary undertaking of a task. The undertaking of the task, of variable complexity and modularity, and in which the crowd should participate bringing their work, money, knowledge and/or experience, always entails mutual benefit.
- *Storage management module*: The storage management module is served for data transfer between application layer and data layer. It can transform data format, and provide various data views and abstractness. The important component of storage management module is metadata. Metadata is structured data about data. Good metadata is helpful for accessing materials in a digital repository, and for representing information about a document such as structure, creators, format etc.

6.4 Data Layer

The data layer is the bottom layer of the system which is used to preserve the images, re-generating contents of historical documents as well as the mined knowledge from digitalized texts. Three databases namely image database, text database and knowledge database constitute this layer.

- *Image database*: The database stores all the scanned images.
- *Text database*: Text database keeps the contents of digitalized images.
- *Knowledge base*: Knowledge base is responsible for saving both explicit and tacit knowledge in a structural form.

The built KB-AMS can ultimately realize the objectives which are the driving force around which functions and services are developed. Objectives of KB-AMS are as follows:

- Construct a central repository for the digital historical archives information of Canton Customs,
- Facilitate access to the historical archive information fast and precisely,
- Encourage sharing and exchange of the historical archive information between institutions, scholars, and fans,
- Provide knowledge-based services to professionals and the public,

- Facilitate preservation and reuse of the digital historical archive information.

7 Developing and Implementing the KB-AMS

In general, before implementing a knowledge-based system, KM capability for an archive or a team should be measured. A 5-level capability maturity model proposed by Kulkarni and Freeze (2006) can be used for this purpose as shown in Table 1, in which the following issues are taken into account, they are the meaning of knowledge assets is understood, the value of knowledge assets is recognized, knowledge assets are stored/tracked in some fashion, sharing of knowledge assets is practiced, and systems/tools to enable KM activities exist.

Once the team or organization reaches the higher level, say level 4 or level 5, it implies that they can begin to work on the development of system. When developing the knowledge-based archive management system, the 'waterfall model' can be adopted. The waterfall model is a sequential design process, in which progress is seen as flowing steadily downwards (like a waterfall) through the phases of conception, initiation, analysis, design, construction, testing, production/implementation and maintenance. It contains six main phases which are followed in order:

1. *System requirements*: captured in a requirements document
2. *Analysis*: resulting in models, schema, and rules
3. *Design*: resulting in the system architecture
4. *Coding*: the development, proving, and integration of system

Table 1 KM capability maturity

Capability level	General goals
Level 1: Possible	Knowledge sharing is not discouraged
	There is a general willingness to share
	People who understand the value of sharing do it
	Meaning of knowledge assets is understood
Level 2: Encouraged	Culture encourages sharing of knowledge assets
	Value of knowledge assets is recognized
	Knowledge assets are stored/tracked in some fashion
Level 3: Enabled/practiced	Sharing of knowledge assets is practiced
	Systems/tools to enable KM activities exist
	Rewards/incentives promote knowledge sharing
Level 4: Managed	Employees expect to locate knowledge
	Training is available
	KM-related activities are part of workflow
	System/tools for supporting KM activities are easy to use
	KM capabilities and benefits are assessed
	Leadership exhibits commitment to KM
	Leadership provides KM strategy
Level 5: Continuous improvement	KM systems/tools are widely accepted, monitored/updated
	KM processes are reviewed/improved
	KM assessment generates realistic improvement

5. *Testing*: the systematic discovery and debugging of defects
6. *Operations*: the installation, migration, support, and maintenance of complete systems

Building the large system like KB-AMS is in itself not an easy undertaking, which also requires understanding of the environment that the system is to operate within and communication of this understanding to the engineers and designers who ultimately decide what the system should be like.

When implementing the KB-AMS, there may be some problems in terms of the KM level to be encountered, they include:

- lack of clear KM vision and strategy;
- misalignment of KM strategy to business goals;
- absence of a learning culture within the organization;
- no incentives for knowledge creation and reuse;
- negative attitudes towards knowledge sharing;
- absence of continuous top management support;
- technology infrastructure and scalability issues in KM systems; and
- inadequate resourcing.

Such problems make the implementation of KB-AMS be an endless management activity. If the system can be properly implemented and fully comprehended by its users, the service level will be improved.

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Systemic Knowledge Synthesis and Justification

Yoshiteru Nakamori

Abstract We understand that mathematical systems approaches are not sufficient to provide effective answers to contemporary complex problems. The author has been developing a theory of knowledge construction systems that is a systems approach to synthesize a variety of knowledge and to justify new knowledge. The theory consists of three parts that relate to each other, which are: a knowledge construction model, analysis of abilities of actors against social structures, and knowledge justification principles. This theory deals with different types of knowledge integration such as specialized integration, interdisciplinary integration, or intercultural integration.

Keywords Knowledge synthesis • Knowledge justification • Knowledge coordinator

1 Introduction

Recently, a new academic discipline called knowledge science has attracted attention, which is an attempt to make knowledge a target of academic study. The most popular area is knowledge management in knowledge science. In the beginning, knowledge management was a mix of collaboration and document management. After Nonaka (1991) established the discipline in 1991, it included courses taught in the fields of business administration, information systems, management, and library and information sciences (Alavi and Leidner, 1999). Knowledge management is growing rapidly and has attracted considerable interest from the academic community, and much research is emerging every year. Recently, Serenko (2013) summarized the knowledge management field using a meta-analysis of scientometric research.

Wierzbicki (the author of chapters "Systemic Synthesis and Metaphysics: Eastern Versus Western Thinking" and "Evolutionary Knowledge Creation from an Eastern Perspective" of this book) characterized knowledge science as the third

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approach to the question: How is knowledge created? His idea is explained in details in Nakamori (2013). A brief summary is presented below. Historically there have been many diverse attempts to understand how knowledge is created. Generally, until the last decade of the twentieth century we could distinguish two main schools of thinking. The groupings reflect an attitude which leads to the possibility of distinguishing *the context of knowledge discovery* and *the context of knowledge justification or validation*.

The first school maintains that knowledge creation is essentially different from knowledge justification and validation, thus distinguishing the context of discovery and the context of justification or validation. This school also maintains that creative abilities are irrational, intuitive, instinctive, and subconscious. This view is represented by many great thinkers of very diverse philosophical persuasions and disciplinary specialists such as Bergson (1903), Poincaré (1913), Popper (1934), Kuhn (1962), Selye (1964) and Polanyi (1966).

The second school keeps to the old interpretations of science as a result of empirical experience, induction and logics, and refuses to see creative acts as irrational. This school maintains that there is no distinction between the context of discovery and the context of justification or validation, in other words, there is only a joint creative process that is perfectly logically planned, that intuition is only accumulated experience and that revelation (inspiration) is only a revision of hidden assumptions.

We propose a third approach by synthesizing the first and the second approaches. That is, knowledge emerges from creative activities or intuitive (emotional) creative processes; however, the process can be analyzed rationally. The first example is the organizational knowledge creation model (Nonaka and Takeuchi, 1995). This model provides a rational and algorithmic-like recipe for increasing knowledge, using arational abilities of the human mind. According to this idea, Wierzbicki and Nakamori (2006) proposed several academic knowledge creation models, and Tian et al. (2009) examined these models in a graduate university.

At present, however, it is difficult to say that knowledge science has been established as a discipline. Instead, knowledge science is a problem-oriented interdisciplinary or trans-disciplinary academic field, related to methodologies, techniques, tools, or systems, for knowledge creation/synthesis and knowledge verification/justification. The special feature of knowledge science is that it deals with knowledge of hard and soft systems, objective and subjective, explicit and tacit, distributed and shared. The distinctive difference with information science is that knowledge science manages knowledge or information that depends on the person.

Now let us consider the special features of innovation through knowledge science. Knowledge science contributes the creation of innovation in various fields, including academic disciplines and human societies. But for social innovation we must use knowledge of less universality, which is related to humans who have their own intention. We must utilize such knowledge, understanding its logicality and effectiveness. So innovation through knowledge science is differentiated from traditional approaches in terms of whether or not we understand the principles of knowledge creation and justification.

Here arises two questions: (1) How can we synthesize objective and subjective knowledge? (2) How can we justify the synthesized knowledge? This chapter will try to answer these questions.

2 Knowledge Synthesis

For social innovation we must use knowledge of less universality, which is related to humans who have their own intention. We must utilize such knowledge, and understand its logicality and effectiveness. A theory of knowledge construction systems proposed in Nakamori et al. (2011) takes this point of view, and suggests how to construct the necessary knowledge to solve contemporary complex problems. The theory consists of three parts:

1. Knowledge construction (integration/synthesis/creation) model;
2. Knowledge collection capabilities (actions) under social structures; and
3. Knowledge justification (validation/verification) principles.

This theory might be useful, especially for a young researcher, when writing a research proposal:

- How to intervene in the problem situation;
- How to collect scientific knowledge as well as social knowledge;
- How to create your own knowledge; and
- How to synthesize and justify knowledge systemically.

This section explains the knowledge construction model briefly, and proposes a new method of knowledge synthesis based on the idea of *Yin-Yang*, a Chinese philosophy.

2.1 A Knowledge Construction Model

A knowledge construction model (Nakamori, 2000, 2003) is a procedural (but virtually systemic) approach to knowledge creation. The five ontological elements or subsystems of the knowledge synthesis model are:

- *Intervention*: the will to solve problems;
- *Intelligence*: existing scientific knowledge;
- *Involvement*: social motivation;
- *Imagination*: an important aspect of creativity; and
- *Integration*: systemic knowledge.

If you have a problematic situation, you have to structure the situation and identify problems at *Intervention*, which includes requirements and perspectives, as well as ideas on how to collect knowledge, how to create knowledge, how

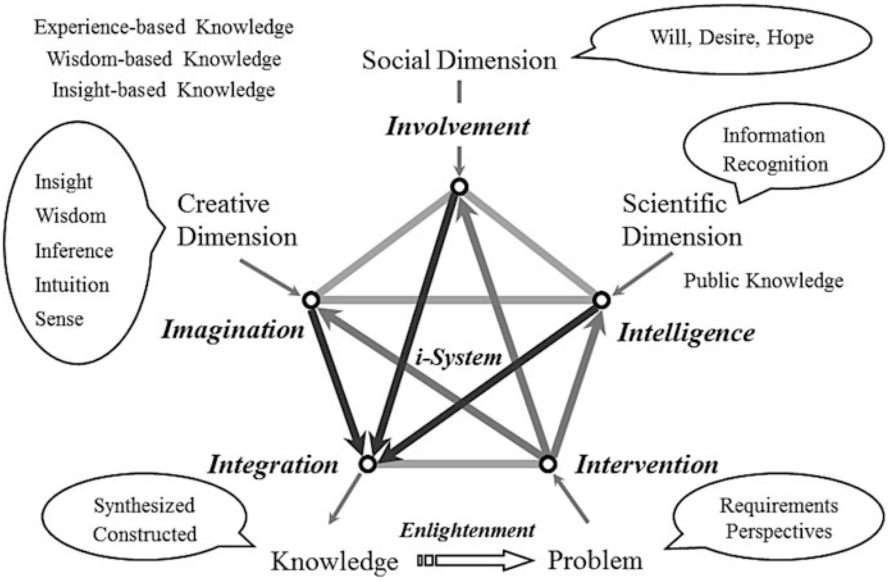

Fig. 1 A knowledge construction mode called the *i*-System

to integrate knowledge, and how to justify the results. As shown in Fig. 1, at *Intelligence*, you collect objective knowledge and at *Involvement* and *Imagination* you collect experience-based knowledge, wisdom-based knowledge, or insight-based knowledge, and finally at *Integration* you synthesize knowledge and justify created knowledge. Here you usually find a new problem by enlightenment.

We tried to interpret the *i*-System from the viewpoint of sociology (Nakamori and Zhu, 2004), where the scientific, social, and creative dimensions are regarded as the scientific-actual, social-relational, and cognitive-mental fronts, respectively, as shown in Fig. 2. These fronts correspond to the structures of our society, which are the systemic, collective contexts and their underlying principles which constrain and enable human action.

As shown in Fig. 2, in the scientific-actual front we consider established theories, concepts, categories, and dominant design, etc., in the social-relational front we consider social norms, values, expectations, obligations, and power relations, etc., and in the cognitive-mental front we consider structured mentality, habitus, assumptions, and beliefs, etc.

In this interpretation, the nodes *Intelligence*, *Involvement*, and *Imagination* in Fig. 1 are regarded as agencies of actors. Agency is the capability with which actors, who are socio-technologically embedded, reproduce and transform the world. The *Intelligence* agency includes logic, experience, technical skills, intelligent quotient, and rationality, etc., the *Involvement* agency includes interest, emotion, intent, faith, trust, social capital, social skills, and political skills, etc., and the *Imagination* agency includes intuition, innocence, ignorance, and the skill of enlightenment, etc.

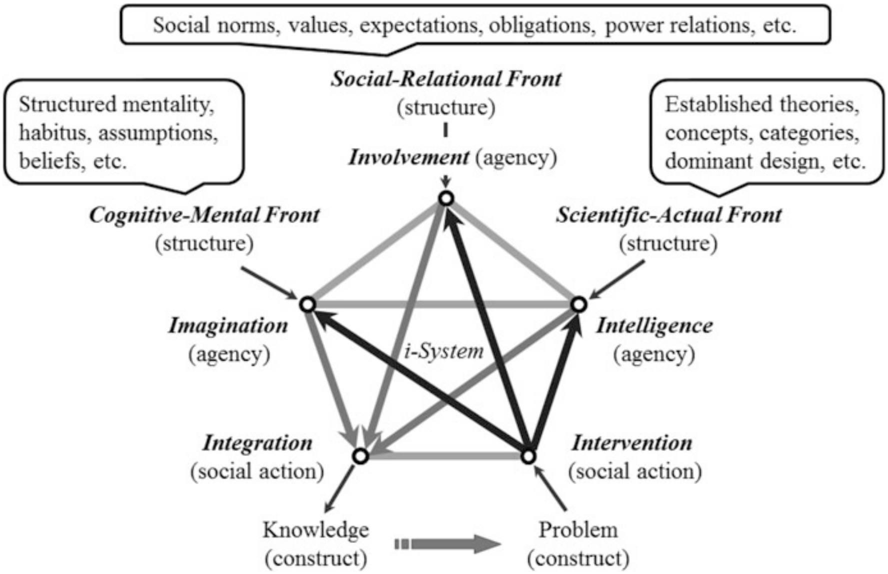

Fig. 2 A sociological interpretation of the *i*-System

The remaining two nodes in Fig. 1, *Intervention* and *Integration*, are a pair that cannot be disconnected. A famous Chinese philosopher Wang Yangming (1472–1529) said that *knowledge and action are but one*, implying that knowledge is not knowledge if you do not use it. Here we interpret this from a constructivist viewpoint. If you want to find good knowledge, you have to set up a good problem. But if you wish to set up a good problem, you have to have some knowledge already.

2.2 An Approach to Knowledge Synthesis

A major problem in Fig. 1 is how to synthesize the different types of knowledge. In actual fact, new knowledge must emerge through the interaction of knowledge from three dimensions. Figure 3 shows the *Yin-Yang* approach to systemic knowledge synthesis. First we consider the interaction between society and science in the dimension of explicit knowledge. Then we consider the interaction between individuals and the whole in the dimension of tacit knowledge. Thus, we use the knowledge from the social dimension twice, since this knowledge consists of both explicit and tacit knowledge. We finally consider the interaction between tacit and explicit knowledge in the epistemological dimension.

We can use the kind of synthesis diagram as shown in Fig. 4. Using a mechanistic view or a reductionist stance, we synthesize knowledge from scientific and social dimensions, and obtain knowledge based on objective data or widely recognized

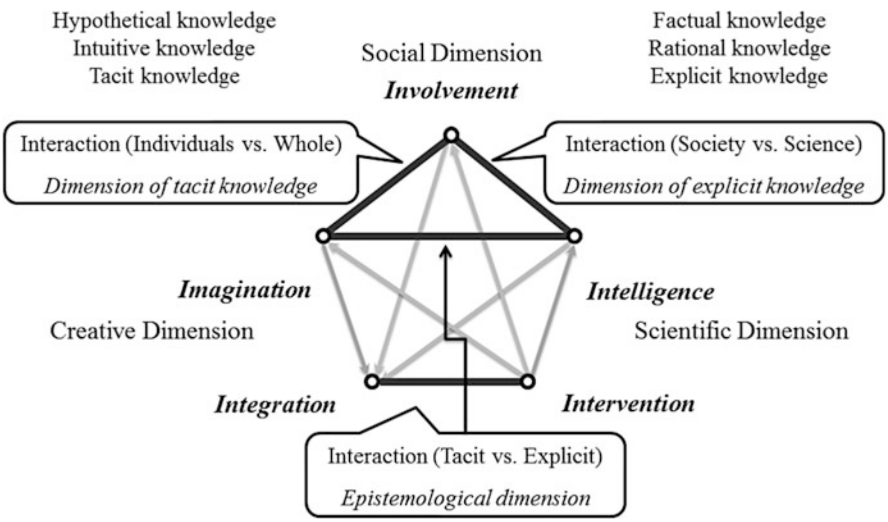

Fig. 3 Synthesis of every two items

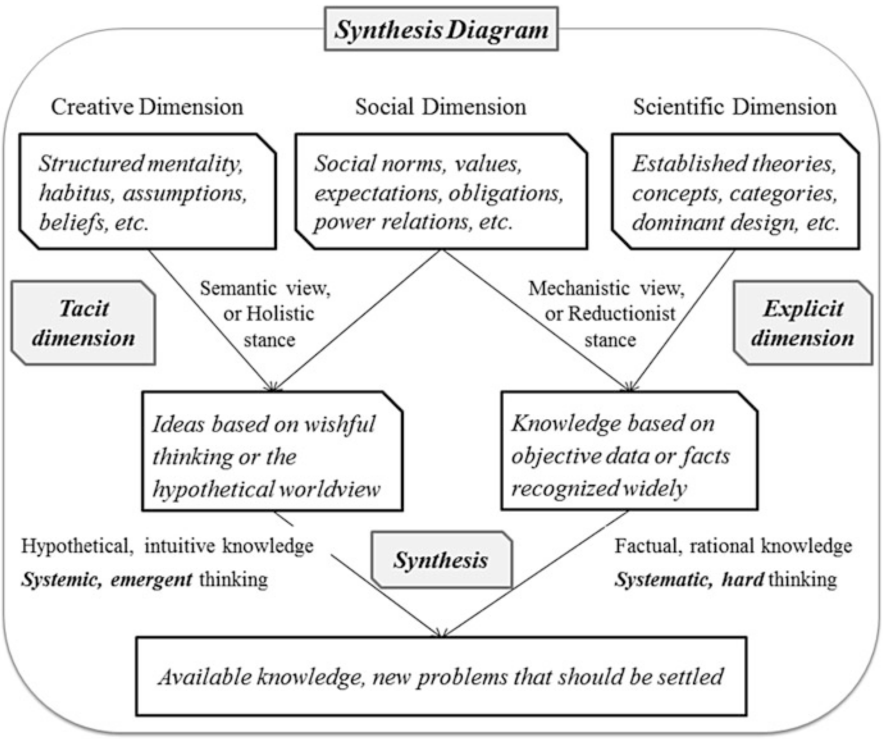

Fig. 4 A knowledge synthesis diagram

facts. Using a semantic view or a holistic stance, we synthesize knowledge from the social dimension and the creative dimension, and obtain ideas based on wishful thinking or a hypothetical worldview. Thus we create factual, rational knowledge through systematic, hard systems thinking in the dimension of explicit knowledge, and hypothetical, intuitive knowledge through systemic, emergent thinking in the dimension of tacit knowledge. Finally we synthesize these two types of knowledge to obtain the summarized knowledge, and the new problems that should be established as such.

Yin and yang (dark and light) are not opposing forces, but complementary opposites that interact within a greater whole, as part of a dynamic system. We need to synthesize *yin and yang* with systemic thinking, while paying attention to the fact that they never merge into a synthesis. The loss of opposites means death. How can we understand the sentence above, which is somewhat contradictory? One of the main theories in knowledge science provides a hint: *new knowledge is created through the interaction between tacit knowledge and explicit knowledge*. Another hint lies in systems science, that is, its fundamental concept of emergence, which is the property of a system as a whole that is irreducible to its parts: *A system to us is a set of components, connected such that properties emerging from the system cannot be found in its components*. We cannot analyze it, but perceive its complexity with systemic thinking.

2.3 An Illustrative Example

As a concrete example of knowledge synthesis, let us consider demand forecasting of food sales in a supermarket chain. The following are the concerns of the food sales department manager:

1. Much food remains unsold every day. The manager wants to reduce the cost of waste disposal. On the other hand, some food is often sold out before closing. It would be possible to sell more if it was available. Some customers go to other stores. The manager's conflicting objectives are: Minimization of waste loss and minimization of opportunity loss.
2. About 20 % of the food is determined by the supermarket headquarters. But this food accounts for 80 % of sales. About 80 % of the food is determined by this supermarket. But this food accounts for only 20 % of sales. The manager's efforts are not rewarded very much: A lot of management is involved but there is only a small contribution to sales.
3. The manager can use a demand forecasting model that predicts the amount of food demand under certain conditions (explicit knowledge). However, because it takes a week to receive food after the order, the model requires the exact conditions (weather, events, etc.) one week ahead. However precise conditions after one week cannot be obtained. Also, the model cannot cope with a sudden change of weather or other factors. The prediction might be accurate, but it is not

flexible. The manager can also use an experienced person (an expert) who has the ability to predict the approximate amount of demand (tacit knowledge). To some extent, the expert may stock appropriately, to cope with possible changes of weather or other possible occurrences. This expert intuition is not as accurate as the mathematical model, but the risk might be lower. How can the manager use these two tools in a mutually complementary manner?

4. What should the manager do if some food is likely to be unsold? The manager can make the price cheaper. In some supermarkets, boxed meals may become half price after 5:00 p.m. What should the manager do when a certain food is about to be sold out? If the same food is left in a chain store nearby, the manager can ask the manager of that store to send the food, or the manager can provide an alternative food. Daily management experience is internalized in the person in charge as empirical knowledge. On the other hand, it is difficult to reflect such experience in a computer system.

The tasks of the food sales department manager are shown in Fig. 5.

Interdisciplinary integration of knowledge is needed to help the manager as follows:

- *Intervention*: To deal with a demand prediction problem, a new approach was necessary to integrate the systems engineering approach and the knowledge management approach.
- *Intelligence*: We built a mathematical demand prediction model based on past sales data, and developed a system for risk management to cope with waste and opportunity losses.

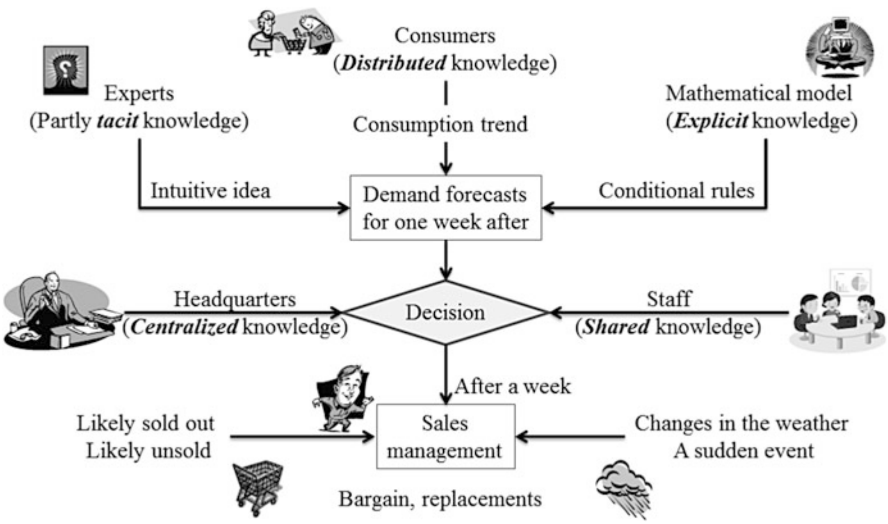

Fig. 5 The tasks of the food sales department manager

- *Involvement*: We analyzed consumers' opinions to investigate important factors that affect purchasing decisions, which cannot be found from the point-of-sale data or from the opinions of managers.
- *Imagination*: We collected managerial knowledge from competent managers, which included factors regarding decisions on types and amounts of goods, and decisions regarding advertising promotions, taking into account special circumstances.
- *Integration*: The final decision should be made by a competent manager based on the knowledge from the above three subsystems.

We actually considered three types of knowledge in Fig. 5, which are explicit knowledge (a mathematical model), tacit knowledge (experts' ideas), and distributed knowledge (consumers' opinions).

- A demand forecasting model was developed by grouping the date into clusters with the same conditions (Ohn Mar San et al., 2003, 2004) and extracting distributions of sales amounts extracted under those conditions. Then, risk analysis was performed by introducing two measures: waste loss (loss due to discarding unsold product) and opportunity loss (loss due to being sold out). The expectation curves of waste loss and opportunity loss are drawn depending on conditions such as weather, temperature, and events, etc., and the optimal point to balance the two losses is detected.
- We conducted an interview survey with ten prepared food department managers and gathered managerial knowledge for the prepared food department. We used the semi-structured interview method, which is flexible, allowing new questions to be brought up during the interview as a result of what the interviewee says. After making a transcript of the information from the interview, we structured the knowledge using the affinity diagram (Kawakita, 1969), which allows for large numbers of ideas to be sorted into groups, based on their natural relationships, for review and analysis. We finally summarized a system of managerial methods, including decision-making on product type and amount, ordinary promotion activities, ad-hoc responses, activities after closing, and fundamental information.
- In order to investigate the purchasing behaviors of consumers, we conducted a web survey of 1,000 people from 16 to 69 years of age living in Tokyo, who make prepared food purchases two or more times a week at supermarkets. We summarized the typical opinions from the survey, and added this knowledge to the system of managerial methods.

Figure 6 shows these activities to support the manager.

We need to integrate or synthesize knowledge from the three dimensions or fronts. In any case, consumers' preferences are reflected in the demand prediction model and in the management methods. Information and knowledge will be used in decision-making on-site by a competent person in charge. Figure 7 shows a simple example of knowledge synthesis.

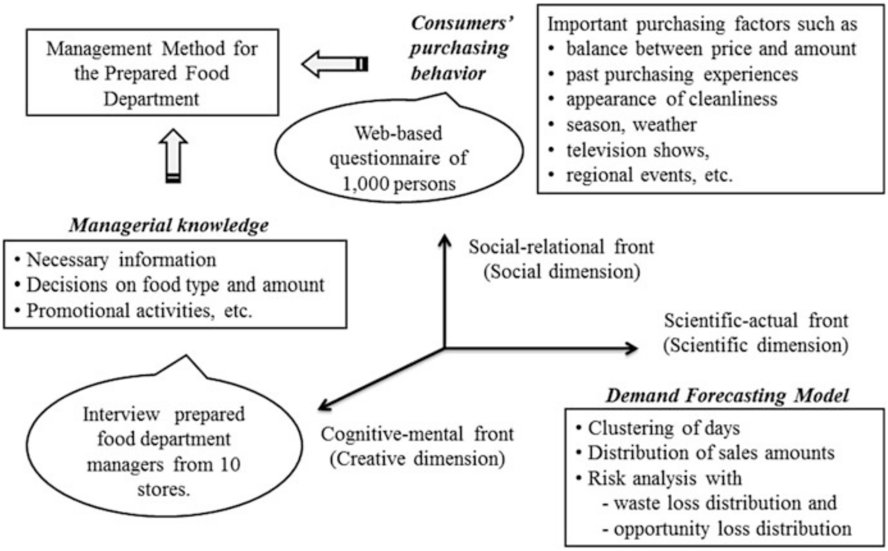

Fig. 6 The necessity of interdisciplinary knowledge synthesis

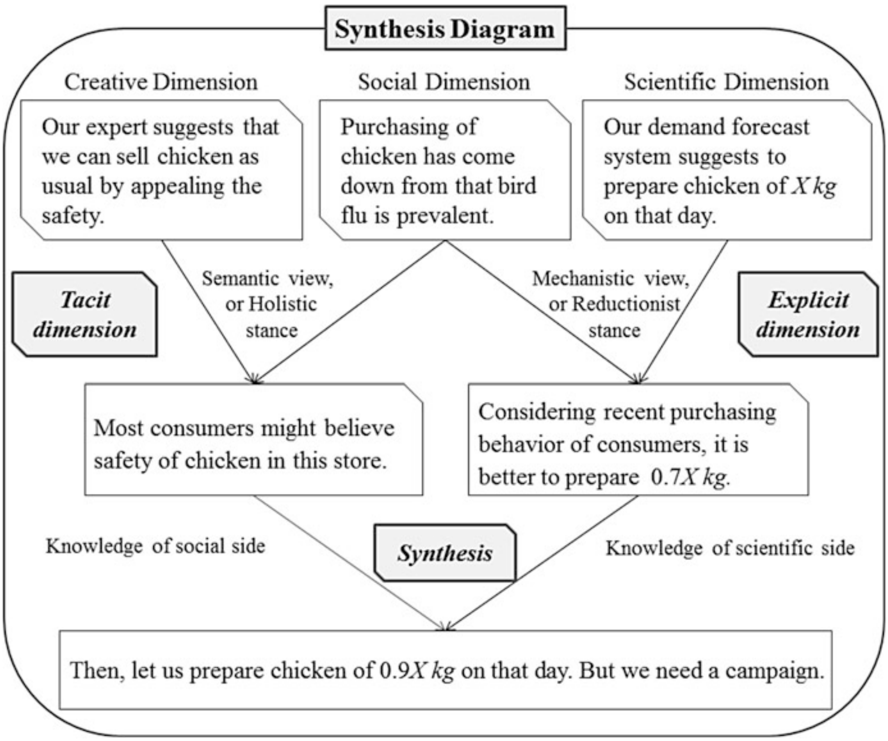

Fig. 7 An example of everyday knowledge synthesis

3 Knowledge Justification

Now, let us consider knowledge justification principles. The science of the industrial civilization era perceived the world as a system that could be explained by the behavior of its elementary parts or particles. The reductionism, that is, the reduction of the behavior of a complex system to the behavior of its parts is valid only if the level of complexity of the system is rather low. With the very complex systems of today, mathematical modeling, biological sciences but also technical and informational sciences adhere rather to the emergence principle.

The emergence principle stresses the emergence of new properties of a system with an increased level of complexity, properties which are qualitatively different to the properties of its parts. Together with those new properties, new concepts are necessary, irreducible to concepts and properties at a lower level of complexity. Emergence is a feature that appears in the system as a whole through the interaction of system elements. It cannot be explained by the features of system elements. Human designed machines do not have such a feature; therefore they can be analyzed by reductionism.

This section first considers the existing knowledge justification principles, and then proposes new justification principles suitable in the knowledge-based society.

3.1 Existing Justification Principles

The reduction principle in the industrialized society is being destroyed. This has led to a divergent development of separate justification principles for the three cultural spheres: hard and natural sciences, technology, and social sciences and humanities. The first one is a paradigmatic position in the sphere of natural sciences. Theories that contradict the paradigm (belief in a certain era) are rejected, even if they would better fit observations or empirical outcomes. The second one is the falsificationism in the sphere of technology. Since theories might be formed by inadequate induction, they should be subjected to tests aimed at disproving the theories. The third one is most radical, which is postmodern subjectivism. Because it is made by people, knowledge is subjective. The justification is carried out through inter-subjective conversations.

- *Paradigmatism*: This is related to the works of Kuhn (1962), and particularly his concept of scientific revolutions and a normal, paradigmatic development of science between these revolutions. Theories should fit observations or outcomes of empirical tests. Although theories that are consistent with the paradigm are welcome, theories that contradict the paradigm are rejected, even if they would better fit observations or empirical outcomes.

- *Falsificationism*: Opposing the Kuhnian paradigmatic position was the Popperian falsification position or falsificationism. In Popper (1934), the main goal was to show the logical inconsistency of the positivistic concept of induction from facts. Theories might be formed by inadequate induction, or by any other intuitive illumination. They should be falsified, and subjected to tests aimed at disproving the theories.
- *Postmodern subjectivism*: The most radical position with respect to knowledge validation developed in the social sciences and humanities together with post-modernism; we shall call it the postmodern subjectivist position or postmodern subjectivism. Knowledge is constructed by people, thus subjective, and its justification occurs only through inter-subjective discourse.

3.2 Evolutionary Constructive Objectivism

We proposed *evolutionary constructive objectivism* as a possible knowledge justification theory in the knowledge-based society, and adopted it as one of the elements of the theory of knowledge construction systems. It was originally considered for testing knowledge creation theories in Wierzbicki and Nakamori (2007, 2008). It consists of three principles:

- *Evolutionary falsification principle*: Hypotheses, theories, and models evolve, and the measure of their evolutionary fitness is the number of either attempted falsification tests that they have successfully passed, or of critical discussion tests leading to an inter-subjective agreement about their validity. If you cannot show that it is wrong, you have to admit it tentatively.
- *Emergence principle*: New properties of a system emerge with increased levels of complexity, and these properties are qualitatively different from, and irreducible to, the properties of its parts. We should not hesitate to make a new concept with insight. If you can explain it with existing knowledge, can you call it new knowledge?
- *Multimedia principle*: Words are just an approximate code to describe a much more complex reality. Visual and nonverbal information in general is much more powerful and relates to intuitive knowledge and reasoning. We should stimulate maximum creativity using multiple types of media. Have you tried to make people understand by using all possible media?

Figure 8 shows where to use these principles in the *i*-System. Justification usually follows the paradigm when you submit a paper to an academic journal. Your paper is evaluated from the viewpoints of novelty, usefulness, and logicality. But here we emphasize these principles to evaluate the emerged new knowledge in treating a complex, difficult social problem.

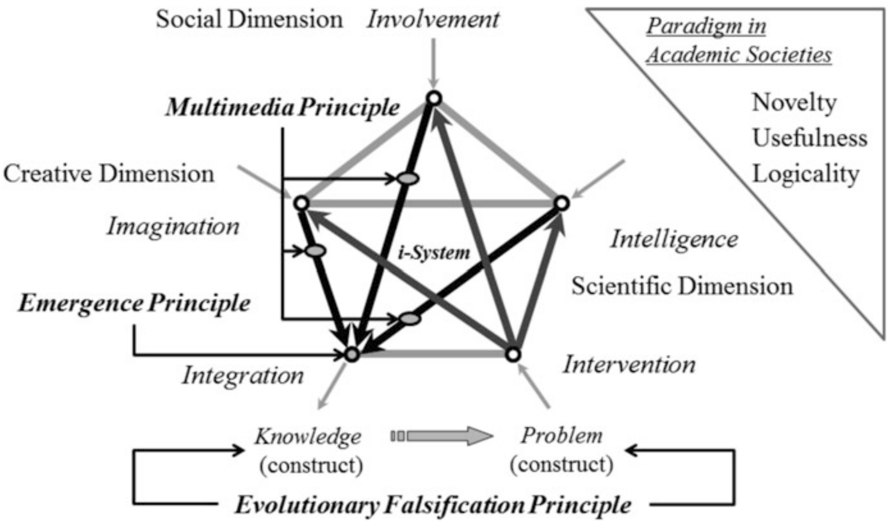

Fig. 8 Justification of collected and synthesized knowledge

4 Concluding Remarks

Why not knowledge verification but justification? Because time is necessary for verification of new knowledge in the real society, new knowledge has to be justified before putting it into practice (If we do not execute it, knowledge cannot be verified). The importance of knowing the mechanism of knowledge creation and justification is quite important when our project treats emotional or intuitive knowledge. However, the theory of justifying or verifying new knowledge in the knowledge-based society has not yet been established. Our efforts should be extended to invent such a theory.

The science of knowledge science is not science in the narrow sense. It is important to acquire a systemic view through trained intuition and using methods of justifying new knowledge without simply relying on the scientific method in the narrow sense, because knowledge science manages knowledge that depends on the person. Systematic means that something is well organized or arranged according to a set plan and or is grouped into systems. Conversely, systemic means something matters to the entire system. One of the main tasks of knowledge science is to support people to create their systemic view.

Appendix: Some Notes on Knowledge Science

Knowledge synthesis is one of the major topics in knowledge science that is an emerging discipline resulting from the demands of a knowledge-based economy and information evolution. Its definition and roles are summarized below, emphasizing its importance in liberal arts for graduate students of any fields of study. Knowledge science is expected to promote co-evolution of disciplines as well as to train the thinking-power and skills of young students.

If we are asked what knowledge science is or should be, we might prepare the following answers:

1. It is a field of study that is related to how to create knowledge or how to synthesize a variety of knowledge. Many researchers have been developing models, environments, techniques and support systems for knowledge creation.
2. It is a field of study that is related to how to accumulate knowledge and how to effectively utilize knowledge. The School of Knowledge Science at JAIST has been concentrating on the management of knowledge, technology and services, as special application fields of knowledge science.
3. It is a field of study that is related to how to verify/justify knowledge. We need to pay more attention to principles of knowledge verification or justification, because we have to treat knowledge of less universality in knowledge science.
4. It is a field of study that is related to how to integrate existing fields of studies. Knowledge science is expected to integrate existing fields of studies in order to solve large-scale, complex problems in the twenty-first century.

Roles of knowledge science can be summarized as follows:

1. Knowledge science provides the data/information/knowledge and even a wisdom management methodology to those who wish to change society for the better.
2. Knowledge science teaches the knowledge creation/verification methodology to those who wish to make developments in natural science, technology, or social science and humanities, including knowledge science itself.
3. Knowledge science is an important liberal art in the twenty-first century, which promotes co-evolution of disciplines and leads to socio/technical innovations.

It is said that complex problems of twenty-first century cannot be solved by only one expert; instead they must be solved through the cooperation of multiple experts beyond the fields of social and natural sciences. The mission of knowledge science includes the development of methodologies to support the cooperation of different fields to co-create new value/knowledge. The methodologies of knowledge science are essential skills for professionals in the twenty-first century to co-create knowledge in organizations or societies.

We feel there is a necessity to develop a human ability enhancement program based on knowledge science methodologies. That is, an education program to cultivate interpersonal social skills and self-control capabilities, and enhance the ability to design the career of an individual student, by utilizing methodologies based on knowledge science, and promoting interactions between a variety of students, using two-way lectures, active learning, group work, and workshops, etc.

We also feel there is a necessity to nurture competent scientists or engineers, who will play active roles globally with their abilities to create innovation, while utilizing the individual excellence they have gained by training in a specialty. Most traditional lectures follow a lecture style in which a lecturer tries to transfer knowledge to

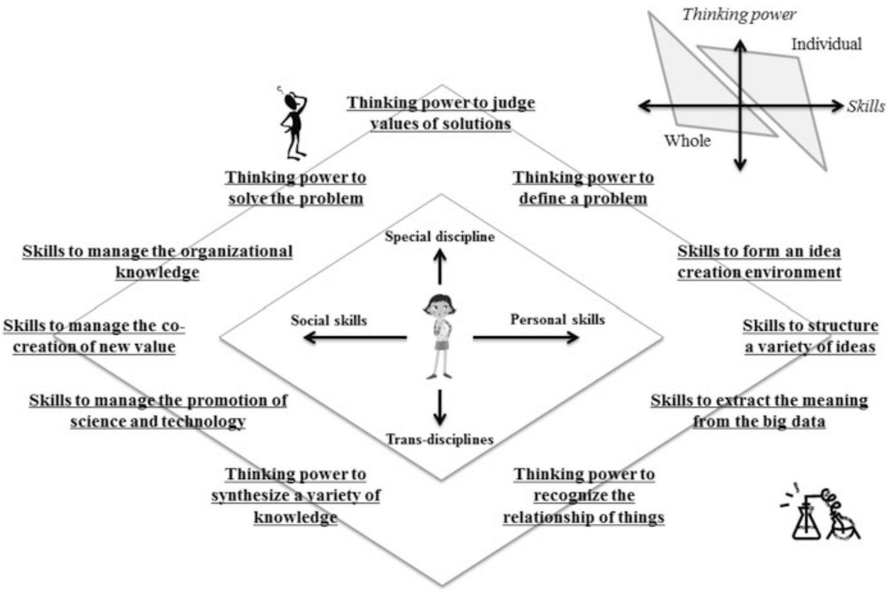

Fig. 9 Thinking-power and skills necessary to be trained in a graduate school

students unilaterally. Active learning refers to a lecture style that incorporates the active learning of students, utilizing project/problem based learning, discussions and presentations. Human ability is a very important skill in making a career, which consists of three elements: intellectual capacity, interpersonal social skills, and self-control capabilities. But, the current graduate education does not necessarily provide a well-balanced educational opportunity to develop these three capabilities.

Knowledge science methodology could be the most influential liberal art in the twenty-first century that promotes the co-evolution of disciplines and leads to socio/technical innovations. Figure 9 shows the thinking-power and skills necessary to be trained in a graduate school.

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Community Service Systems Development

Yoshiteru Nakamori

Abstract This chapter presents an application of the theory of knowledge construction systems, introduced in the previous chapter, to the development of community service systems. Regional development and vitalization is a major social problem especially in an aging society. Various activation projects by local governments, enterprises, or citizens can be regarded as service providing systems in which value will not be created unless there is a big contribution of users. This chapter proposes a methodology of developing community service systems based on the theory of knowledge construction systems, emphasizing service value co-creation between providers and users. As a concrete example of this methodology, this chapter introduces a social experiment for developing a community health care system.

Keywords Community service system • Knowledge management • Value co-creation

1 Introduction

Recently, the term *service system* has often appeared in the context of service science, service management, service marketing, or service engineering (for example, see Maglio et al., 2010; Looy et al., 2003; Srinivasan, 2004; Dustdar and Li, 2011). A service system can be defined as follows when focusing on the emergent property of a system: A service system consists of many elements in the form of people and techniques, which are designed and combined to provide consumers tangible/intangible products with value emerging through the interaction of the elements. Recently, however, the concept of value co-creation between providers and consumers has been highlighted. This tendency may indicate an attempt to exceed the conventional systems concept.

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To do so, the service system must be diverse, so that it can respond flexibly to the changeable needs of customers. In the customization of cars or computers, it is possible to consider that such products are provided to satisfy customers' desired level of quality, which is, however, enabled simply by combining prepared parts. This is a way that attempts to maximize the utility of customers with a corresponding range of providers. The value co-creation with consumers includes the maximization of consumers' utility by dynamically changing production elements and their combinations. However, even the provider must be able to decide that there is a valuable benefit in keeping good customers, even at the expense of others.

In this way, the pursuit of profit over a certain time span, rather than the pursuit of short-term profit, has been highly sought after recently, while economic activity will obtain as much benefit as possible for the lowest cost possible. This chapter will discuss a theory of service systems construction, in which the service value is co-created by the service providers such as local government and the service recipients such as citizens.

Firstly, some practices underlying the debate will be introduced. We have offered public lectures named *Regional Activation Systems Theory* since 2006, in which we provide general remarks, detailed expositions, and success cases, and then we ask participants to discuss actual regional vitalization plans in groups. This activity has produced a number of success stories already, some of which will be introduced later in this chapter. In parallel, graduate students in the School of Knowledge Science are developing methods and methodologies to create and validate knowledge for vitalizing local areas, using the technique of participant observation (Nakamori, 2011a; Cabinet Office, 2013).

Secondly, the theory underlying the debate will be introduced. This chapter considers value creation as knowledge creation related to mechanisms or actions that produce it. Nowadays, we can see a number of theories for knowledge creation that originated from the organizational knowledge creation theory (Nonaka and Takeuchi, 1995) that became an academic factor in the establishment of the School of Knowledge Science at the Japan Advanced Institute of Science and Technology (Wierzbicki and Nakamori, 2006, 2007). This chapter will develop a theory of community service systems construction using *the theory of knowledge construction systems* (Nakamori et al., 2011; Nakamori, 2010), which has developed as an approach to knowledge science and knowledge management from systems science and engineering (Nakamori, 2011b, 2013).

The next section will introduce the history of research and education in the School of Knowledge Science, and the theory and practice of regional revitalization in particular. Then, after having considered approaches to service value co-creation, the chapter will discuss the construction of regional social service systems, based on the practical example of a regional health care system.

2 A Practical Background of Service Systems Development

The root of the service system construction theory to be discussed in this chapter can be traced back to the organizational knowledge creation theory (Nonaka and Takeuchi, 1995), which has been elaborated on in the School of Knowledge Science of the Japan Advanced Institute of Science and Technology. We have been working on regional revitalization/activation problems such as a practical application of the theory in the community. This section will present an overview of the efforts toward regional revitalization/activation as well as an overview of the School.

2.1 Knowledge Science Research and Education

The School of Knowledge Science at the Japan Advanced Institute of Science and Technology is the first academic institution in the world to make knowledge a focus of science. Research and education have centered on knowledge management evident from the fact that Ikujiro Nonaka[1] was appointed as the first dean in 1998. From around 2002, the School adopted technology management and tried to expand its research and education to corporate management based on knowledge called technology. Stemming from social momentum, the School began adult education at its Tokyo Satellite campus. Then, from around 2009, the School extended its research and education to service management, which can be regarded as integrated research from three fields within the School: management science, information science, and systems science.

Put simply, knowledge science is a field of research and education related to methodologies, techniques, and systems for knowledge creation and verification. However, at present, knowledge science is more a problem-oriented interdisciplinary academic field than a single discipline. In the near future, we must establish a research and education field as a system of trans-disciplinary academic fields. The problem lies in its mission, which this chapter tentatively defines as follows: The mission of knowledge science is to organize and process both objective and subjective information in society (especially, information that depends on individuals), and return it to society adding new value/knowledge to it. Here, information that depends on individuals has been added to discriminate knowledge science from information science.

How can we perform the above mission? Firstly, we must focus on observing and modeling the actual process needed to carry out the mission. The first relevant work is the organizational knowledge creation theory by Nonaka and his colleagues, which was actually an academic factor in the establishment of the School of

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[1]Ikujiro Nonaka, also known as 'Mr. Knowledge', is famous worldwide for his theory of organizational knowledge creation.

Knowledge Science. Several knowledge creation models have been proposed since then, and one of them is the theory of knowledge construction systems (Nakamori et al., 2011), which is an approach to knowledge creation theory from a systems science/engineering perspective.

The School is also developing methods to carry out the mission, which are mainly being developed through the existing three fields in the School. These are the fields of business science/organizational theories (practical use of tacit knowledge, management of technology, innovation theory); information technology/artistic methods (knowledge discovery methods, ways to support creation, knowledge engineering, cognitive science); and mathematical systems theory (systems thinking, the emergence principle, socio-technical systems).

Because it is difficult to develop the new academic discipline called knowledge science by integrating the above three fields at the theoretical level, the School is trying to fuse them together at the practical level. Examples are technology management and service management; the latter is the subject of this chapter. One of the School researchers' dreams is to establish a new discipline through these practices.

2.2 The Practice of Constructing Regional Revitalization Systems

The School organized a national project, called the 21st Center of Excellence program, on the *Creation and Practice of Science and Technology based on Knowledge Science* (2003–2008), with the objective of expanding knowledge and technology management in large enterprises to research and education management in graduate schools. Then, we tried to expand our activities to include knowledge, technology, and service management in regional societies, one of which was in offering an open lecture series named *Regional Revitalization Systems Theory* that started in 2006. This was also related to the new mission for universities in Japan to contribute directly to the local community as a knowledge base in the region.

Regional Revitalization Systems Theory is a series of lectures with new features such as the following: Participants include leaders of the community and persons in charge of industry-government-academia collaboration, (for example, local government officials, local business managers, or representatives of NPOs), in addition to our graduate students. Lectures are provided on general theory, regional revitalization policies, and case studies, followed by group work where participants have to propose new regional revitalization plans.

We have been implementing various regional revitalization projects through collaboration with universities, local governments, and private sectors. The major projects are listed in Table 1 (Cabinet Office, 2013).

Table 1 Regional vitalization projects at the Japan Advanced Institute of Science and Technology

Year	Relevant ministry	Group (city)	Contents
2006	Cabinet Office	Environment (Kaga City)	Best Minister Award in a policy competition for regional economy rebuilding
2007 – 2011	Ministry of Education, Culture, Sports, Science & Technology	Traditional crafts (Ishikawa Prefecture)	Traditional crafts innovators training unit in Ishikawa Prefecture (Education of technology management)
2008	Ministry of Environment	Environment (Kaga City)	Excellence Award by the activity 'CO2 reduction through food recycling of civil initiative'
2008	Cabinet Office	Tourism (Kaga City)	Yamanaka Hot Springs regional revitalization plan 'Hometown of lacquer'
2009		Human resources (Nomi City)	'Human resources development for town planning' at a private school
2009	Ministry of Internal Affairs and Communications	Community healthcare (Nomi City)	A remote health monitoring system by 'Mobile phone promotion program'
2009	Ministry of Agriculture, Forestry and Fisheries	Mountainous area vitalization (Hakusan City)	Regional power support in agriculture, forestry and fishing villages
2009		Tourism (Tonami City)	An application business for Italian bio-fango

3 Policy Towards Service Systems Construction

We are developing a theory of regional social service systems construction, based on the accumulated theories and practices of innovation management in corporate management or academic research, and experiences in regional revitalization projects. In other words, we explore the mechanism of co-creating new service value, which cannot be produced by the service provider alone.

3.1 Platform of Theory and Practice

Service science is a new academic field that integrates or comprehensively manages science and technology, sociology, knowledge, etc. as well as managing theories in advanced science and technology. For the purpose of value co-creation, we have to review the local conditions on the basis of scientific evidence, and integrate knowledge beyond positions such as industry, government, or academia, with consideration for and cooperation with citizens. This is true knowledge management, and could become a successful example to contribute to the establishment of service science research infrastructure.

The platform for current research is through the public lecture series *Regional Revitalization Systems Theory* that has been offered every year in autumn since 2006. In this lecture, based on close cooperation with government officials, we have been involved in building a regional environmental improvement system, revitalizing traditional craft industries, constructing a regional health management system, and rejuvenating mountainous, sparsely populated areas, etc. These activities have been highly regarded by local governments, local enterprises, and residents.

However, the central focus for stakeholders has gradually been deviating away from community-based activation, and more towards how to get subsidies. Then, the cycle of launching a new project one after another with the subsidy has occurred, and as a result, a series of projects almost depend on the central government, and the cross-sectional cooperation between projects is very weak. Thus, we are in the middle of autonomous regional revitalization including the creation of new value with organic cooperation.

Figure 1 is an illustration of community service systems construction with the open lecture series *Regional Revitalization Systems Theory* as its platform. Various local issues are discussed through this platform. Knowledge from central and local governments, or knowledge from local residents is synthesized with knowledge from educational institutions, and service systems for real society are produced in sequence. A service systems construction theory is refined while observing such processes, and a new system operates based on it, which is then fed back again into the theory.

3.2 The Challenge for Co-creation of Service Value

There are many service systems, for example, those related to education, health, transportation, hospitality, and utilities, etc. It is not an exaggeration to say that all economic activities are services. When we think about the value of the service, we are able to place them into two distinct groups. One is the group in which the customer pays money for the value of the service, but the customer does not create the value. This group includes the services at restaurants and hotels, etc. For the customer, the money is considered equivalent to the value of the service received.

On the other hand, there is the other group in which a service system cannot create big value unless the user makes an effort. Private supplementary schools are a typical example. Even if you pay the high tuition fees, value is not created unless you do enough personal learning. Hospitals are a similar example, too. Even if you receive appropriate medical treatment and advice from a doctor, unless you take care of your health properly you may need to receive medical treatment again.

In this way, like hospitals, clinics, and sports gyms, there are service systems where the value varies depending on whether you manage yourself according to the advice given. Moreover, like a school, there are service systems that require users' efforts to create value. A community health care system, which will be introduced

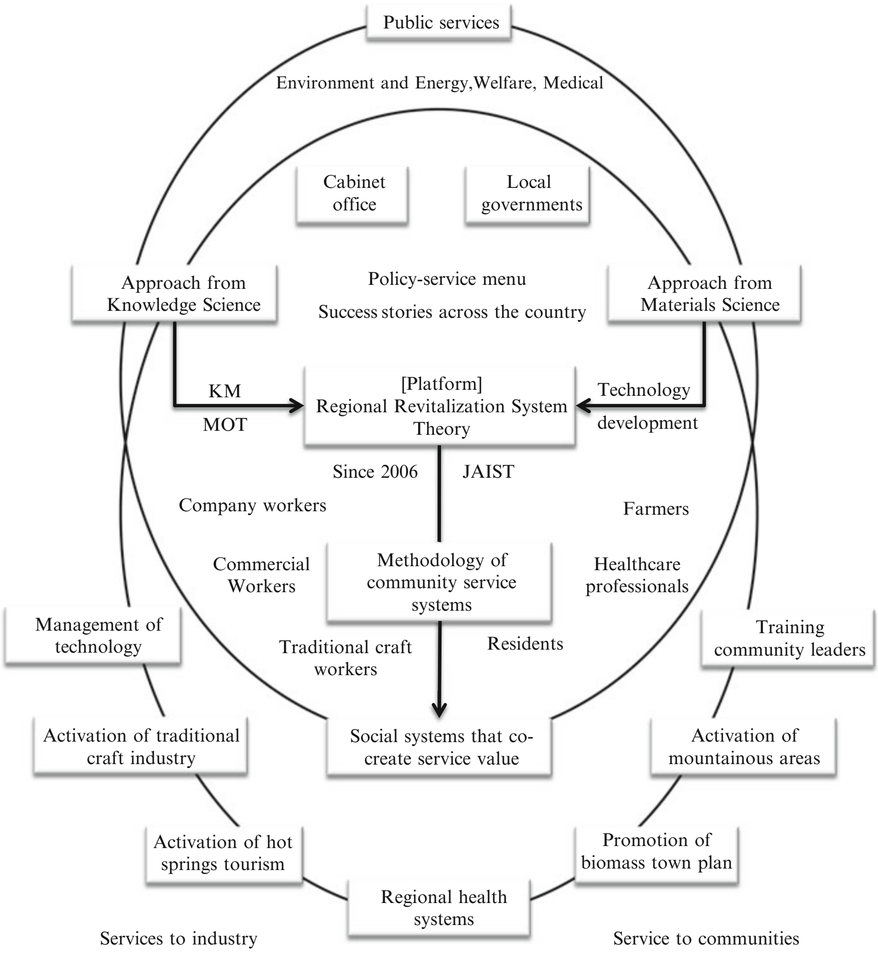

Fig. 1 The concept of developing regional service systems

later in this chapter, is a system that provides service, but is a system that will not succeed unless users of the system contribute towards creating the value. Figure 2 explains such a situation illustratively.

Here, a value co-creation service system indicates a system with the following properties:

- When the cooperation (effort) of the system user is not provided, value does not increase.
- The input element (user) of the system constitutes a part of the system temporarily.
- Value is co-created by the interaction between the elements of the system and the input element (user).

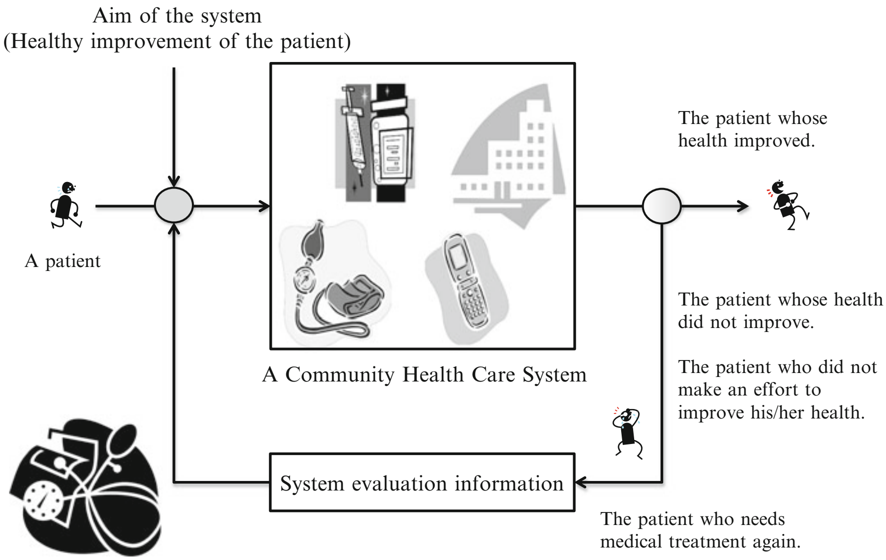

Fig. 2 A community health care system

In this chapter, the value is defined as the new knowledge that a system gains in total, and the knowledge:

- That none of the system's elements had.
- That emerges through the interaction between elements of the system and inputs to the system.

New knowledge, however, does not emerge automatically. Value is not generated just by receiving a service, because you are only being provided with information. The service value is not seen as a level of information. It is seen as the level of knowledge. Energy is needed to convert information into knowledge or wisdom. The energy or capability to do this is also knowledge. However, such knowledge can only be refined through its repeated use. That is the reason why repeated reconstruction of knowledge is emphasized in the previous chapter.

3.3 A Methodology for Developing Social Service Systems

In this chapter, the term *system* is used in the following context: it consists of multiple elements (persons); its properties as a whole (group) cannot be reduced to the nature of its elements (individuals); and even if we examine the elements, we would not be able to discover the nature of the whole. The whole is not simply a collection of elements, rather through their interaction the elements

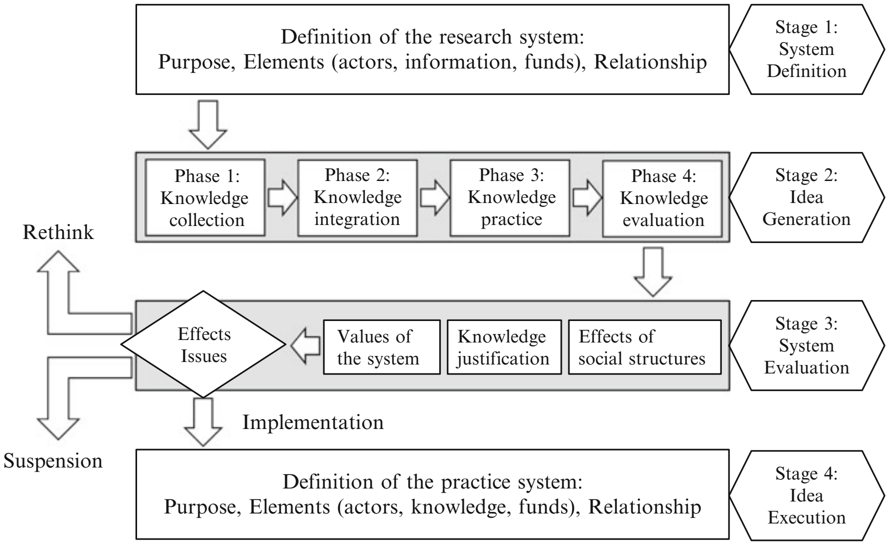

Fig. 3 A methodology of community service system construction

make up the whole. Such a system property is called *emergence*. New knowledge emerges through the interactions between a variety of high-quality information and knowledge. Otherwise, it would already be present in existing information, which would contradict the *new*.

This section proposes a methodology for developing community service systems based on the knowledge reconstruction model, using the presentation of an example. See Fig. 3.

4 A Remote Health Management System

With the increase in the elderly, the government's spending on health care and medical treatment is increasing year by year. Nomi city (where JAIST is located) tried to establish a remote health management system for mild diabetes patients. To develop such a system, we needed to integrate interdisciplinary, or even intercultural knowledge from politics, economics, medicine, bioscience, information technology, and management technology. The main difficulty in this project was to alter the opinions and interests of the system's elements (the mayor, medical doctors, engineers, etc.) as well as the users of the system (patients).

The steps to build a remote health monitoring service system in the city will be explained in the following section, using the knowledge reconstruction model, and its effectiveness and difficulties will be clarified with a social experiment.

4.1 Stage 1: System Definition

The system promotes lifestyle improvements for mild diabetes patients with health monitoring using mobile phones, and whereby reduces the risk of stroke or heart attacks, etc., over their lifetime. Here, diabetes is a serious disease in which there is too much sugar in the blood, and if someone has a stroke, an artery (= tube carrying blood) in the brain suddenly bursts or becomes blocked, so that they may die or be unable to use certain muscles.

The elements (actors) of the system are:

- The city government with its roles of grant applications and overall management;
- A hospital as a representative of medical institutions with its role of system evaluation;
- An NPO in the health network with its role of nutritional guidance by a dietitian;
- An IT company with its role of development and operation of a mobile communications system; and
- A bio-technology device company with its role of development of a simple test system.

Thus, this project is interdisciplinary because it deals with knowledge from systems methodology, knowledge management, information technology, data analysis, materials science, bioscience, medicine and pharmacy.

This project is also inter-cultural because it involves people from different cultures such as city officials, knowledge scientists, information engineers, data analysts, materials scientists, medical doctors, dietitians, and pharmacists.

Users of the system (input/output) are mild diabetes patients who are working during the day. Actions required of them are:

- To monitor diabetes (Urine test results, blood glucose test values)
- To record health management data (Body weight, body fat percentage, number of steps, photos of meals)
- To keep health management notes (Setting and managing goals, recording blood pressure, etc.)
- To transmit the data by mobile phone (Exchanging e-mails with dietitians, or sometimes a medical examination is suggested.)

4.2 Stage 2: Idea Generation

The contents and values of the developing service system will be confirmed through the following four phases:

- Phase 1: Knowledge collection to establish a problem from a complex situation through information coordination.
- Phase 2: Knowledge integration to make a plan based on the problem and adjustment between the parties concerned.

- Phase 3: Knowledge practice to operate the service system, adjusting the system through a social experiment.
- Phase 4: Knowledge evaluation to evaluate the system using the information collected by the social experiment.

The following figures (Figs. 4, 5, 6, 7, 8, 9, 10, and 11) show the knowledge construction processes using the *i*-System and the knowledge synthesis processes with the *Yin-Yang* approach.

4.3 Stage 3: System Evaluation

The characteristics of the service system which has been designed will be examined and justified from the viewpoints of the effects of social structure, justification of new knowledge, creation of the system value, and effectiveness and obstacles for actual implementation.

4.3.1 Effects of Social Structure

The question here is: What are the effects of social structure on the agency and the actions of the actors? We noticed the effects of social structures as follows:

1. (Structure) Scientific-actual front
    - The fact of rapid progress of the aging society promoted the plan.
    - The recognition of the limit of the capacity of medical institutions to cope with the increasing number of patients promoted the plan.
    - Development achievements of the remote health monitoring system using simple bio-sensors and the mobile phone prompted the plan.
2. (Structure) Social-relational front
    - The cooperation between organizations constituting the system and users of the system promoted the plan.
    - The collaborative relationship between the municipal authorities and the medical association, although their duty and responsibility are different, promoted the plan.
    - The regulation of remote medical treatment of the doctor by law obstructed the plan promotion.
3. (Structure) Cognitive-mental front
    - The worry of people that the local medical institutions will not be able to cope with the aging society promoted the plan.
    - The intention of people that the society should maintain the health of residents promoted the plan.
    - The recognition of people that the remote health monitoring is a promising attempt promoted the plan.

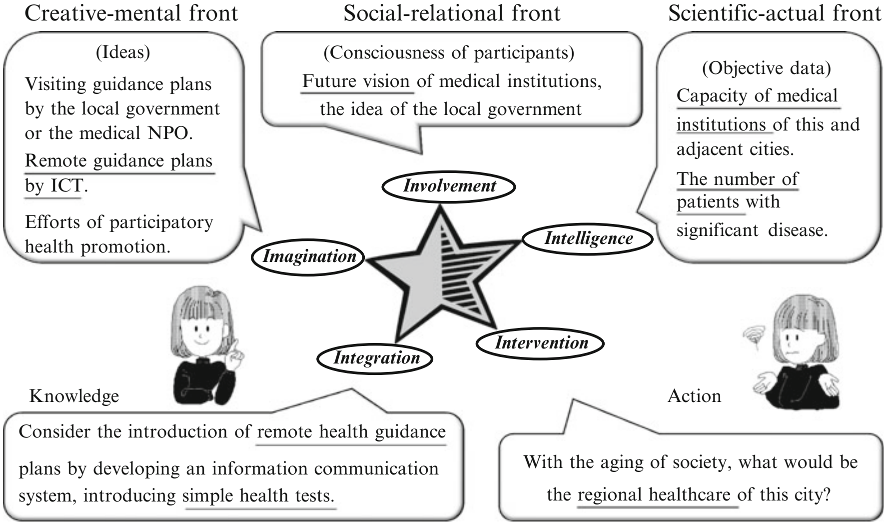

Fig. 4 Knowledge construction process in Phase 1: knowledge collection

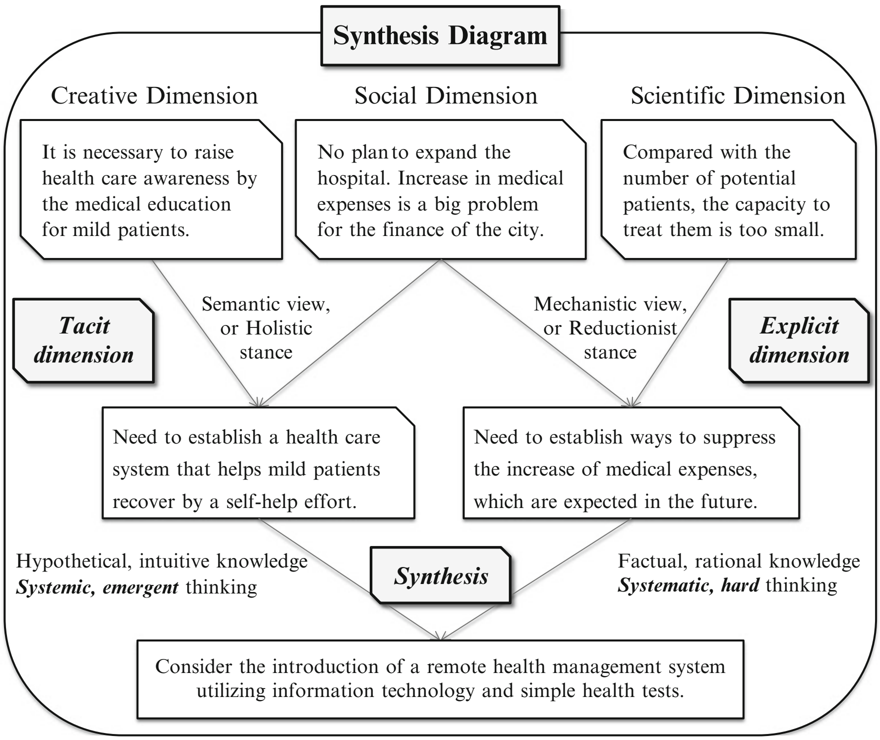

Fig. 5 Knowledge synthesis process in Phase 1: knowledge collection

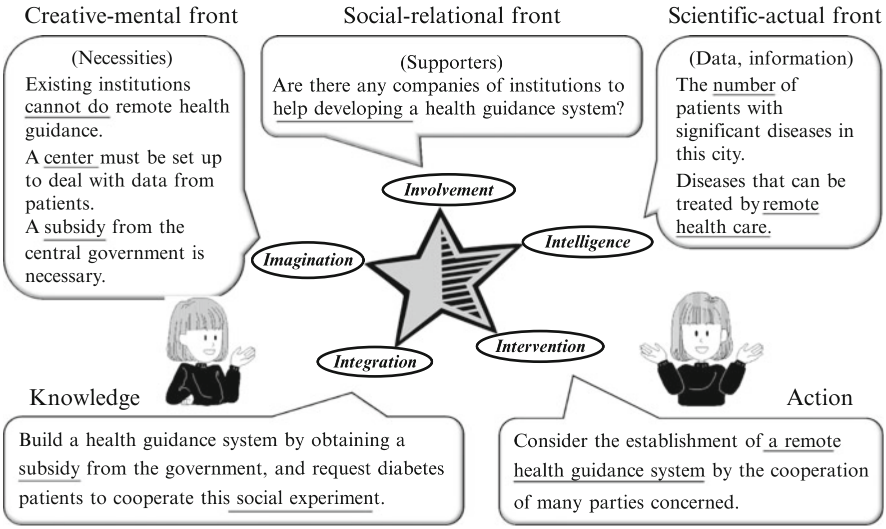

Fig. 6 Knowledge construction process in Phase 2: knowledge integration

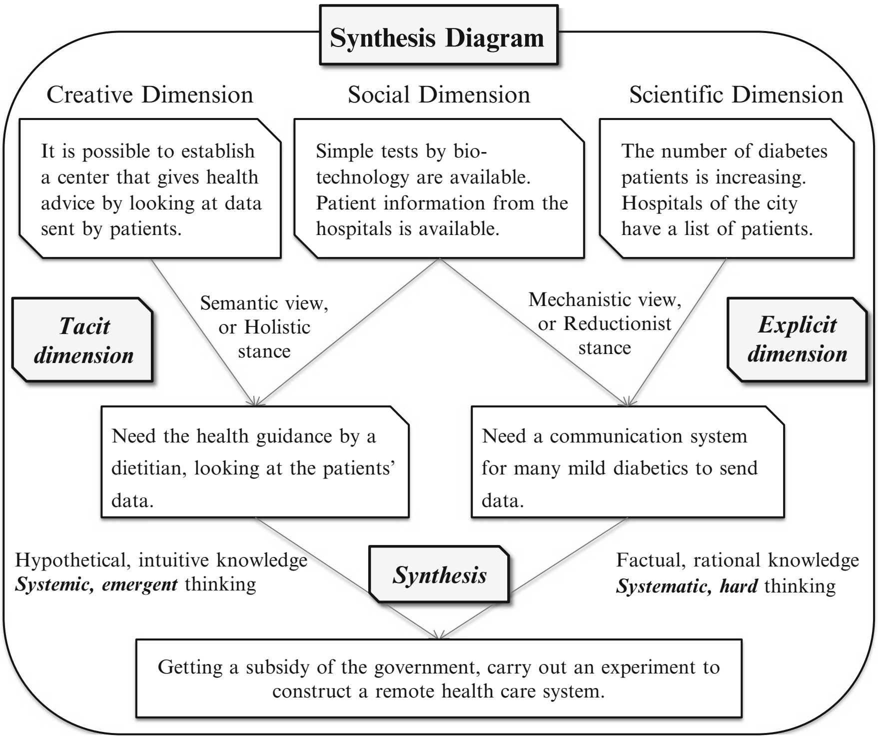

Fig. 7 Knowledge synthesis process in Phase 2: knowledge integration

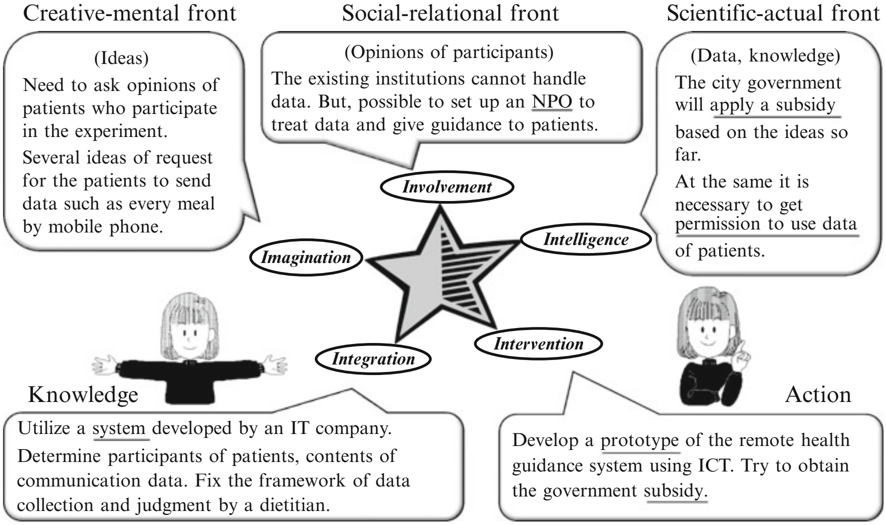

Fig. 8 Knowledge construction process in Phase 3: knowledge practice

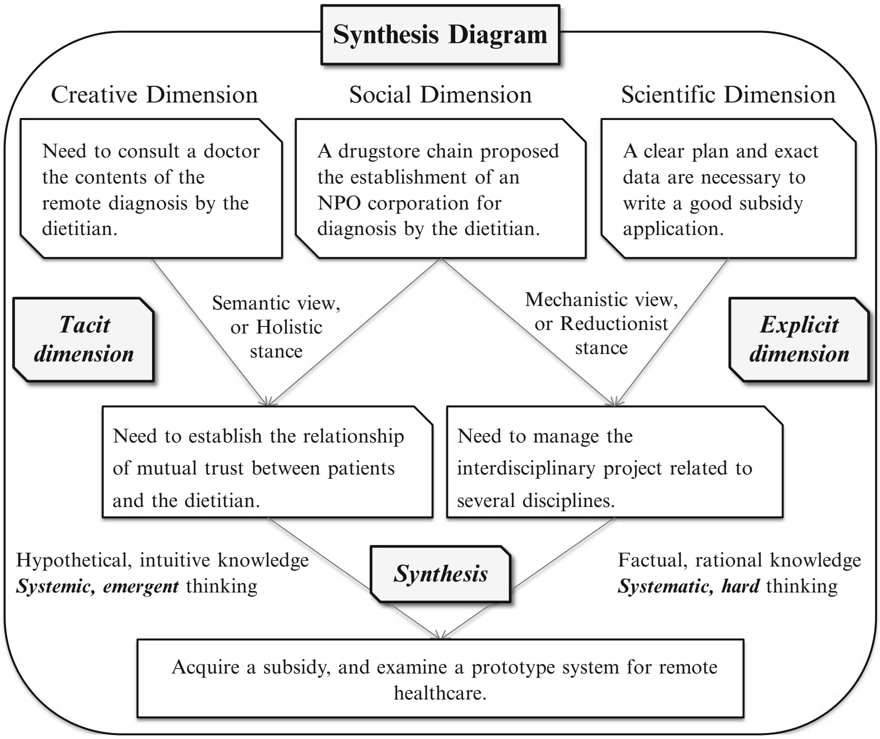

Fig. 9 Knowledge synthesis process in Phase 3: knowledge practice

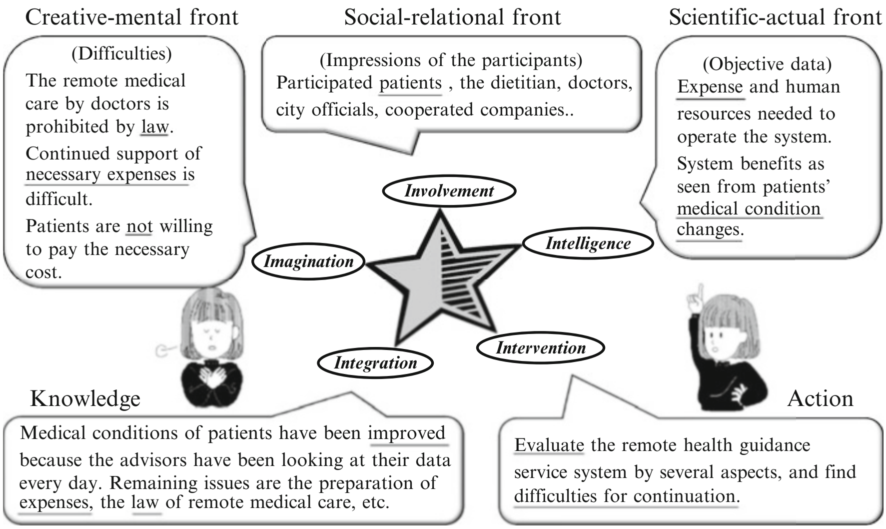

Fig. 10 Knowledge construction process in Phase 4: knowledge evaluation

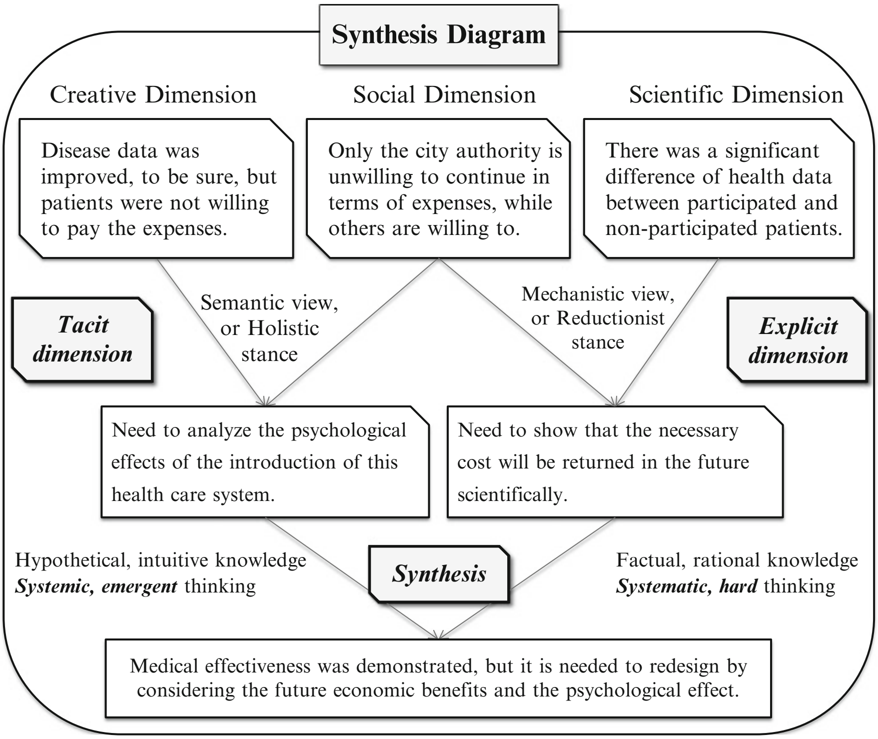

Fig. 11 Knowledge synthesis process in Phase 4: knowledge evaluation

4.3.2 Justification of Knowledge

Here we should ask ourselves the main question from the theory of knowledge construction systems: How was created knowledge justified? Justification according to the respective principles can be summarized as follows:

1. (Principle) Evolutionary falsification principle
   - The social experiment was planned and evaluated through an in-depth discussion with participants.
   - Effectiveness of the health recovery of patients was verified through a social experiment. (This is not really a disproof.)
   - Issues are the lack of operating funds, and the need for a revision in laws involved with remote medical care.
2. (Principle) Emergence principle
   - Figures for most users improved, which can be interpreted as emergence through interaction of system elements.
   - One point in particular is that raising the awareness of users was achieved in a short period of time.
3. (Principle) Multimedia principle
   - In addition to the transmission of numerical data by mobile phone, sending photos of meals aided decisions made by the nutritionist.
   - Exchanging emails with the dietitian day-to-day promoted self-management for users.
   - Occasional interviews with doctors, and observing the time-series data, also promoted self-management for users.

4.3.3 Creation of System Value

Here we consider creation of system value from the viewpoint of ideal service systems: Where and how have values of the system emerged? The value of this service system must be:

- The system promotes lifestyle improvements for patients with mild diabetes through health monitoring using mobile phones, whereby reducing the risk of stroke and myocardial infarction etc., over their lifetime; or at least making the patients become more conscious about such things.
- Value is evaluated through regular inspections (blood glucose levels, body weight, blood pressure, cholesterol, etc.).

To generate the value, the patients receiving the service have to implement the following every day:

- Diabetes monitoring (Urine test results, blood glucose test values)

- Health management (Body weight, body fat percentage, number of steps, photos of meals)
- Health notes (Setting and management of goals, recording of blood pressure, etc.)
- Data transmission by mobile phone (Exchanging e-mails with dietitians, or sometimes a medical examination is suggested.)

In particular, they have to control their own health:

- The system must have a function to promote the above.
- Normally, such an attitude is created through face-to-face medical care with a doctor.

4.3.4 Effectiveness and Obstacles for Actual Implementation

The effectiveness of the system is confirmed. In fact, a comparison of the results between users (the intervention group) and non-users (non-intervention group) after three months of medical care shows that:

- Blood glucose levels, body weight, blood pressure, and cholesterol values improved for the users.

However, there are obstacles towards its continuation. In addition to the medical care being remote, it would be classed as mixed medical care that includes medical treatment without insurance.

- There is a need to apply for a remote medical care special zone.
- Patients want to receive face-to-face medical treatment from doctors, but remote medical care is more suitable because they generally work during the day.

In addition, the continued support for the necessary funding is difficult:

- Labor costs for nutritionists, management fees for the system, and bio-device usage fees are too high for the load of the users.
- Continuing support from the government is difficult because it is unknown whether the investment will be recovered in the future.

In consideration of the above, full-scale development was postponed until some issues could be settled. Therefore, with this example, we were unable to advance to *Stage 4: Idea execution*.

5 Consideration of Quantification of Value

The social experiment reported in the previous section took a year, spending six months on preparation, three months on the experiment, and three months on evaluation. The reason why it took six months to prepare is that, in addition to examining the contents and procuring the equipment, it took time to coordinate between the relevant agencies, and to recruit patients to participate and provide them with sufficient explanations. In addition, this project used subsidies from the government, and it was required to complete the project within the fiscal year. This is the reason why the period of system operation was only three months.

Before starting this project, we conducted a statistical study on the characteristics of health and illnesses of Nomi city residents, and set the regional characteristics and challenges as follows:

- There are many patients with mild diabetes.
- There are many patients with poor control during treatment.
- In conjunction with the Nomi medical association, it is necessary to improve the rate of people with diabetes receiving medical care, and to provide them with guidance on treatment.
- Screening rates for specific medical diagnoses of citizens is relatively high at 40 %, but the consultation rate for workers in the 40–50 year old generation is low, which does not lead to early detection and treatment of lifestyle-related diseases.

The effectiveness of the health management system using mobile phones, which has been developed through our project, has been shown to solve the above mentioned local issues. For example, according to our survey, 71 % of participants answered that their health awareness had changed. Many of them have become aware of how to balance and regulate what they eat, the need for exercise, and the importance in improvement of lifestyle. Comparing the results of medical treatment after three months between the users (the intervention group) and the non-users (the non-intervention group), we found that blood sugar levels, weight, blood pressure, and cholesterol had all improved in the users (the intervention group).

However, it became clear that if we decided to charge the users it would become unusually expensive for them. As a result of the survey, we realized that we could not anticipate an increase in users. Unfortunately we found that for the participants the *value* does not balance with the cost of this experiment. The aim of this system was to improve the lifestyles of mild diabetics, and also to reduce risks such as stroke or myocardial infarction throughout their lives, through home monitoring using mobile phones. However, it is difficult to quantify the achievement level for this aim. Because judging the value of the system is difficult, many users reflected that they would not want to participate if they would have to pay for the expense.

Now, let us enumerate the value to each party who participated in the system:

- *The local government*: Reduction of medical expenses burden on local government.
- *The medical association*: An improved possibility for mixed medical treatment.
- *The NPO of dietitians*: Ongoing jobs relating to nourishment instruction.
- *The mobile system development company*: Increase in the uptake of their system.
- *The bio-sensor development company*: Ongoing sales of their sensors.

It is difficult to ask for the cooperation of the medical association, except in an experimental project, because of the problem that mixed medical treatment includes elective medical treatment that is not covered by health insurance.

Active participation by Nomi city is needed from both the financial aspect and the system aspect to solve the problems mentioned above. However, because the project was a short-term experiment, we could not quantitatively evaluate the reduction in the medical expense burden on local government.

When we looked back over our activities to date, value was undoubtedly co-created. However, the users did not feel that the value could justify the cost. Therefore, we or the doctors should explain to users the importance of the service system to their lives so that they are willing to pay the expense. If this service system improves their health, which would lead to a reduction in the medical expense burden on local government, it is theoretically possible that we could turn this reduction into assistance for the service system.

Quantification of value, which is hard to see, is quite important. However, how do we carry it out? Knowledge management is necessary here. How can we access the knowledge that medical doctors have and pass it onto citizens? We must build a *Ba*[2] for knowledge management, where people recognize values. We should also prepare techniques to quantify invisible values or sensible values (for example, see Nakamori and Ryoke, 2006).

6 Conclusion

We have expanded the target of knowledge science to regional revitalization or activation issues, and introduced a theory of knowledge construction systems. In addition, we expanded the perspective from knowledge creation to service value co-creation, and discussed community service systems. Using a concrete example, we discussed the effectiveness of the service system, the contents that emerged from the system, and their justification. In the future, it will be necessary to advance the theory through further practice.

Another important factor is quantification of value. Generally, people are willing to pay the price for a service that might be valuable to them. People pay the tuition fees at an English conversation school where the value is not created without their own self-efforts. This is because they believe that they can create more value if they do their best. For a community service system, we must quantify people's values to make a forward investment. An important issue for the future is the development of techniques for that purpose.

[2] Nonaka et al. (2000) identified the dynamic context *Ba*, which is shared and redefined in the knowledge creation process. It does not just refer to a physical space, but includes for instance; virtual spaces based on the Internet, and other mental spaces which involve sharing experiences and ideas. Nonaka et al. claimed that knowledge is not something which can exist independently; it can only exist in a form embedded in *Ba*, which acts as a context that is constantly shared by people.

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