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META-SYNTHESIS SYSTEM APPROACH TO KNOWLEDGE SCIENCE

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Meta-synthesis system approach (MSA) is proposed to tackle with open complex giant systems (OCGS) problems by Chinese system scientists since the late 1980s. Its essential idea can be simplified as from confident qualitative hypothesis to vigorous quantitative validation. To apply this approach, the synthesis of human expert opinions and emergent knowing, machines' powerful computing capacity and the available knowledge and cases are specifically emphasized from the perspective of systems engineering practice. Then the MSA practice may bring new understandings, knowledge and even paradigms about messy and unknown issues, which are under exploration in knowledge science research. In this paper, MSA to knowledge science is addressed. After brief introduction of meta-synthesis approach, a working flow of MSA during problem solving process is addressed and leads to meta-synthetic view toward knowledge science, especially on knowledge creation. Next comes brief introduction to a test for demonstrating the MSA to a macroeconomic problem, which shows a new paradigm to macroeconomic problem solving, a kind of knowledge creation which is different from general macroeconomic problem solving.

Keywords: Meta-synthesis; complex system modeling; knowledge science; GDP.

1. Introduction

Quantitative models (mainly refer to mathematical models) about problems are the main foci in systems approach around 1960s to 1970s. Checkland classified that school as hard system approach. Since 1980s more attentions were given to qualitative models (conceptual models), as referred as soft system approach by Checkland.[1,2] Meta-synthesis system approach (MSA) is proposed to tackle with open complex giant systems by Chinese system scientist Qian, Xuesen (Tsien HsueShen) and his colleagues around late 1980s.[3] The method emphasizes the synthesis of collected information and knowledge of various kinds of experts, and synthesis of quantitative methods with qualitative knowledge, as regarded as taking advantages of both hard and soft system approaches. In 1992, Qian proposed a concept *Hall of Workshop for Meta-Synthetic Engineering* (HWMSE)[4,5] as a platform to apply MSA to complex problems where breaking advances in information

technologies are strongly emphasized, even at that time, community intelligence burst out from the vast Internet has not been gained lots of attentions. Then continuous endeavors have been taken to test the power of those ideas in practical problem solving. In 1999, the national Natural Sciences Foundation of China (NSFC) approved a 4-year major project engaging to implement a pilot HWMSE demonstration for macroeconomic decision making, one of the largest investment for one project supported by NSFC in 1990s and 14 research institutes and universities were involved.

In that major project, one of the most highlighted concerns denotes to the platform of meta-synthesis of knowledge of experts from different disciplines, which is expected by many followers, supporters, skeptic and opponents of MSA. During the exploration, two problems are studied, one is consensus problem, i.e. how to building a consensus or even a compromise with even different expert opinions with conflicted evidences[6]; another is idea problem, i.e. how to enable new idea generating when facing new issues.[7] Actually, different schools around the world have engaged in investigations and explorations toward both problems; one of those academic organizations is School of Knowledge Science, Japan Advanced Institute of Science and Technology (JAIST), the first graduate school dedicated in knowledge science research in this world and whose first dean of that school Professor I. Nonaka proposed the famous knowledge creating model (SECI model).[8,9] To absorb those widely-accepted knowledge creation theoretical results and pioneering explorations on diverse facets of knowledge science regarded as a new discipline under construction into meta-synthesis system approach to problem solving is then of in-depth study. This paper reports the fundamental ideas among those initial endeavors. At first, we still address the basic ideas of MSA together with a possible practicing pathway toward problem solving which can then bring out the meta-synthetic perspective toward constructing the new discipline, knowledge science. The latter part of this paper presents the application of MSA using the pathway to practical macro-economic problem, *how national GDP grows with SARS impact* which is undertaken in May 2003. Such a test shows the new paradigm of such kind of complex problem solving, as new knowledge as expected.

2. Meta-Synthesis System Approach

Here only very basic ideas of MSA are addressed. A possible working flow of applying MSA to macro-economic problem solving, one kind of open giant complex system (OCGS) problems is also depicted.

2.1. *Basic ideas of meta-synthesis system approach and its practising platform*

Actually MSA is evolving. The first formal introduction about this approach was published in 1990 while explorations, especially based on system engineering practice on some macro-economic problems, had already started in 1980s.[3] Lots of

original ideas can be seen from those letters between Qian and his colleagues.[5] MSA is based on the systems theory and noetic science or cognitive science. It aims to unite organically the expert group, data, all sorts of information, and the computer technology, and to unite scientific theory of various disciplines and human experience and knowledge.[3]

MSA combines the advantages of both hard and soft systems approach. The main features of MSA to complex problem solving are briefly as follows:

- combine the qualitative and quantitative approach
- use system theory
- unify the microscopic and macroscopic studies
- conduct interdisciplinary research from social science, natural science and engineering science
- integrate knowledge, information and wisdom of mankind
- combine the abilities of both machine and human
- work through cooperation among a group of experts
- undertake both analysis and synthesis, etc.

From the view of thinking or cognitive science, both left and right brains and both logical thinking and intuition thinking are used. MSA also suggests the combination of computers and humans, while human plays the primary roles. When applying MSA, the collective knowledge instead of only individual knowledge is of many concerns.

There are three types of meta-synthesis in applying MSA, qualitative meta-synthesis, qualitative-quantitative meta-synthesis, meta-synthesis from qualitative hypothesis to quantitative validation, which refer to different tasks or goals during different stages in system practice of transforming confident qualitative hypothesis into vigorous quantitative and validated knowledge.[10]

To facilitate better experiencing the power of MSA, Qian proposed the concept of HWMSE in 1992 as a platform to practice MSA to complex problems where breaking advances in information technologies are strongly emphasized to be fully utilized. HWMSE consists of three systems *human expert system, machine system* and *knowledge system.*[4,5] It aims to make use of advantages of both qualitative intelligence mainly contributed by *human expert system* and quantitative intelligence performed well by *machine system* so as to generate more new knowledge stored into *knowledge system.* Gu and Tang[11] explain the differences between a HWMSE and a traditional decision support system (DSS). They also compare it with other systems for knowledge creation or technology innovation, such as *i*-System[12] proposed by Professor Nakamori, the 3rd dean of School of Knowledge Science, JAIST.

2.2. *A working process of MSA practice supported by HWMSE*

To fulfill tasks within HWMSE, a possible working process with three stages is designed to facilitate implementation of three kinds of meta-synthesis from the

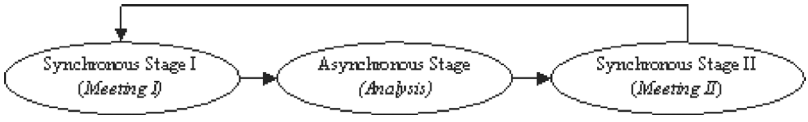

Fig. 1. One kind of working process of MSA.

point of view of different kind of meetings (see Fig. 1). Activities at synchronous or asynchronous stages are relatively differentiated under time pressure. Meeting Type I held in Synchronous Stage I aims to achieve qualitative meta-synthesis, such as perspective development or hypothesis generation for meta-synthetic modeling, i.e. qualitative-quantitative meta-synthesis at Asynchronous Stage.

Gu and Tang[11] also discussed tasks in each stage and supporting technologies required in correspondence with three kinds of meta-synthesis. Some details are given here.

- Synchronous Stage I
  Usually group divergent thinking is applied for a group of experts for the concerned issues. Take the China's macroeconomic situation in 2003 as an example, some important factors of that macroeconomic problem will be related, such as GDP growth and SARS impacts. A variety of methods and tools, such as Delphi method, brainstorming, groupware and computer supported cooperative work (CSCW), etc. may be applied to help experts with different knowledge backgrounds and enable the expert discussion to be more effective and efficient. It is expected to reach some results based on group discussion and argumentation at this stage. However, those results are still qualitative hypothesis which should be under verification and validation.

- Asynchronous Stage (analysis)
  At this stage, analysis will be given to those hypotheses proposed at Synchronous Stage I. Usually various models will be applied for analysis. In our NSFC major project, different models have been built to describe macro economic system from different perspectives or based on different modeling principles, such as econometric model, time series models, multi-agent system simulation model, evolutionary economic model, neural network model, Bayesian network, system reconstruction model, etc. Model integration mechanism is applied to integrate various models for a comprehensive scenario about macro economic system operation. Experts or analysts may run those models based on those hypotheses or their own opinions about GDP growth and then acquire quantitative analytical results individually. Usually time pressure in the analysis stage is less than that at synchronous discussion stage. Analysis may be undertaken on distributed sites. At this stage, quantitative analysis is fulfilled based on qualitative hypothesis.

- Synchronous Stage II
  At this stage, not only experts with different knowledge but decision-makers from different offices related to the macroeconomic decision making and some decision

makers with high responsibility may also be invited for group argumentation and decision making. The meeting is not only for free discussion, but also for decision-making or consensus building. Convergent thinking will be applied to reach some compromise or consensus. Usually various methods or models for decision analysis will be applied, such as analytical hierarchy process (AHP), nominal group technique (NGT), multiple criteria decision making (MCDM), etc. Other methods, for example, system reconstruction method and feasible desirable method are available. The former can be applied to quantitative analysis individually, while by integration of data, information and knowledge, it becomes meta-synthetic reconstructive analysis. Lots of tools or platforms can support group work at this stage, such as Expert Choice (based on AHP), PathMaker and various group support systems.

The third kind of meta-synthesis is to validate the results from the second kind of meta-synthesis achieved at Asynchronous Stage. If it works, solution toward the original complex problem is gained. If not, new perspectives need to be explored by three kinds of meta-synthesis for another problem solving process.

Figure 2 is an extensive working flow of MSA working process, i.e. an application of Fig. 1 at the referred NSFC major project.[13] The principal process, functions and tasks including meta-synthetic modeling of different facets of macroeconomic problems, together with group supporting resources are integrated by the simplified synchronous meeting → asynchronous analysis → synchronous meeting. This meeting-analysis mode only shows one possible practicing way of MSA to practical problems.

By Fig. 2's simple logical working framework, intelligence research results achieved by a variety of research units involved into the referred NSFC major project are integrated into an embryo HWMSE system for macroeconomic decision making. It could be said that Fig. 2 may be a new paradigm of macroeconomic decision making emergent from a group of researchers from diverse disciplines. We regard it as one kind of new knowing gained through multi-disciplinary research, part of which includes interdisciplinary research. That is knowledge created by meta-synthesis research. Next, we address MSA to knowledge science.

3. Meta-Synthesis System Approach to Knowledge Science

In this section, several facets of research on knowledge science by meta-synthesis system approach to complex problems are briefly discussed.

3.1. *Multidiscipline, interdiscipline and meta-synthetic discipline*

If we organize experts with different knowledge background into one group or organization, as departmental members work and discuss together, we may call this group as a multidisciplinary one. If those experts often work for same topics, discuss and try to know each other, then it can be regarded as interdisciplinary research. If those experts may work together and merge thoughts with each

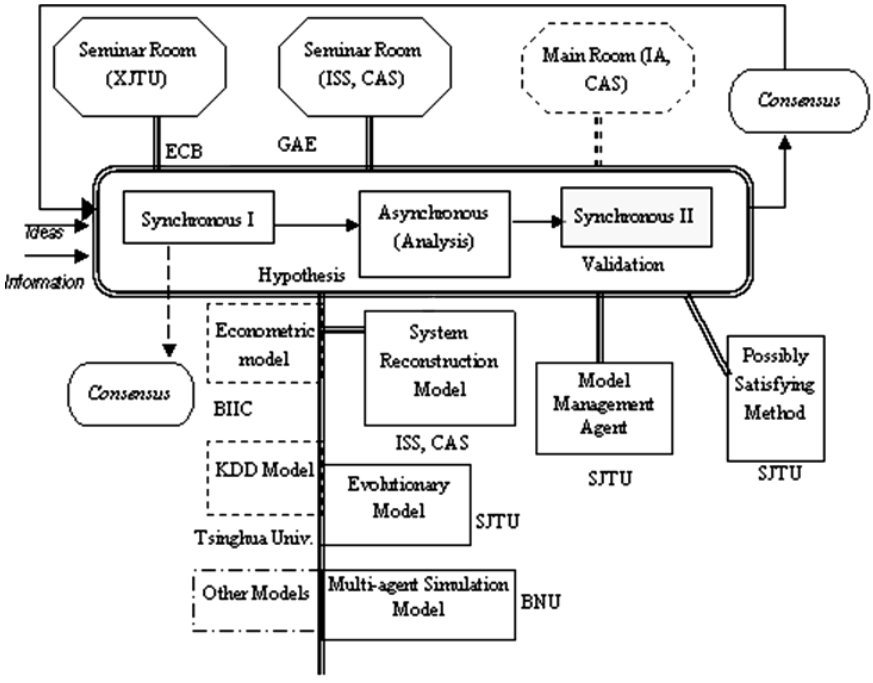

Fig. 2. Extensive working flow of MSA in the NSFC major project.

Note: double line or rectangle: web-enabled resources in HWMSE; arrow line: information flow; dashed box: non-Group 3's work; BIIC: Beijing Institute of Information and Control; BNU: Beijing Normal University; CAS: Chinese Academy of Sciences; IA: Institute of Automation; ISS: Institute of Systems Science; SJTU: Shanghai Jiaotong University; XJTU: Xi'an Jiaotong University. Those units all participated the referred NSFC major project, while SJTU, XJTU, BNU and ISS-CAS belong to Group 3 on methods research at the NSFC major project.

ECB: electronic common brain; GAE: group argumentation environment

other, and finally new knowledge emerges from the whole group, we may call it as meta-synthesis disciplinary group. Gu[14] discussed the evolving meta-synthetic disciplinary process along the movement of knowledge science as shown in Fig. 3, where different disciplines are classified into natural sciences, social sciences and engineering. The evolving process of meta-synthetic disciplines can be achieved by a C^3 process.

3.2. *Communication-Collaboration-Consensus process*

For MSA practice, a C^3 process (Communication-Collaboration-Consensus) is often applied to group activities happened all through the MSA working process. During communication, the involved participants expect some common grounds for further collaboration. Through such a C^3 process, knowing and doing are interrelated while new knowledge may be created for resolution of issues based on group work (Fig. 4).

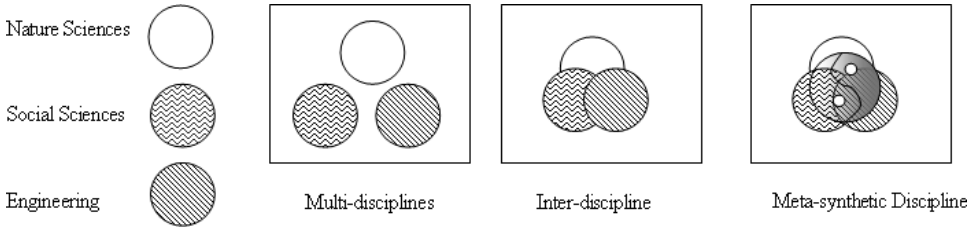

Fig. 3. Movement of knowledge science.

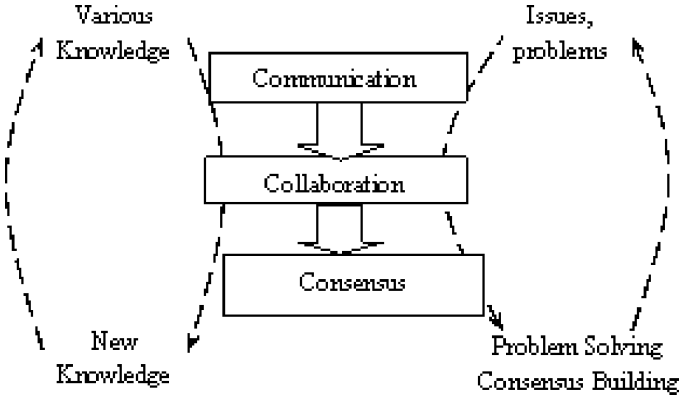

Fig. 4. C^3 type process.

3.3. *Knowledge science based on meta-synthesis view*

School of Knowledge Science in JAIST proposed a pyramid of knowledge science as shown in Fig. 5. Based on above-addressed ideas achieved from MSA studies, we change it to a framework of meta-synthesis approach to knowledge system (Fig. 6).

The contents at the base of the pyramid are changed with system science fundamental to all others, actually a reflection of Qian's idea of establishing systematology.[5] In correspondence with role of HWMSE in knowledge production and wisdom emergence, the contents of those four support bases of knowledge are changed, too. One support base labeled as knowledge processed by machines mainly corresponds to machine system in HWMSE, the other three support bases are related to the knowledge of living systems including human experts systems. The knowledge of individuals can refer to knowledge about an individual living system, which is a typical open complex giant system. Along the ontological dimension at SECI model,[8] knowledge of organizations remains and knowledge of society is added. Those disciplines or even topics around the fundamental systems science refer to the representative topics of each respective knowledge base. Based on those four support bases with the fundamental system sciences, knowledge production

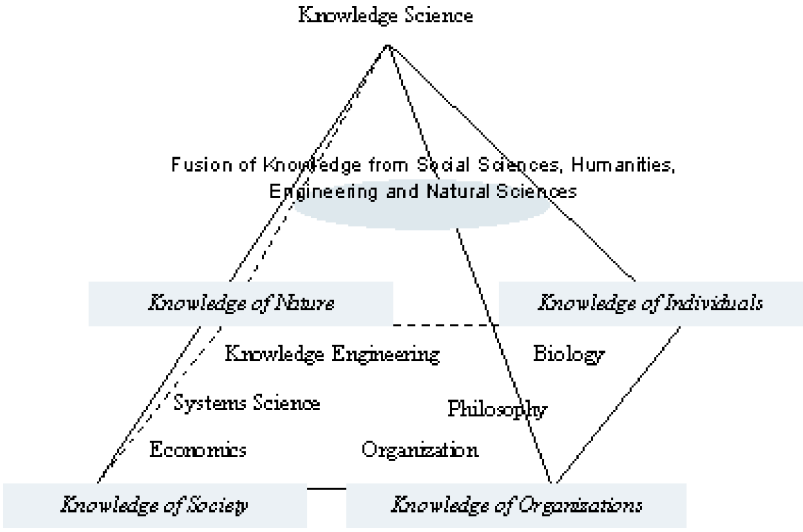

Fig. 5. Framework of knowledge science.

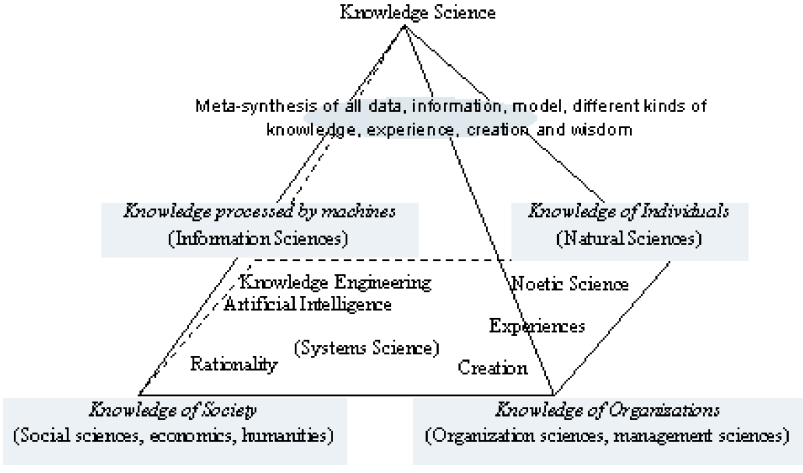

Fig. 6. Meta-synthetic framework of knowledge science.

comes from meta-synthesis of any modes of synthesizing of those sources or elements from any knowledge bases. New knowledge comes from problem solving process where data, information, models, different knowledge, experiences, creation and wisdom are considered. Actually, such a reformation brings a supporting framework to Fig. 2's new working paradigm for macroeconomic decision making implemented at HWMSE.

The MSA process is helpful to knowledge conversion, i.e. from tacit knowledge to explicit knowledge and from explicit knowledge to tacit knowledge based on the

interactions between individuals and collectives, human and machine, denoted as knowledge creating *ba* by Nonaka and his colleagues.[8,9,15] Moreover, HWMSE can also be considered as a *ba* for knowledge creation. Tang[7] discussed respective *ba*s regarding to different kinds of meta-synthesis implemented within HWMSE. Next a test for demonstrating the MSA to a macroeconomic problem is given briefly to show the so-called meta-synthetic paradigm to macroeconomic problem solving.

4. A Demonstration of MSA to Macroeconomic Decision-Making Supported by Available Resources at HWMSE

As lots of studies undertaken during the NSFC major project on MSA, the principal goal is to show a demonstration of MSA to macroeconomic decision-making supported by available resources, such as national economic data and senior economic experts, econometric models, other various models for GDP growth forecast, group support systems including groupware and any kind of supporting collaboration tools, consensus methods, etc. at HWMSE. The concerned problem is annual GDP growth forecast. Gu and Tang[13] had given a framework of Data-Model-Tool-Method-Consensus (DMTMC) as one kind of logical integration of resources of HWMSE for the concerned problem solving. In this section, we mainly apply Fig. 2's working process to national GDP growth forecast in 2003 when SARS crisis burst out in China.

4.1. *Working process of MSA to the GDP growth forecast*

Figure 7 shows the improved working process of the demonstration of MSA to 2003 national GDP growth forecast with the serious SARS crisis across China. It still follows Fig. 1, while different divergent discussion meeting activities are set for different levels along different kinds of meta-synthesis. At the synchronous stage I, a series of meetings are held. By Prepare Meeting (M0), the agenda of collective problem solving to the concerned issue is settled. Simultaneously, a variety of information is prepared for next meeting. The information includes the introduction of some methods including MSA, the situation of SARS crisis, various new reports from different agencies about their evaluation of SARS impacts to economy, etc. Case refers to research result by applying case-based reasoning about Asian financial crisis during 1997–1999. Then a group of experts are invited to join Free Discussion (Meeting 1-1), which is mainly for divergent group thinking to depict basic viewpoints of the concerned issue. At this stage, some methods and tools are applied to support group divergent thinking and summarization, to help the facilitator to get some topics for concentrated discussion at Topic Discussion (M1-2). A variety of data, information, knowledge and cases are still required during Topic Discussion, which aims to achieve basic scenarios, i.e. hypothesis of the macroeconomic situation in consideration of SARS impact. The participants to Topic Discussion may be different from those to Free Discussion. The results of the Topic Discussion will be processed and provided to the experts participated to the Further Discussion

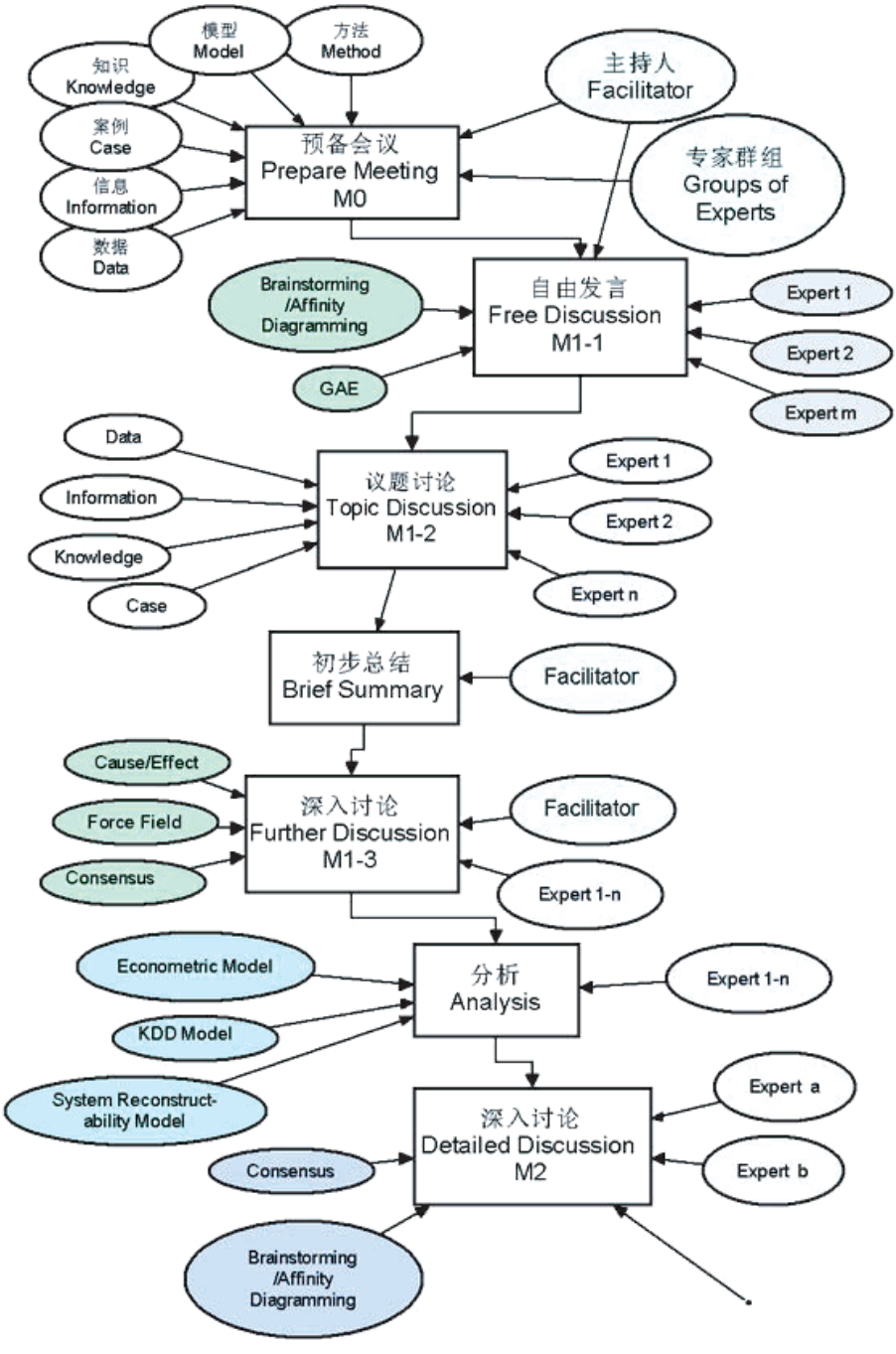

Fig. 7. Working process of a demonstration of MSA to GDP growth forecast with SARS impacts.

(M1-3) where some qualitative methods such as cause/effect analysis, force field analysis, etc. may be applied to deal with many factors suggested for quantitative modeling. As several scenarios are depicted clearly based on consensus of experts, qualitative-quantitative meta-synthesis will be practiced. The synchronous stage is finished.

At the asynchronous analytical stage, several models are provided for quantitative modeling with qualitative assumptions. Each model reflects one paradigm of macroeconomic modeling of the concerned issue. The econometric model is a kind of mechanism modeling, while most of discussions held during the first stage are about uncertainties of input factors (variables). Another model is artificial neural network, reflecting modeling by learning from data. The third model is system reconstruction model which considers expert knowledge and the evaluation of the experts besides the economic data used by the econometric model. The output of each model may be analyzed by modelers themselves, then submitted to the final group of experts and decision-makers for validation. In reality, those people may come from government departments. All quantitative modeling results will be studied while new opinions may be elicited from those senior experienced analysts. Then models in consideration of new factors or change of parameters may be run again for hypothesis validation. The participation of those experienced experts may enhance the quality of Detailed Discussion (M2) and lead to more ideas for in-depth study, which may then actuate another round of meeting-analysis working process. By several rounds of such kind of process, the solutions to the concerned issue may be achieved. Simultaneously, the validation of those models toward the concerned problem is also performed.

4.2. *Some details of the demonstration*

Figure 8 shows a pathway of Fig. 7, where a collaborative tool PathMaker is used. At the Free Discussion (M1), seven discussions were designed. Two of them were cases really happened as on-line dialogues between economists from China mainland and north American launched by the economic research center of Beijing University and two famous news portals in China (sina.com.cn, ynet.com) held in the start of June 2003. The records of those webcasting discussions were also information for qualitative meta-synthesis at Further Discussion (M1-3) and original materials for a group discussion test supported by GAE (group argumentation environment).[16] Another five free discussions are mainly about those policy factors.

For convergence of discussion, opinions about GDP growth trends in 2003 were divided into three levels in consideration of three kinds of SARS impacts (no impact, light impact and heavy impact). The high growth trend indicated that 2003 year's GDP rise rate was higher than 8.0%, smooth growth trend indicated to hold the line 7.6–8.0% and low growth as the GDP growth lower than 7.6%. Then nine scenarios about GDP growth in 2003 were acquired.[17]

All participants were expected to study different scenarios or even different models provided for analysis. After the whole process of testing, some conclusions were

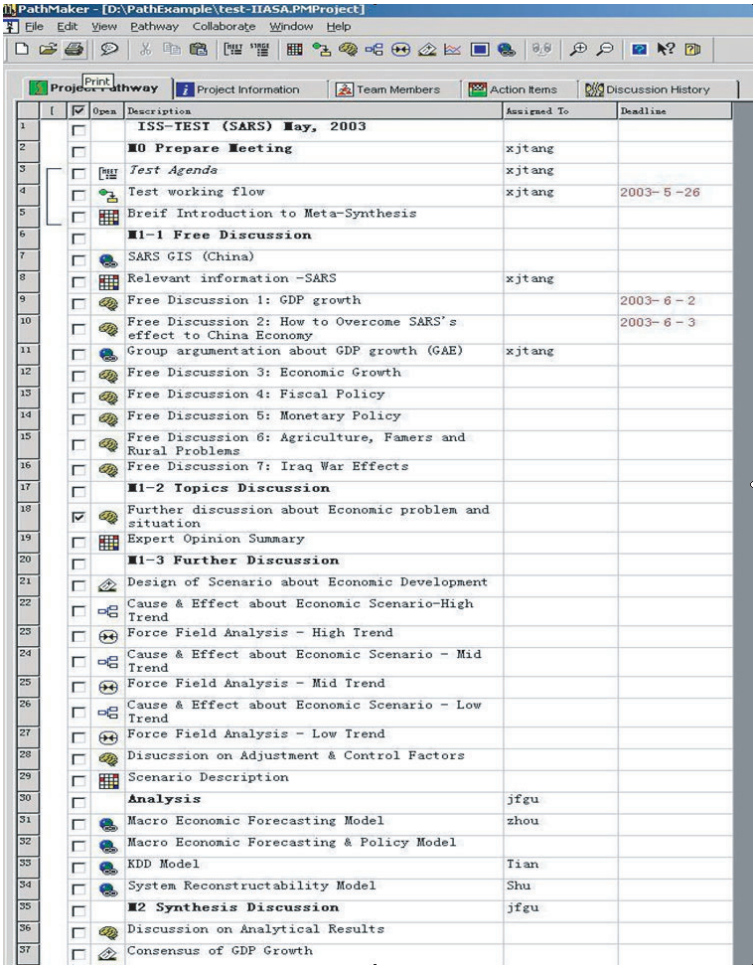

Fig. 8. Pathway of a demonstration of MSA to GDP growth forecast by PathMaker.

expected acquired. If participants or decision makers were not satisfied, the testing process will be in iteration until some consensus or compromises were achieved. Certainly this test was running under some prerequisites and limited resources.

This test was designed for a special session on meta-synthesis just after 17th JISR-IIASA Workshop on Methodologies and Tools for Complex System Modeling and Integrated Policy Assessment held at IIASA during September 8–10, 2003.[18–20] Eight volunteer experts from those participants of CSM'03 joined this session, watched the demonstration and proposed many comments.

5. Concluding Remarks

In this paper, the MSA to knowledge science is addressed. Even studied for nearly two decades, the research of MSA gains impetus as it enters into knowledge-based

economy with the continuously expanding Internet. After brief introduction of its basic ideas, a working process of MSA during problem solving process is addressed together with its application to the major project on MSA sponsored by NSFC. Actually the integrative working process exhibits a meta-synthetic process toward the resolution of issue about how to synthesize and integrate all research results achieved by multiple units involved into the major project. Such a framework reveals a new paradigm of macroeconomic problem solving, a kind of new knowing, which is within the scope of knowledge science.

From our designed technical way to problem solving whose process brings out new knowing, we propose a modified pyramid of knowledge science where the original contents designed at the 1st graduate school of knowledge science in this world are changed. Based on meta-synthetic perspective toward knowledge movement, the new framework adopts the components of HWMSE as its four support bases, where dynamic knowledge creation is of more concerns regarding the meta-synthesis of data, information, model, different knowledge, experiences and wisdom. Such a modification reflects our understanding that HWMSE is a *ba* for knowledge creation.

The second half part of this paper mainly applies the working process of MSA to a practical complex problem, as a demonstration of MSA to a macroeconomic problem, which shows a different paradigm to macroeconomic problem solving. Even it only shows one possible way, it is still a kind of knowledge creation. The design about the demo shown in IIASA is an extensive implementation of the new paradigm of macroeconomic problem solving in China GDP growth forecast under SARS crisis in 2003.

Despite of rapid progress in recent years with more concerns in complexity research,[13] MSA research is still at very early stage of development and fundamental research is required to focus on how to implement meta-synthesis about information, knowledge and wisdom respectively. More modes of MSA practicing are being expected so as to help people acquire new understandings and validated knowledge.

Acknowledgments

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