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Contents

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Initiative of Systems and Human Science for Safe, Secure and Reliable Society

TATSUO ARAI

Osaka University

Keywords: systems science, human science, safe, secure, reliable

As described in the Government Grand Plan for Science and Technology, Japan should aim to be a safe, secure, and reliable country where people are able to lead their happy and comfortable daily life. Securing and supporting our daily life, building reliable infrastructures against large scale disasters, and preventing unexpected human errors are crucial issues in our highly developed complex society. The reports from the Science Council of Japan stress that systems science should be applied properly to analysis and synthesis of safety. If the human nature is analyzed and treated properly in the process of designing machines and systems, we may create safer, more reliable, and more intelligent machines and systems that can support the safe, secure, and reliable society (SSR society). Systems science deals with analysis and synthesis for large-scale complex systems, while human science covers various aspects of the human nature, such as human behavior, social psychology, and human communications.

The project founded by MEXT under Grant-in-Aid for Creative Scientific Research (Project No. 13GS0018) aims at establishing innovative science and technology by integrating the above two sciences in order to realize our SSR society. First, human behaviors and their mental states will be analyzed quantitatively and systematically by the systems science. Then, the analyzed results will be applied in designing optimal systems and infrastructures and will be used in their operations. Finally, the systems and human science for the SSR society will be clearly established through these activities. The project has three major research categories:

1. Systems and human science for evaluating SSR factors,
2. Monitoring and support systems for creating SSR society, and
3. Crisis management for SSR society against large-scale disasters.

Eight research groups of the Department of Systems & Human Science, Osaka University are involved in the project as described in the followings.

For analyzing and evaluating Safety, Security, and Reliability (SSR factors) systematically we try to identify a utility function that reflects individual and/or societal preference for SSR factors from the view point of risk, uncertainty, imperfect information, cost for improving safety, and so forth. Based on this utility function new methodologies and tools will be developed for supporting decision-making in order to choose an appropriate alternative from many alternatives in various situations as shown in Fig. 1. It is also essential to design a mechanism for detecting human errors and reliable control systems for improving SSR factors in large-scale complex systems.

In the extensive surveillance against crimes, disasters, and accidents, it is important to observe human actions and facial expressions more closely with detecting state changes of mobile objects and environments. In the second category we study intelligent systems of detection, tracking, recognition, and identification of human body, action, and facial expression simultaneously with the comprehensive observation of environment using numerous fixed cameras and mobile robots connected with each other via the network.

Detection of a suspicious person, a passenger rushing into a street, and a patient taking a turn for the worse is performed based on not only particular observation of action and facial expression but also

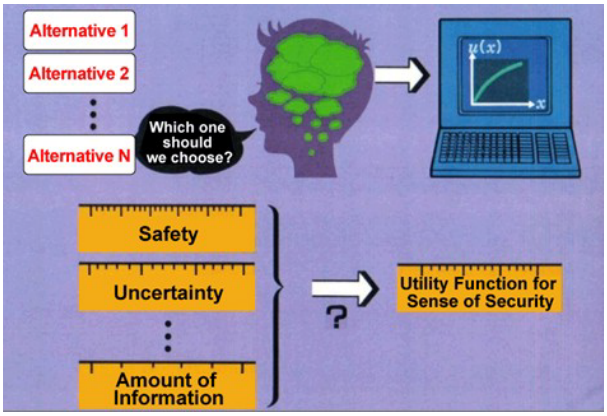

Figure 1: Architecture of a DSS

prediction and understanding of human action using the knowledge of behavioral sciences for human. Human-like robots are applied to secure individuals and protect them against detected troubles or expected dangers. Robot motions and/or behaviors should be carefully planned by analyzing the human nature in order to bring no interruption, no trouble, and no fear to users.

It is of great importance to secure communication and evacuation channels in case of large-scale disasters. In the last category we design communication and transportation networks that work with high reliability even if link failures occur due to disasters or accidents. We also construct communication support systems with information-filtering and advice functions that work under time-varying environments where available information and channel capacities are extremely restricted. Furthermore, we design evacuation systems to secure people's safety as quick as possible, based on the available information about disasters.

Composition of Product Ability Limit Line By Using Data Envelopment Analysis

MASAO ARAKAWA

Kagawa University, Japan

TOMOKI MITANI

Maruzen Kogyo, Japan

HIROSHI ISHIKAWA

Kagawa University, Japan

Keywords: product management, data envelopment analysis, Shinayaka system

In Japan, many small and middle class industries are in the request of small amount and much variety of products, under the pressure of supply-chain management. In these companies, although they correct daily data, and sometimes they make database from them, they did not use them properly. Therefore, there are a lot of products which are delay in approved date, and which becomes a big problem for them. They cannot introduce administration tools, like ERP. In some companies, they introduce administration system to overcome miss handling of product scheduling. In fact, most of them failed in improvement, and loose product ability, in order to follow ”optimum scheduling”. But, why such an expensive and effective system does not work properly? Partly because it is not designed for small company. But main reason is as follow. In the most cases, they make a product only once; therefore, it is difficult to estimate how much time they need to make products by their machines. What they did is estimate approximate product time to make Gant chart. As they do not want to change schedule by any accident nor miss-estimation, they estimate product time a little longer, so that it might not break the optimum scheduling. As a result, they can keep optimum scheduling and they are succeeded in handling scheduling, but loose their product ability. These administration systems are designed to use as precise and minute data as possible to estimate scheduling. They do not want to include estimation error that has possibility to expand to break the scheduling. In that sense, they are luck in flexibility.

In this study, we would like to make administration system that is as ”shinnayaka” as possible. ”Shinayaka” is Japanese words which means flexible or supple. In this system, we aimed to correct as less data as possible, and we would like to watch as less functions as possible. And we would like to aim those function to some particular value, and we would like them to synchronize to the other functions and end up in good conditions.

In this study, as a case study, we applied the philosophy of ”shinayaka” approach to administration system of small industry. Among various existed data, we only limit data to three types; total amount of products, total setups that they need and total time that they work per day. Functions are product ability limit lines. Product ability limit line is upper boundary of product ability for each machine per day. From three data, we need to make product ability limit line of machine. In this study, we propose a method to use Data Envelopment Analysis. We will show some useful data that come out of product ability limit line.

An ontological framework for structuring process knowledge specified for the process of model-based problem solving

ADRIE J.M. BEULENS *and* HUUB SCHOLTEN

Information Technology Group, Department of Social Sciences, Wageningen University, the Netherlands

Keywords: process knowledge, ontologies, workflow management

Introduction

An important problem in business and science continues to be associated with managing development and design projects. Managing is then briefly described with activities such as making a proposal and quotation, negotiation and obtaining the project, and then executing and controlling the project aiming at:

- A product and service with integrity and quality attributes as envisaged in the negotiated and agreed upon proposal. An important feature of that quality is that the interpretation of quality attributes may change or further develop in the course of the project and due to increased mutual understanding of the customer and the project manager and associates in the team. Next to that it is assumed that there are a number agreed upon measures both associated with the product and the execution and management process of the project. These for example in terms of:
  – What activities need to be done?
  – What are accepted and or best practices in a disciplinary community for executing these activities in relation to the problem and problem domain?
  – How can one evaluate the merits of alternative approaches for an activity and over a number of activities?
- Delivery of that product and service in time as agreed upon with the customer (quality assurance).
- Delivering the project within allocated budgets and using allowed resources.
- Project administration and reporting. For reasons of accountability, auditing and quality assurance and control, both within the project and externally, it is currently also necessary to closely monitor the execution of the process by having proper administrations and associated reporting about project execution and resources used in place. This involves more in particular:
  – Activities executed.
  – Methods, tools, models, data resources and systems used. In that context it is appropriate to monitor and evaluate results obtained by the usage of the resources just mentioned.
  – Associates executing the activities (with their knowledge, experiences, skills and competencies).
  – Time and other resources used in activities. We are interested in knowing what the cost and (accrued) benefits of the project are project-to-date and projected to the end of the project. We are also interested in the time spent per resource in the project-to-date and the duration to-date as well as projected time measures till the end of the project.

  With administrations in place as just described one can closely monitor within the project what has been achieved and for external auditors the process and resource usage can be controlled.

Basically, in the previous description of a development project, we distinguish two major phases:

- Initial project definition, proposal and acquisition.
- Project execution and delivery.

Both phases have commonalities such as the need for a proper and well-understood problem statement, an agreed upon cost-benefit report, and an approach to execute and manage the project. Differences in these phases often lie in the level of abstraction. In the proposal phase we necessarily have to confine our selves to a less detailed description of the project (with all its inherent perils). Details about resources used (especially people) may be restricted to the type of people and expertise and experience envisaged rather then who actually does it. For methods, tools, models data resources and systems it may hold that we have to limit ourselves to restricting the possible allowed choice of these rather then being specific per task.

However, in both these phases one can easily discern a number of important dimensions to take into account:

1. The *process dimension* of the project. In the process dimension the participants must have a shared understanding about what the problem and problem domain are and about the team and process necessary to tackle the problem.
2. The *content dimension*. In a problem domain we may find a variety of disciplinary persons focusing on problems or sub-problems bringing with them the disciplinary methods, models and tools to tackle problems within problem domains. These disciplinary, paradigmatic, approaches have their merits and limitations. Referring to an earlier paper (Beulens and Scholten, 2002) from a problem perspective we arrive at a need for a certain representation power with respect to modelling an object system while disciplinary approaches 'only' give us methods and models with a limited representation power. As a consequence the project team and manager are confronted in the modelling process with consciously dealing with the gaps between what is needed and what can be obtained from different paradigms.
3. The *transparency and quality assurance dimension*. Briefly stated we may say that in the project acquisition phase we need to arrive at a shared understanding about what is to be achieved (product, quality and process), at what cost and when. In the project execution phase it is important to do the activities according to the specifications and rules agreed upon and being able to show, both internally and externally, that the project team has actually done precisely that. The latter requirement can only be satisfied by an appropriate and extensive project administration that goes beyond what one can find in many project management systems.

Problems of project management for development, research and design projects and quality assurance are addressed in a variety of literature. See for example Van der Weide *et al.* (2003), Scholten *et al.* (2001), Humphries (1989), OGC (2002), and many others.

Process specification

In the previous section we have addressed the problem of a project manager with its three dimensions (process oriented, content or Object System model oriented and transparency and quality oriented). On a generic level these pertain to all projects. Differences occur depending on the problem domain, the problems addressed and on domain knowledge available. For a project manager and team it is a major effort to first arrive at an agreed upon process definition and thereafter to execute it, monitor and control it and arrange for transparency and quality assurance.

In the following list we describe the main components of a research or development process:

Phase 1: Project Initialisation. The project manager and problem owner define the problem, sketch a vision on an approach to solve the problem and constitute a project team (given that the project acquisition phase has been successfully concluded). In that approach one refers to the project assignment and to the accepted best practices as reference models.

Phase 2: Process definition. In this phase a detailed process description needs to be made and agreed upon within the team and with the problem owner. Referring to a *domain template* (an ontology) one has to decided about:

1. Which approach(es) to use from the reference model. That is choices of paradigms and methodologies. If different approaches are to be used as alternatives to tackle a (sub) problem then we may call these alternatives process-scenario.

2. The process in terms of:
   - Sub processes
   - Tasks
   - Activities + methods + models used.

Phase 3a: Execution of a process scenario involves that for each data-scenario (alternative sets of inputs (control variables) that needs to be examined:
1. The modelling process is executed. That means the execution of:
   - Sub processes
   - Tasks (including internal audit)
   - Activities + methods + models
   - Evaluation of results obtained.
2. The modelling process is closely monitored and administrated (data and meta-data), again on the level of:
   - Sub processes
   - Tasks (including internal audit)
   - Activities + methods + models + results obtained
   - Evaluation of results obtained.
3. The internal monitoring and control may lead to adaptations of the process scenarios.

Phase 3b: Process control, transparency and quality reporting. For each process and data scenario process monitoring, control may be used to:
1. Report about them.
2. Adjust and increase the mentioned scenarios.
3. Externally evaluate the quality of the process and results in comparison with the assignment obtained.
4. Check reproducibility of results obtained.

Closure of Phase 3a: The final activities of this phase. Synthesis of results. If more process and data-scenarios are available a conscious process of evaluating and combining results has to take place.

Closure of Phase 3b: External Project evaluation and closure.

In the table above we address the major phases of the project initialisation, definition, execution and monitoring and control.

Making the detailed specifications of these phases and thereafter obtaining the meta-data about the execution for monitoring and control with their effect on the specification is the project management task to be supported that we address in this paper.

An ontological framework for structuring process knowledge

In our department, in close collaboration with partners inside our university, the business community and universities in Europe (EU-HarmoniQuA project) we address in particular supporting the project management tasks addressed at the end of the previous section. Automated support for making the specifications of these phases and thereafter obtaining the meta-data about the execution for monitoring and control with their effect on the specification for processes of model-based problem solving is the topic of this paper.

Automated support calls for:
- A formal and precise description of the specification.
- A specification using terms and relationships that are in particular unambiguous for both man and machine.
- A specification that is derived from a generic one in the problem domain. A generic one that is accepted as a best or accepted good practice in that domain for named reference problems. Practices too, that develop over time as the knowledge base increases. As a consequence we may assume that a resulting

specification will adhere to dynamic quality requirements in the problem domain. We therefore also opt for this reference strategy, as is also done by many approaches in the area of ICT projects.

In order to be able to satisfy the needs for automated support we have opted for, as just suggested:

- A reference strategy. So we assume that both models and approaches, as used for named and accepted reference problems and projects, can be effectively used to come up with solutions for new problems that have similarities with these named reference problems. In turn these new problems and solutions may contribute to enhancing the knowledge base in the problem domain.
- An ontological approach for structuring and describing the knowledge about process specifications. In the previous bullet list we have described the need to be able to come up with a formal, precise, unambiguous and machine processable specification of process-models. An ontological approach just provides us with a method to achieve that if we follow definitions as given by Gruber (1993, 1995) and Borst (1997). The most used definition in knowledge engineering of the term 'ontology' is of Gruber (1993, 1995): an ontology is an explicit specification of a conceptualisation, referring to what can be represented in terms of concepts and the relationships among them. Borst (1997) added to this definition that there should be consensus about the concepts and the relations between them, resulting in the following definition: an ontology is a formal specification of a shared conceptualisation. For a further elaboration on the topic of ontology and its use to support process-modelling we would like to refer to two other papers Scholten et.al. (2004), Kassahun et.al. (2004). Further important publications on the topic of ontology are the ones by Uschold et.al. (1998) and Chandreskaran et.al. (1999).

In the previous part of this paper we have now described the problem to be solved, the characteristics of the problem and the approach adopted to arrive at a model based support system. In our projects we have been able to design and develop:

- A detailed ontological framework for developing a knowledgebase for process-models.
- A generic process model ontology (Scholten et al., 2004).
- A specific domain process ontology in the area of Water Management. This ontology and knowledge base provides for proof of principle.
- Based on qualitative evaluation and experiences so far we have concluded that the approach can also be used in other domains.
- Further, evaluations by current partners indicate that the objectives of effectiveness, transparency and quality assurance can be met by our approach.

Closing remarks

In this paper we have dealt with the conceptual part of the problem addressed. How can we effectively support the creation of a model and knowledge based system that can support the creation of good process models for research, development and design projects. To solve this problem we have opted for an ontological approach of which the framework has been briefly described in this paper. In papers by Scholten *et al.* (2004) we deal in more detail with the development of the ontology and knowledge base and with the tools developed. For further details of the project we would like to refer to other papers in a series where one can find details about the detailed design of the knowledge base and about the system developed.

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A Multicriteria Approach for the Choice of Remote Load Control Strategies

JOAO CLIMACO *and* MARIA JOAO ALVES *and* CARLOS HENGGELER ANTUNES *and* HUMBERTO JORGE *and* ANTONIO GOMES MARTINS

Coimbra University and INESC Coimbra

Keywords: load management, multicriteria analysis

Load management actions entail changing the regular working cycles of loads through the implementation of appropriate power curtailment actions. These actions consist of on/off patterns generally applied to groups of loads associated with energy services whose quality is not substantially affected by supply interruptions of short duration, such as electric water heaters and air conditioners in the residential sector. Since these are thermostatic loads, external changes to their working cycle have influence on their demand pattern in subsequent time periods. The use of these demand-side resources has been a current practice by electric utilities. The goals of these activities are associated with operational benefits, such as increasing load factor, reducing peak power demand, reliability concerns or loss and costs reduction. More recently, further attention has been paid to this kind of programs mainly due to the volatility of wholesale electricity prices and reliability concerns (transmission congestion and generation shortfalls). These programs, which include direct load control and voluntary load shedding, can be very attractive for a retailer dealing with volatile wholesale prices and fixed, over a certain time period, retail prices. However, load management programs can also give rise to undesirable effects, such as the payback effect (whenever power is restored simultaneously to loads thus eventually creating another peak) and possible reduction in revenues.

The selection of load control actions requires the explicit consideration of multiple, incommensurate and conflicting evaluation criteria of the merit of alternative load shedding strategies, capable of reflecting economic, technical and quality of service aspects. Note that the quality of service dimension is crucial because consumers' acceptance is indispensable for the success of load management programs. The model presented in this communication is a slightly altered version of the model previously proposed by Jorge et al. (2000), taking into account the main concerns that have an important role in load management. The three criteria intend to minimize peak demand as perceived by the distribution network dispatch center, to maximize utility profit corresponding to the energy services delivered by the controlled loads and to maximize quality of service in the context of load management.

The well known STEM method was used to analyze a case study using the tricriteria model referred to above. The quality of the solutions proposed in Jorge et al. (2000) is good, but due to the limitations of STEM method it was not possible to make a comprehensive search of the non-dominated solution set. This is strongly recommendable namely because the a priori points of view of the electricity supply company and the points of view of the consumers are not compatible. So, the multicriteria interactive analysis should contribute to an indispensable learning process putting in evidence not only all the relevant profiles of well contrasted non-dominated alternative options but also providing aids to achieve a satisfactory compromise solution for the various actors.

The software used to reach these goals is based on an interactive reference point method for multicriteria integer linear programming (MCILP) combining Chebychev scalarizing programs with branch and bound techniques (Alves and Climaco, 2000), and a visualization approach to the indifference sets of reference points dedicated to tricriteria integer linear programming (Alves and Climaco, 2001). Note that, as non-dominated solutions are a discrete set in MCILP, there are multiple reference points that lead to the same solution, i.e. there are indifference sets on the reference point space. The sensitivity analysis procedure included in the method provides the foundations to calculate at least a good approximation of those areas with a small computational effort. The flexibility of the search and the visual interface constitute the main characteristics of the software tool to analyze the tricriteria integer programming model for aiding the definition of remote load control strategies. In this talk we describe in detail the analysis of the tricriteria load management model using the MCILP software package and we compare the results with those obtained using the STEM method.

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Sample-Based Methods for Sensitivity and Uncertainty Analyses of Model Output

MICHAEL FLECHSIG

Potsdam Institute for Climate Impact Research, Germany

Keywords: sensitivity analysis, uncertainty analysis, model output

This paper gives an overview on state-of-the-art methods in sample-based sensitivity and uncertainty analyses (SUA) of model output.

SUA studies are conducted (i) to decide whether the model represents the system under investigation, (ii) to identify those input factors (see below) that mostly contribute to the model variability and those that are insignificant, (iii) to get information on interacting input factors, and (iv) to identify in the input factor space regions with special properties. Finally, quantification of SUA measures for output of complex dynamical models is a prerequisite for a subsequent reliable model-based decision making process.

Originally, SUA methods were designed to study uncertainties in model inputs and model parameters as input factors. This approach has been extended to incorporate more types of uncertainty. Among others, nowadays sources of model output uncertainty and consequently input factors as described above are incomplete knowledge about the real system, the delimitation of the modelled system's part, the model structure, model calibration / parameterisation values, numerical algorithms, and machine dependent number representation:

Y = F (X) with

X = (x1 , x2 , ... , xnx) model input factors and

Y = (y1 , y2 , ... , yny) model output

Sensitivity analysis methods determine the effect how model output Y responds to individual changes in the input factors X while uncertainty analysis methods aim to qualify the overall uncertainty of model output Y as a result of uncertainties in the model input X.

The basic steps in performing a SUA are (i) to identify what question is to be answered by the SUA, (ii) to determine the model input factors X, (iii) to apply a sampling strategy for the input factors, (iv) to perform the model for the whole sample Xns of size ns, and (v) to determine SUA measures from the model output Yns over the sample space Xns.

The further course of a SUA study and its computational costs are heavily influenced by the selection of an appropriate sampling strategy. A basic approach is factor screening to get an overview for problems with many input factors. Factor screening methods use deterministic sampling techniques to study the model behaviour. The opposite approach exploits a probabilistic sampling. It is based on assigning a distributions to each of the input factors under consideration followed by corresponding sampling procedures (e.g., random, Latin hypercube or LP-tau sampling). A plausible identification of the input distributions often proves as the bottleneck of a probabilistic SUA. Control of correlation within the sample can be very important. Probabilistic sampling strategies always result in performing a Monte-Carlo study on the model under investigation. Another classification schema for SUA experiment designs is whether impacts of the input factors on the model output are to be studied locally or globally with respect to the nominal value of X.

Monte-Carlo experiments enable application of statistical operators on the ensemble of model outputs Yns. Sensitivity measures mainly base on a variance decomposition of Yns. Special methods have to be applied if Y is multi-dimensional and has to be studied for each element rather than in an aggregated manner.

The paper gives examples for sampling strategies as well as for related SUA measures, compares the computational costs and evaluates scientific tools for conducting a SUA.

Top-down and Bottom-up Modeling for Energy Pricing Policy in Indonesia

WESLEY FOELL

Resource Management Associates, Madison, Wisconsin

Keywords: Indonesia, energy policy analysis, energy system modeling

Last year at CSM'2004 I presented a general retrospective and prospective overview of policy-based modeling of Indonesian energy systems. The discusssion treated the needs of a developing country to develop analytical tools and skills to use them in a way to improve both energy system management and good governance in gemeral. It addressed some of the analytical and institutional ways in which these needs were attacked and what assistance might be provided by the international community.

This year I will discuss a specific policy issue in Indonesia, its analysis using several models, and the institutional embedding and results to-date of policy implementation.

The general issue discussed is the implementation in Indonesia of market-based pricing to remove the massive energy subsidies and to foster energy efficiency and new sustainable energy systems displacing those based on petroleum fuels. Energy subsidies were responsible for more than twenty percent of the government budget in year 2000. This massive subsidy, justified as protecting the poor, was mistargeted: the poor received only nineteen percent of the total subsidy while comprising the majority of the population. In addition, price increases were opposed by many vested interests, including energy-intensive industries, smugglers, wealthy consumers, and the poor - who believed they benefited from the existing pricing policy.

In 2000-2002, an energy policy team carried out extensive analysis, using an array of economics and engineering models to assist the Ministry of Energy and Natural Resources (MENR) in designing a five-year program for energy pricing and subsidy removal. Central to the analysis was an array of data bases and models for the Indonesian economy and energy system. These included: 1) sectoral- and technology-specific simulation models (bottom-up analysis) of energy consumption, and 2) a computable general equilibrium (CGE) model for Indonesia (top-down analysis). Equally important was an interdisciplinary inter-institutional team, spanning several universities and research organizations, and created to address this problem. Critically important was the effort to penetrate the boundaries among economics, engineering, and systems analysis, which are so often entrenched in developing countries.

The presentation will describe the analysis, difficulties and successes in integrating the diverse analytic tools and data bases and the implications for this type of analysis in a developing economy. It will present the analytic results and discuss their embedding into government policy and the impacts over the past 2 1/2 years, and discuss observations on this modeling approach.

Structuring Socio-technical Issues of the Ubiquitous Information Society in 2010

MOTOHISA FUNABASHI *and* KOICHI HOMMA

Systems Development Laboratory, Hitachi, Ltd.

Keywords: ubiquitous information society, systems structure, socio-technical issues

Journey to the Ubiquitous Information Society

IT has been changing and changing our life style. Before 1980s, automation by IT was pervasive in the physical world as well as the information world. Computer aided control for the Shinkansen (the bullet trains in Japan) was a landmark information system for the physical world in Japan, and EDP (electronic data processing) was a keyword for the industrial information world. In 1980s, microcomputer technology led new information structures such as office automation and factory automation. In 1990, network technology, particularly the Internet, produced the virtual world and on the other hand cars and home appliances were having powerful embedded processors for their easy, comfortable, and efficient use. In addition to these remarkable waves, people were having mobile phones. The mobile phones have drastically changed our life style, that is, have provided people with their personal information spaces, namely the third world in addition to real and information worlds. In 2000s, advanced devices realized by nano-technology will extend the personal information spaces and rich connections between real and virtual worlds for self- fulfillment and secured life that would be the ultimate goal of the Ubiquitous Information Society.

Layered Structure and Examples of the Ubiquitous Information Technology

In the past, information systems were described by an N-tier model of clients and servers. However, unlimited involvement of new devices with the systems and their diversified ownerships requires different understanding of the systems. For the coming new situations, WWRF (Wireless World Research Forum) researchers [1] have developed a nice layered model. Based on the WWRF idea, the following reference model with examples is developed reflecting current technological advances.

1. The PAN (Personal Area Network) The closest interaction with information technology will happen with the elements that are the nearest to us or might even be part of our body. Communication facilities will be contained in clothes and wearable items. Typical examples will be wearable computers and smart devices for personal identification. Advanced device technology will give opportunities of health diagnosis and cure as well as augmentation of human sensory and memorizing functions. These functions mainly work for extending personal capability.
2. The Immediate Environment At the next level we find the elements of real world around us. Currently we do not interact with them but in near future we will expect that they take notice of us, that they start to interact with us and turn into personalized items rather than general purpose devices. RFID (Radio Frequency Identification) will be attached to every objects for their lifecycle management as well as better usage of them. In this layer, devices and appliances provide people with integrated

services according to the contexts of the people. There will be some possibilities for malicious services including infringement of privacy as well as intrusions to the PANs, however, in case of personal spaces such as individual residences, the risk will be abbreviated. The Immediate Environment is mainly assumed to be such personal spaces.

3. The Instant Partners One step further we interact with people around us as well as with more complex systems like cars. We may want to talk to them or just relay information through them. It is believed that in the future our wireless possibilities should enable an easier and richer interaction with close-by people than with people on the other continent. This is a distinct feature different from the traditional Internet idea. People interact with others based on the degree of trust that is dynamically revised through the mutual interactions with parameters expressing locations. The future devices will help the people at these interactions by understanding the trust structures, which extend the friendliness as well as reduce the risks in the interactions. Typical example of the Instant Partners will be seen in public/commercial spaces equipped with information devices as well as sensors for enhance comfort and security in addition to better service / merchandising opportunities.
4. The Integrated Virtual and Real World The Internet provided us with the virtual world, but device and wireless technologies such as RFID are giving a way connecting the virtual world to the real world. Integrated understanding and design of virtual and real worlds is expected to produce the dedicated society. Traceability and SCM systems will be examples of integration of virtual and real worlds.

Socio-technical Issues for the Layered Structure

According to the structure of the Ubiquitous Information Technology, extraction of the socio-technical issues for each layer is underway. The current study has revealed the following items:

- for the PAN: In this layer, integration of biological and man-made systems will proceed signifcantly. As the results, boundaries of these two systems will become fuzzy. For example, the record for memory augmentation can be seen equal to the wet human brain if outflow from the memory owner is strictly inhibited.
- for the Immediate Environment: M. Weiser, who coined the Ubiquitous Computing, envisaged disappearing computing where computers should provide best services without appreciation of their existence. However, people often want to know who handles their environment. We need much more detailed understanding for the automated services.
- for the Instant Partners: The future devices will help the people in interactions among instant partners according to the mutual trust level. This mechanism might provide safe services with protection of privacy, however it should concerned that people are accustomed to this mechanical trust handling even though definition and expression of the trust will be improved step by step.
- for the Virtual and Real World : Traceability and SCM systems are representative applications for this level, but it is very difficult to derive a plausible model for sharing cost among the participants. On one hand, if some participant gets the position to monitor all the data in the chain, the participant might get a super power dominating other participants.

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About Distributed Simulation-based Optimization Of Forming Processes using a Grid Architecture

MANFRED GRAUER *and* THOMAS BARTH *and* FRANK THILO

Institute for Information Systems, University of Siegen, Germany

Keywords: simulation-based optimization, metal forming processes, Grid computing

Permanently increasing complexity of products and their manufacturing processes combined with a shorter "time-to-market" leads to more and more use of simulation and optimization software systems for product design. Finding a "good" design of a product implies the solution of computationally expensive optimization problems based on the results of simulation. Due to the computational load caused by the solution of these problems, the requirements on the Information & Telecommunication (IT) infrastructure of an enterprise or research facility are shifting from stand-alone resources towards the integration of software and hardware resources in a distributed environment for high-performance computing. Resources can either comprise software systems, hardware systems, or communication networks.

An appropriate IT-infrastructure must provide the means to integrate all these resources and enable their use even across a network to cope with requirements from geographically distributed scenarios, e.g. in computational engineering and/or collaborative engineering. Integrating expert's knowledge into the optimization process is inevitable in order to reduce the complexity caused by the number of design variables and the high dimensionality of the design space. Hence, utilization of knowledge-based systems must be supported by providing data management facilities as a basis for knowledge extraction from product data. In this paper, the focus is put on a distributed problem solving environment (PSE) capable of providing access to a variety of necessary resources and services. A distributed approach integrating simulation and optimization on a network of workstations and cluster systems is presented. For geometry generation the CAD-system CATIA is used which is coupled with the FEM-simulation system INDEED for simulation of sheet-metal forming processes and the problem solving environment OpTiX for distributed optimization.

Environmental Indicators for Horticultural Management: Lessons from an Assessment Project

KIYOTADA HAYASHI

National Agricultural Research Center, Japan

Keywords: impact assessment, multicriteria analysis, nitrate issue, pesticide application

Introduction

The impacts of agricultural systems on the environment, as well as the impacts of the environment on agricultural production, are causing widespread public concern and the impacts are related to a wide range of phenomena. As a result, various methodologies for integrated evaluation have been used in practice. Multicriteria analysis for selecting agricultural systems is an example of the methodologies. The attention in the analysis, however, centers on the selection of an appropriate agricultural system with respect to pre-described evaluation criteria. This means that the problems of how to construct evaluation criteria, which are equivalent to the issues of environmental indicators, have not been considered sufficiently.

Therefore, this paper describes the possibility of constructing appropriate environmental indicators on the basis of an integrated framework in order to evaluate the environmental impacts of agricultural practices. An assessment project on greenhouse tomato cultivation using the drip fertigation system, which is considered as a sustainable fertilizer management practice, is discussed to clarify the possibility. Since considering these problems resolves itself into problem structuring and discussing problem structuring takes us to the field of life cycle impact assessment (LCIA), this paper mainly deals with the indicator-based method from the perspective of multicriteria analysis.

Impact Assessment of Greenhouse Vegetable Production

This paper compares the environmental impacts of three tomato cultivation systems. A strategy generation table for defining alternatives in decision analysis is utilized. Tomatoes are supposed to be produced in greenhouses in all the systems. The first alternative is the conventional system, in which 8 fruit clusters are used. The second and third alternatives are the cultivation systems using drip fertigation. 16 fruit clusters are utilized in the drip fertigation system A and 24 fruit clusters are used in the drip fertigation system B. That is, the alternative training methods are practiced in the drip fertigation systems. It is supposed that as a result of the introduction of the new fertilizer application method, the farmer increases the number of fruit clusters and thus increases the number of pesticide application [2, 3].

The results of a field experiment and an on-farm trial were used to compile the data for each cultivation systems. Gaseous nitrogen losses and nitrate leaching, as well as nitrogen into the cultivation systems, were estimated by relying on gas analysis data measured by the flow-through chamber method. The levels of nitrogen application in the drip fertigation systems and the amounts of pesticide application were calculated from the on-farm trial conducted in 2003-2004. All pesticides were applied according to application standards defined by the Ministry of Agriculture, Forestry and Fisheries and the Ministry of the Environment.

The analysis is based on both the environmental themes (midpoint) approach and the damage-oriented (endpoint) approach to LCIA. Impact categories include climate change, human toxicity, eco-toxicity, acidification, and eutrophication; ecotoxicity contains fresh water aquatic ecotoxicity, marine aquatic ecotoxicity, fresh water sediment etotoxicity, marine sediment exotoxicity, and terrestrial ecotoxicity. Damage categories include human health and ecosystem quality.

Modeling Issues

Although the methodology will clarify the environmental impacts of agricultural practices as the previous section shows, there is a need for further developing the methodology in order to analyze a wide rage of problems caused by modern agricultural practices. The following lists illustrate the modeling issues. Since the applicability of life cycle assessment to agricultural production has already discussed by several groups [6, 1, 4], this paper focuses on the issues that are raised from the above application.

System boundary. Since horticultural management involves fertilizer and pesticide applications and the construction of greenhouses, the definition of the system boundary is important in identifying the environmental hot spot [5]. Attention has to be paid also to data availability and data quality.

Functional unit. Two functional units, 1 ha and 1 kg fruit, are applicable to the evaluation of horticultural management. Both units are important because the former provides the information related to land use and the latter presents the information on products and because the result is dependent on the units.

Area of protection. In general LCIA does not define the procedures for coping with the nitrate issue. Especially, health impacts of fertilizer application are not considered sufficiently. In addition, attention is not paid to the problem of alien species; for example, the current LCIA methodology can not cope with the introduction of foreign bumblebees into greenhouse production, although the evaluation would be extremely difficult.

Fate and effect modeling. In spite of the introduction of risk analysis into LCIA, LCIA has not yet established the enough characterization or damage factors for assessing the environmental impacts of pesticide application. Uncertainty analysis will be important especially in this part of impact assessment.

Site-specific assessment. There are geographical and climatic variations in horticultural and agricultural productions. Moreover, various kinds of farmers introduce a variety of farming practices. Incorporating GIS-type approaches will be useful for identifying site-dependent parameters in the assessment.

Concluding Remarks

In LCIA of agricultural production, attention has been paid to the environmental impacts. In order to evaluate the system as a whole, however, we have to consider the economic performance and societal issues. The results of the project indicate the importance of considering the relationship between environmental management and economic performance because environmentally sustainable management is not necessarily sustainable in economic performance. Consumer behavior and acceptance and thus eco-labeling in agricultural products become important topics. Balanced assessment of the economic, social, and environmental impacts will be necessary to construct sustainable agricultural and horticultural production systems.

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A Conflict of Values: Trade versus the Environment in Policy Analysis

KEITH HIPEL *and* AMER OBEIDI

University of Waterloo

Keywords: conflict analysis, ethics and values, globalization, graph model for conflict resolution, market economy, sustainable development

The key goals of this research are to clearly identify the ubiquitous conflict taking place at the local, national and global levels between the basic values underlying trading agreements and those principles providing the foundations for environmental stewardship, especially with respect to water, and to suggest solutions as to how this most basic of disputes can be responsibly resolved. Subsequent to outlining the current situation with respect to free trade among nations and associated environmental problems, the positions of both sides in this chronic dispute between trade and the environment are summarized. Supporting the stance of free trade are the fundamental driving forces of profit maximization and bottom-line economics that are reflected in international trading agreements such as those coming under the umbrella of the World Trade Organization (WTO) and the North American Free Trade Agreement (NAFTA). In direct opposition to this market-driven value system are the principles of maintaining a healthy environment and related social welfare objectives. Accordingly, this global clash of values is systematically studied as a game in which the values of the Global Market-Driven Economy (GMDE) are in confrontation with those of a Sustainable Ecosystem (SES) philosophy. A strategic analysis using the Graph Model for Conflict Resolution reveals that the environment and social standards will continue to deteriorate if the entrenched positions and related value systems of both camps persist. However, based on the strategic insights gained from this formal conflict study, a number of positive proposals are put forward for resolving this conflict from a win/win perspective, at least in the long run. For example, SES proponents should be encouraged to carry out extensive educational and lobbying programs to educate the general public and positively influence GMDE supporters regarding the economic benefits of practicing sustainable development. Associated shifts in the value system of GMDE could lead to reforming international trade agreements such that both sides would benefit.

As explained in an overview paper by Hipel (2003) and in articles contained within Theme 1.40 on Conflict Resolution in the Encyclopedia of Life Support Systems (EOLSS), a wide range of psychological, sociological, operational research, game theory, systems engineering and other kinds of models have been developed for systematically studying conflict and its resolution. Here, a formal systems engineering approach called the Graph Model for Conflict Resolution (Fang et al., 1993) is employed to model and analyze the Conflict of Values. This flexible methodology is implemented in practice using the decision support system called GMCR II (Fang et al., 2003 a,b; Hipel et al., 1997; Kilgour et al., 2001).

An earlier version of the research appearing in this presentation was presented at an international conference held in Delft, The Netherlands, in November 2002, and published in the conference proceedings (Hipel and Obeidi, 2004). As far as the authors are aware, their research constitutes the first time that a formal conflict resolution methodology has been employed to analyze rigorously the ongoing global conflict between the ethics of free trade and the environment. Whatever the case, a systematic study of a strategic dispute permits one to better understand what is taking place, put the dispute into better perspective, gain insights about how the conflict can be best resolved in both the short and long term, and suggest innovative solutions. In fact, a conflict technique furnishes an effective and precise language of communication for discussing a specific conflict in the process of searching for a win/win resolution for everyone concerned. For the situation of the ongoing conflict of values between free traders and environmentalists, both sides have become entrenched within their own value systems and a better comprehension of the actual situation and an empathetic appreciation of both sides' fundamental values, could lead to an eventual breakthrough.

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Systematic design of recombination operators

ANDRZEJ JASZKIEWICZ

Institute of Computing Science, Poznan University of Technology, Poznan, Poland

Keywords: metaheuristics, hybrid evolutionary algorithms, design patterns

The paper describes a systematic approach to the design (a design pattern) of recombination operator for hybrid evolutionary algorithms. The design pattern is based on experimental tests of quality-similarity correlations for a range of similarity measures that take into account various features of the solutions. The goal of the pattern is to reduce the workload needed to develop an efficient algorithm for a given problem. The use of the pattern is illustrated by exemplary applications to the problems of vehicle routing, Earth observation satellites management and car production scheduling.

Hybrid Evolutionary Algorithms that hybridize recombination operators with local search, or more generally with other local heuristics, constitute a relatively new class of metaheuristics. Other frequently used names are Memetic Algorithms or Genetic Local Search. Methods of this type often perform very well on combinatorial optimization problems, e.g., on the traveling salesperson problems (TSP) [4], the graph coloring problems [1], the quadratic assignment problems [11], [12], vehicle routing problem [4], and the set covering problem [1].

Metaheuristics define general schemes for the optimization procedures that have to be adapted for specific problems. The way a given metaheuristic is adapted to a particular problem may have a crucial influence on its performance.

The process of adapting a metaheuristic to a given problem is, however, a challenging task even for problems with a simple definition. For example, efficient algorithms for TSP [4] are results of dozens of years of research on this problem.

In our opinion, in order to reduce the time needed to adapt efficiently a metaheuristics to a given problem some general adaptation patterns should be derived from the past successful works. This concept is similar to design patterns widely used in software engineering [4]. In fact, the schemes of metaheuristics may also be interpreted as adaptation patterns.

The reader of many publications on evolutionary algorithms and other metaheuristics may get an impression that the methods can efficiently solve any optimization problem. However, the "No Free Lunch" (NFL) theorem [13] clearly states that there is no algorithm with a performance, averaged over all possible objective functions, that outperforms systematic enumeration. Thus, all optimization algorithms, including metaheuristics, are based on some, possibly implicit, assumptions; i.e. they are appropriate for some classes of functions. The NFL theorem is based on an assumption of a uniform probability distribution over the set of all possible objective functions. The probability distribution corresponding to the "real-life" problems can be much different. The success of metaheuristics in many applications proves that their assumptions are often met in practice.

Our hypothesis is that metaheuristics, and especially hybrid evolutionary algorithms, perform well on objective functions for which quality-similarity correlation may be observed, i.e. good solutions become more and more similar. Note, that we do not claim that metaheuristics perform well only on this class on objective functions.

Quality-similarity correlation has been observed for instances of many combinatorial problems [2], [6], [7], [10], [11]. However, the similarity of solutions may be measured in many ways, taking into account various features of solutions. For example, in the case of practical vehicle routing problems one

may consider the following features:
• selected orders (if not all orders have to be handled),
• assignment of orders to vehicles,
• pairs/groups of orders handled together in a single route,
• arcs on the routes,
• pairs of orders carried together by a vehicle.

Corresponding similarity measures may count the number or percentage of features common to both parents. Of course, it is possible that the quality-similarity correlation is observed for some of the features while for others it is not [7]. Thus, testing quality-similarity correlation allows identifying significant features of solutions.

The quality-similarity correlation of a given instance may be exploited in several ways (see e.g. [2]). One of the most successful approaches is the use of distance preserving recombination operators within hybrid evolutionary algorithms [6], [10], [11]. Such operators preserve in the offspring all instances of significant features that were common to both parents. For example, Merz and Freisleben [10] proposed a well-performing recombination operator for TSP problem that preserves all arcs common to both parents.

Generalizing the previous works of Merz and Freisleben [10], [11], Jaszkiewicz and Kominek [6], and Kubiak [7] we formulate the following adaptation pattern for (hybrid) evolutionary algorithms:
• Generate sets of good (e.g. being local optima) and diversified solutions for a set of instances of a given problem.
• Formulate a number of hypotheses about solution features important for a given problem.
• For each feature and each instance test quality-similarity correlation using as the similarity measure the number (or percentage) of common instances of the feature.
• Design a distance preserving recombination operator assuring (or aiming at) preservation of common instances of features for which global convexity was observed. The operator may preserve common instances of several features.

The use of this design pattern is illustrated by its application to some combinatorial problems, especially to vehicle routing problems. The hybrid evolutionary algorithms using operators designed in this way are experimentally compared to multiple start local search and to hybrid evolutionary algorithms using other recombination operators.

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Optimized groundwater management

STEFAN KADEN

WASY Institute for Water Resources Planning and System Research Ltd.

MANFRED GRAUER

University Siegen

Keywords: optimization, water management

Surface water logging as a result of massive subsidence caused by coal mining activities on the left shore of the Lower Rhine can only be prevented by extensive drainage measures. Numerous pumping stations are being used to preserve the depth to water table with regard to urban areas. Some of these pumping stations are additionally used for the extraction of drinking water. In a case study the control of three pumping stations has been optimized at the center of the Binsheimer Feld subsidence area. The groundwater flow of the Binsheimer Feld area, a region close to the Rhine with a high amount of subsidence and in whith over 20 groundwater pumps in use, is described by a two-dimensional transient groundwater flow model over a period of three years. The groundwater flow model was established on the basis of the FEFLOW groundwater flow modeling software, taking into account the factors of transient groundwater regeneration, water level of the Rhine in daily steps and subsidence. Pumping station control is performed in dependence on the depth to water table using control observation points, in order to maintain a depth to water table of 1 m at 10 critical points. The control of one pumping station is infinetely variable. A minimum capacity must be extracted for water supply. For the remaining stations, pump capacity control is available in three stages or one stage, respectively. The optimization process variables are the control points in the observation points, which have to be applied in real processes.

The Distributed Polytope Algorithm was used to find optimal values for these variables. Starting from a randomly created set of feasible solutions, the algorithm tries to apply geometrical operations to create better solutions. This is done in parallel, thus allowing to speed up the costly optimization process by running several simulations simultaneously. The software is implemented in C++ and uses the message passing library PVM to coordinate the optimizer and the simulations. All calculations have been performed on 16 Linux P4 workstations. In the groundwater model, control was mapped using the FEFLOW internal program interface. During runtime, the groundwater level is measured at control observation points and the resulting pump capacity is assigned in the model. In a first approach, the target function to be minimized is the overall capacity. As the control function with the lowest pump capacity is not necessarily the most cost-efficient due to various contracts with the energy supplier, the cost function is defined as the target function in a second approach. In doing so, alternatives with both fixed and adaptive contracts were considered. Adaptive contracts can be adjusted at the beginning of each year with regard to the minimum amounts of electricity purchased from the energy supplier. When looking at the optimization process cost function, it becomes evident that expenditures for fixed contracts can be reduced by more than 10%, and by more than 20% for adaptive contracts.

Linking nature conservation and sustainable water resources management in the river valleys the case of NATURA 2000 sites

JANUSZ KINDLER

Institute of Environmental Engineering Systems, Warsaw University of Technology

Keywords: water resources, nature conservation

Biodiversity is increasingly recognised as an inestimable element of our common heritage. To protect the rare and endangered species and habitats, the NATURA 2000 ecological network is being established in Europe, following the EU *Habitat's* Directive 92/43/92 adopted in 1992. The Directive promotes biodiversity at the NATURA 2000 sites, by maintaining or restoring specific species and habitats (listed in the Directive) at *favourable conservation status*. At the same time the Directive underlines that economic, social, cultural and regional requirements should be taken into account, to achieve sustainable development of these sites.

Among potential NATURA 2000 sites, especially attractive are river valleys offering a unique habitat for a number of species to be protected. The proximity of water and special geomorphological conditions are of special value for a number of flora and fauna species. River valleys also are important wildlife communication routes, known as the *ecological corridors*. But at the same time, throughout the human history, rivers and their valleys attracted human species. Human settlements were growing on the river banks and the rivers themselves were used as a source of water and important transportation routes. At the same time humans were protecting themselves against devastating floods by building protective dikes, water storage facilities, and flood evacuation canals. Considerable effort was made to maintain river channels, their banks and the entire valleys at the status favourable for delivering the services required, often at a cost of some degradation of natural environment and the associated aquatic and terrestial ecosystems. As long as the intensity of these actions was kept at relatively low level, the problem was not much visible and the harm done to nature was relatively small. But the acceleration of unsustainably managed human activities in the last 50 years caused considerable degradation of natural habitats. Pressures on natural ecosystems arise also from poorly designed laws, policies, social changes, and economic forces.

The paper concentrates on the controversies and potential conflicts between nature protection and water management objectives arising in the river valleys designated as NATURA 2000 sites. The purpose of the paper is to present a management framework for the NATURA 2000 sites located in the river valleys, taking into account both the nature conservation and water management (especially flood protection) objectives. The explicit consideration of such multiple and not always compatible objectives is increasingly becoming a common phenomenon among modelers and system analysts. There is too much at stake to be left to intuition or personal judgement. As a matter of fact, the *Habitat's* Directive provides that the EU Member States should establish, if needed, the appropriate management plans specifically designed for the sites or integrated into other development plans. While no indication is given in the Directive of the specific contents of management plans, the document provides some considerations that should be taken into account in view of the preparation of such plans. Identification what is important about the site, both natural values and water management context, is to be one of the starting points of the plan preparation process. It is imperative that the protected NATURA 2000 sites are managed for multiple benefits, in a way that is based on good understanding of unavoidable tradeoffs and are fully acceptable to local communities. In the management framework proposed, the possibilities of application of the Adaptive Resource Management approaches developed in the early IIASA's years will be explored.

Customer management system for monthly-subscription type mobile game content provider

NORIHISA KOMODA

Graduate School of Information Science and Technology, Osaka University, Japan

YUJI SHONO

Graduate School of Information Science and Technology, Osaka University, Japan

AYAKO HIRAMATSU

Osaka Sangyo University, Japan

HIROAKI OISO

Codetoys K. K., Japan

Keywords: data mining, customer analysis, mobile content, decision tree, C4.5

The mobile content market in Japan has been expanding rapidly since 1998. Almost all mobile contents are monthly-subscription type. In the subscription type content business, the users have to pay a large sum of packet charge and the share of monthly content fee of the total payment is extremely low. Therefore, content providers have to make effort for more users to start and continue subscription. The author of this report has been providing a quiz game content on the official menus of three domestic carriers in Japan since 2002. Taking up this content as an example, plural customer analyses will be reported.

Outline of the content is following. One game consists of maximum 15 questions. In this content, four stages of ranking - the 1st stage (lowest stage) through the 4th stage (highest stage) - are prepared. The top 25% players of each stage can move up to the upper stage at the end of every month. A prize is provided to five highest scorers of the highest stage. Its monthly fee is JPY 180 (1.4 Euro). The average packet charge per one game will amount to about JPY 35. Therefore, if the player plays the game 150 times (maximum) in a month, it will cost JPY 5,250 (about 40 Euro) per month for packet charge.

We are starting following researches using various data:

1. an analysis and survey of the prime reasons for unsubscribing through game activity[1],
2. a prediction of customers who will cancel subscription near future[2],
3. an analysis of open-ended questionnaires data answered when users unsubscribe the contents[3][4].

Through the data analysis, it is found that most users unsubscribe by the end of the 0th or the 1st month. Users' game time is quite different according to each user's job or something. For example, users who have jobs usually tend to play games at from 12 am to 1 pm. Most frequently played time zone is midnight.

By using a data mining technique, from the access log and score information of unsubscribers, a rule for determining users who will unsubscribe near future is derived as a decision tree. The C4.5 algorithm is used as a learning algorithm. The selection of the suitable characteristic values is essential. So, the support to generate the various characteristic values from the access log is prepared. By applying the rule to current subscribers, it is predicted when they will unsubscribe. The result of the experiment using real user data was about 72% recall and 65% precision.

On the one hand, the useful unexpected opinions (the atypical opinions) are included only 5% of all questionnaires answers at unsubscription. The atypical opinions may stimulate the provider to improve the service. For the provider to find out this useful opinions, a support system is developing. This system excludes the typical opinions, and extracts the useful opinions from the open-ended questionnaires data. After morphological analysis, the matching engine compares keywords of opinions with the typical words database, in which the combinations of words are set up beforehand. Against about 3000 opinions that include 270 atypical opinions, all atypical opinions was extracted and the precision of the extraction was 85%.

However, the prediction accuracy of unsubscription and the extraction rate of atypical opinions need to be improved for the practical use. Also, based on these researches, an integrated customer management system is considered.

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Modeling the Hydrology, Ecology and their Uncertainties in the Everglades

DANIEL LOUCKS

Cornell University

Keywords: simulation, control algorithms, optimization, uncertainty, ecology, water resources, Everglades

One of America's largest ecosystem restoration projects is currently taking place in South Florida. The Comprehensive Everglades Restoration Project is a complex and expensive one requiring a sequence of decisions over the next three decades in an attempt to preserve and enhance what remains of the Greater Everglades Region of South Florida. Hydrologic simulation models are a critical part of the restoration effort. Major investment and operating decisions are being made based on these models. The restoration goal is to 'get the water right' with the hope of that leading to a more restored ecosystem. Getting the water right involves getting the timing and amounts of the flows, depths, hydroperiods, and water quality right. Engineering structures that once drained much of the wetland (for economic development) are now being removed, and new ones are being constructed to somehow manage water in a way that provides reliable water supplies and flood protection to those living in Southern Florida - and more are moving there all the time - and at the same time provide a more natural 'historic' regime for the extensive Greater Everglades region.

The simulation modeling effort involves three model components. One is the hydrologic simulator, which must model very slow water flow over a very large flat area where the direction of flow can change depending on rainfall and where there is constant interaction between surface and groundwater. This is called the hydrologic simulation engine (HSE). Within the Everglades Region there are flow control structures. At these sites decisions are made with respect to flows passing through these structures from one subregion to another. The gate openings and pumping rates at each control structure are modeled using one of several available optimal control algorithms (CA). The third model component, the management simulation engine (MSE) is a mixed integer linear optimization model that takes into account the entire region and forecast rainfall to determine the 'best' way to manage water in the region. It sends instructions to the control algorithms at each control site. Then the hydrologic simulation engine simulates the response and produces both hydrologic and ecologic habitat performance measure values. In each decision period the system updates itself, new initial conditions and forecast are made and the models are rerun. This Regional Simulation Model (RSM) is used both for planning as well as for real time management.

This paper outlines the three model components of the newly developed regional simulation model, the technical and political issues that have influenced the development and use of this model, and discusses some of the challenges associated with estimating, quantifying and communicating the uncertainties of system performance measures to various stakeholders, and to those who are responsible for decision making. Planners and decision makers recognize the considerable uncertainty with respect to how this ecosystem functions and what decisions will be most effective in restoring it.

The Comprehensive Everglades Restoration Plan (CERP) involves numerous projects to be implemented over the next 30 years. This effort will also include monitoring of the response of the system to projects as they are implemented. It is the responsibility of the Restoration Coordination and Verification (RECOVER) team to evaluate the system-wide performance of each project and the overall performance of the Plan as it is carried out. Dependent on the results of these performance evaluations, the Plan may be modified and refined.

Key to refining and implementing the CERP is the evaluation of various performance measures derived from model output. Tradeoffs must be made among various system performance measure values. For example, restoring an ecosystem doesn't mean all living plants and animals in the ecosystem will be better off. How do we make the 'best' tradeoffs? This is often uncertain due to lack of knowledge even assuming the system performance values are correct. But we know they are not. Model uncertainty, originating from input uncertainty, parameter uncertainty, model structure uncertainty and algorithmic (numerical) uncertainty is translated into uncertainty in the performance measures. In addition to performance measure uncertainties, there is uncertainty as to whether the specific performance measures used to characterize the overall system performance actually capture that overall performance.

The RECOVER team responsible for evaluating model alternatives must take account of this uncertainty as they make decisions as to the relative merits of each alternative. They will be seeking alternatives that have the highest probability of achieving project goals while minimizing the risk of undesired outcomes. This involves tradeoffs among target performance measures, their reliability (probability of being met), the confidence we have in the estimates of their values and their reliabilities, and the cost of any required infrastructure or operating decisions.

There are many interesting research opportunities and needs with respect to carrying out an uncertainty analysis on a system as complex as the Everglades and with the models being used to identify and evaluate alternative water management policies. Clearly there is uncertainty associated with any prediction of what might happen if any particular water management policy is implemented. Nevertheless, the focus of any scientific study in support of uncertainty analyses for improved decision making should be on the decisions being made (or objectives) associated with the resource and not, as we might do in universities, on the model or on basic science. A predictive model (or more generally, a predictive scientific assessment) should be evaluated in terms of its use in addressing these decisions/objectives. This means that, ideally, predicted endpoints should be decision-based and not tool-(model)-based. In reality, good endpoints will reflect a compromise between what is desirable to aid decision-making and what is feasible for scientific assessment.

Support of Modeling Process by Structured Modeling Technology

MICHAŁ MAJDAN *and* CEZARY CHUDZIAN

International Institute for Applied Systems Analysis, Laxenburg, Austria, and *National Institute of Telecommunications, Warsaw, Poland*

Keywords: model-based decision support, structured modeling, algebraic models, decision rules, model analysis, preferential structure, documentation of modeling process, results analysis, distributed modeling

Structured Modeling Technology (SMT), is a consistent framework for maintenance of the whole complex models development process. SMT is designed to cover all steps of modeling process, from symbolic specification, data management, through model instantiation, analysis and results' maintenance. The system is based on well established technology of relational databases, assumes web access to all functionalities and provides an easy way for documenting modeling activities.

The presentation will cover issues of architecture, design and implementation of SMT Framework components.

1. Model Symbolic Specification

The basic concept of SMT Framework is a model representation. Model representation consists of two components:

- Symbolic model specification composed of collections of indices, sets and entities combined by relations.
- Data, here the actual values for the model parameters and definitions of the sets.

SMT logical architecture is shown in Fig. 2.

The basic component of SMTF is an entity. The other objects are derived from the Abstract Entity type:

- Constants are the Entities that cannot be indexed, and are always given a specific value depending on the value type of the entity.
- Parameters are entities that will be assigned values in the next stages of model development process.
- Variables can be of several roles: decision variables (controlled inputs for the model), output variables, auxiliary variables (the internal variables of the model), external variables (independent inputs).
- Relations are the entities that combine other entities with each other as well as with the indices and defined sets. SMTF defines two kinds of relations: definitions and constraints. Definitions are assignments where on the left side is one of the defined variables while on the other the user provided expression. Assignments are not bounded. Constraints are expressions that are bounded by the values of constants or parameters defined for a particular entity.

Entities are assigned a value type which is one of the following:

- Integer
- Binary
- Real
- Categorical

This allows to control the consistency of the data assigned to the parameters and values of the results.

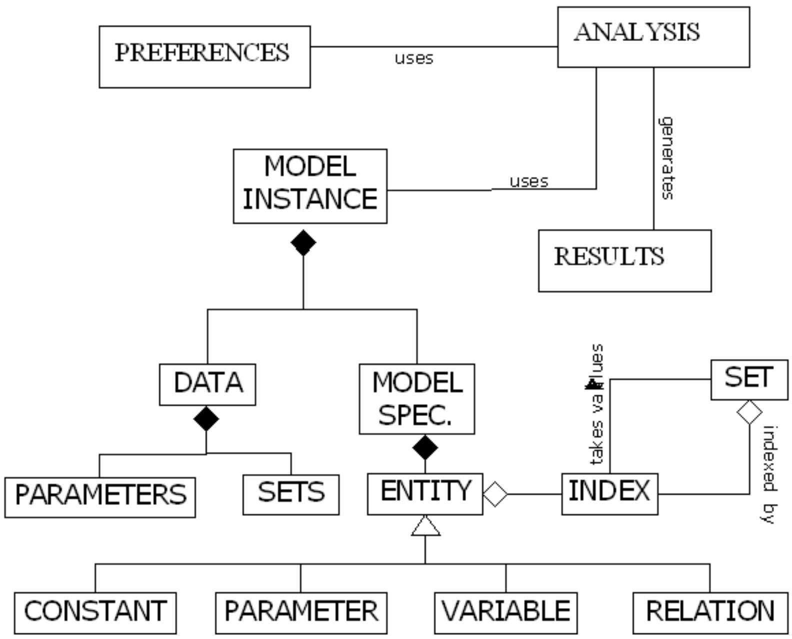

Figure 2: Tree of parameterized bounds

Primitive entities are expanded into compound entities by indices, which in turn are organized in sets. Indices in SMT can be of two types:

- Collection is the type of index that does not require indices to be ordered in any way.
- Sequence is the type of index that allows construction of dynamic models, values of the indices of this type are defined by the starting value step and ending value of the index.

To simplify the notation and to make it more clear so called Aliases and Compound Indices are introduced. Aliases are basically alternative names for other indices while compound indices are indices composed of values of at least two other indices that are used together.

Sets group the values of indices. For each index a default set is created that contains all values of the index. Apart from that the user has a possibility to create custom sets. User defined sets can be indexed so that the composition of set members can differ depending on the values of the indices declared for the set. The values of the sets are provided by user in the following stages of model development process.

The model specification definition built of the elements described above is checked for consistency each time it is modified. One cannot remove any object that is used as well as one cannot use objects that have not been previously defined. This allows the user to develop even a complex model without having to keep in mind all the dependencies implied by the model specification.

2. Model Data

Having defined the model specification the user has come to the stage of providing data for the model. The first step is to generate the data structures of the Data Warehouse that is going to contain values for the model parameters for given combination of indices as well as definitions of the sets and data structures to store the results of instance analysis. Data warehouse is generated automatically based on a provided model specification. When the DW is generated the model specification cannot be changed (this is assured by the system).

Directly after the DW is created, the main set of data should be provided. This should define all values of existing parameters and definitions of the sets. The main data import will usually imply lots of data processing therefore the primary way to do that is via file upload. After the initial import is finished data can be repeatedly updated. Each update has it's own name, description, creator name and date of definition. It also needs to have the parent data set defined. The parent data set can be either initial

import or any other update previously defined. Each update except the initial import has one parent data set defined. Updates form a tree-like structure with the initial import as the root node. The definition of data update consists of new values of the parameters for given values of indices and changes to the index set definitions. The user can override the values of parameters for the sets of indices as well as provide new ones or exclude the values inherited from the parent data set. Set updates can contain new values for the indices added to the sets as well as exclusions of values inherited from parent data set. Data updates can be defined in two ways:
- Multiple Updates are updates defined by files uploaded via the same mechanisms as the initial import data.
- Single Updates are defined interactively by user via web interface.

At any point in time before the update definition is finished and locked the user can switch between the above modes of update definitions to fine tune the update that he/she is working on.

Such structure of data allows concurrent collaboration on the model by users, using and providing different sets of data. It also allows version control of the data, so that each analysis performed can be easily linked to the actual data it was performed for.

3. Model Instance

Having defined the data, the next step in the model analysis process is model instantiation. SMT defines model instance as a combination of model specification and data. SMTF allows the user to select both model specification and specific data update (including initial import) to create the model instance that is going to be the subject of analysis. Model instance is not created physically, that is, no data is retrieved from DW to provide actual values of the parameters in the selected data update. Instead only the identifiers of both model specification and data are saved. The data is retrieved upon generation and execution of a computational task for the problem solver. Such an approach saves significant amounts of storage space and time.

4. Model Analysis

Once the model is instantiated, it may be subject to various analysis. Common practice in the case of algebraic models is specification of preferential structure, selecting a subset of solutions, or even a single one. Set of pareto optimal solutions in multicriteria optimization problem and global optimum for single optimization analysis, are examples of this rule. SMTF currently allows several types of model analysis:
- optimization
- parametric optimization
- simulation
- soft simulation
- decision rules generation

Structuring the preferences is crucial for proper design of module responsible for analysis process maintenance. In all the cases mentioned above elementary preference items may be represented by triples (*variable, role, value*), where *variable* is either the decision or outcome variable, *role* indicates the role of an item in the whole preferential structure and *value* contains optional value needed for some types of items. Variable specification consists of a selected entity of type variable and fixed values for indices associated with an entity. Role depends on the analysis type. For instance it may be goal function, lower or upper bound, desired value of outcome or decision, etc. Variables being in some of the roles (e.g. lower/upper bound), must have additional values assigned. Triples are organized in a tree structure that allows easy and robust implementation of preferential structure especially for iterative analysis tasks such as parametric optimization. The root node is the definition of goal function, the consecutive nodes represent bounds. The preferential structure definition for a single analysis run is defined by a single branch in the created tree. Therefore in case of single (non parametric) optimization analysis, the preferential structure tree degenerates to the single branch. Parametric optimization branches representing inconsistent bounds in preferential structures do not generate computational tasks to be performed so no resources are wasted on trying to solve such problems.

5. Architecture and Technology

The SMTF system architecture relies on widely used web technologies. The persistency layer is build on the top of RDBMS (Oracle 9). Logic of the system is implemented as a Web-Application handled by Servlet Container. Dynamically generated web pages serve as a presentation layer accessed via web browser. The general structure of system software components is presented in Fig. 3.

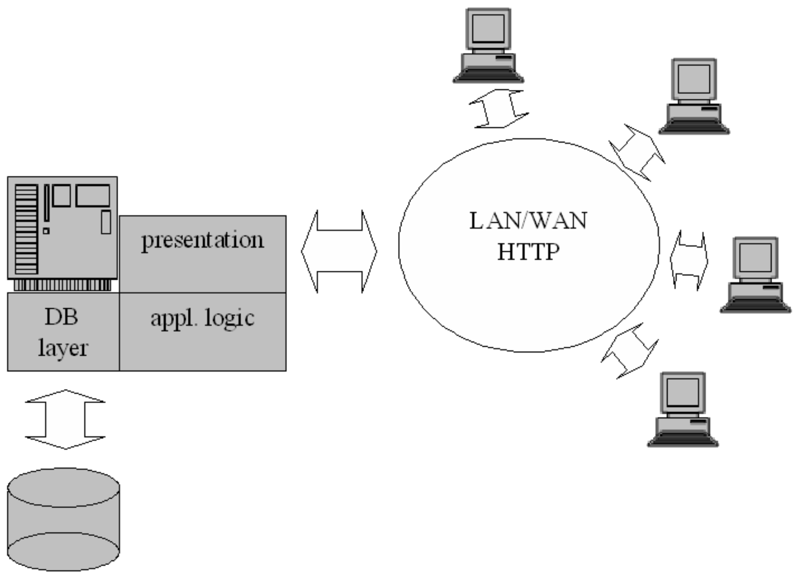

Figure 3: Architecture of the SMT Framework.

6. Conclusions

SMTF system implements now most of the concepts of Structured Modeling Technology. It can be used by users with no previous experience in modeling languages and the modeling process itself. The consecutive steps in the model analysis process are made available for the user only after successfully completing all previously required activities. The system does not require a user to install any software components on his/her own since it is accessed via web browser. It provides an easy way for teams of model developers working on the same model, sharing responsibilities and performing different types of analysis using different model instances. It also provides reliable version control and ability to trace down which data and preferences produced certain results at any point in time. The SMTF system has been under development for almost half a year now. Most of it's functionality has been implemented. There still exist problems that need further attention and testing. Looking into the future the SMTF system can be a starting point for developing functionality of automatic result data analysis (using Data Mining techniques) and visualization. The SMTF has been also successfully applied not only for algebraic models but also for the development of decision rule generation models.

Structured Modeling of Complex Problems

MAREK MAKOWSKI

International Institute for Applied Systems Analysis

Keywords: structured modeling, decision support systems, modeling paradigms, model management, object-oriented programming, distributed systems.

1. Background

The complexity of problems, and the role of corresponding models in decision support, are the two main factors that determine requirements for the type of modeling technology that differs substantially from the technologies successfully applied for modeling well-structured and relatively simple problems. In most publications that deal with modeling, small problems are used as an illustration of the modeling methods and tools presented. Often, these can also be applied to large problems. However, the complexity is characterized not primarily by the size, but rather by the structure of the problem and by the requirements for the corresponding modeling process.

Modeling is a network of activities, often referred to as a *modeling process*, or a *modeling lifecycle*. Such a process should be supported by modeling technology that is a craft of a systematic treatment of modeling tasks using a combination of pertinent elements of applied science, experience, intuition, and modeling resources, the latter being composed of knowledge encoded in models, data, and modeling tools. Thus the key to a successful modeling undertaking is defined by the appropriate choice of *"a combination of pertinent elements"*.

Geoffrion presented in [2] a detailed specification of a modeling cycle. Here, we discuss the modeling cycle composed of more aggregated elements which correspond to the elements of the *Structured Modeling Technology* (SMT) outlined below:

- Analysis of the problem, including the role of a model in the corresponding decision-making process; and the development of the corresponding *model specification*.
- Collection and verification of *the data* to be used for the calculation of the model parameters.
- Definition of various *model instances* (composed of a model specification, and a selection of data defining its parameters).
- Diversified *analyses of the instances*.
- *Documentation* of the whole modeling process.

Often, a well organized modeling process provides more help to solving the given process than any specific result of the model analysis. Obviously, the quality of model-based support is determined by the weakest element of the modeling process. For simple problems it is possible for one person to develop and analyze a model using simple, general-purpose tools like a spreadsheet. However, any complex model is developed by several interdisciplinary teams, each contributing diversified pieces of knowledge that ultimately are organized in a mathematical model that can actually help to solve the problem. Thus, one needs a modeling technology that supports the whole process of modeling complex problems in a consistent way.

2. Structured Modeling Technology (SMT)

SMT is based on two successful paradigms: the *Structured Modeling* (SM) paradigm developed by Geoffrion [1], which provides a proven methodological background, and the *Object-Oriented Programming* (OOP) paradigm which, combined with DBMS, XML, and the Web technologies, provides an efficient and robust implementation framework.

SMT is used through the Web interface, and all persistent elements of the modeling process are maintained by a DBMS. Thus the Web and a DBMS provide an integrating framework for collaborative work of interdisciplinary teams that use SMT applications for various elements of the modeling process.

The functionality of SMT is provided by a suite of applications that currently run on IIASA's network of Sun workstations. However, they can be adapted to run on heterogeneous hardware available at distant locations, if needed. SMT is being implemented for two widely used DBMSs, namely Oracle (which was used for the first version of SMT), and PostgreSQL (to which SMT will be ported in future). SMT is designed to be used by any authorized person having access to the Web. Groups of users (in the sense of groups used by the Unix OS) are defined; each group has different sets of authorizations to perform certain modeling tasks for selected models. Such an approach supports collaborative modeling by teams working at distant locations.

SMT supports the whole modeling process through a structured user interface illustrated in Fig. 4. Thus SMT can be used without learning any modeling language and without even understanding DBMSs; both these technologies (which provide robust and efficient handling of the modeling process of complex problems) are hidden from users. The structured user interface guides users through steps of the

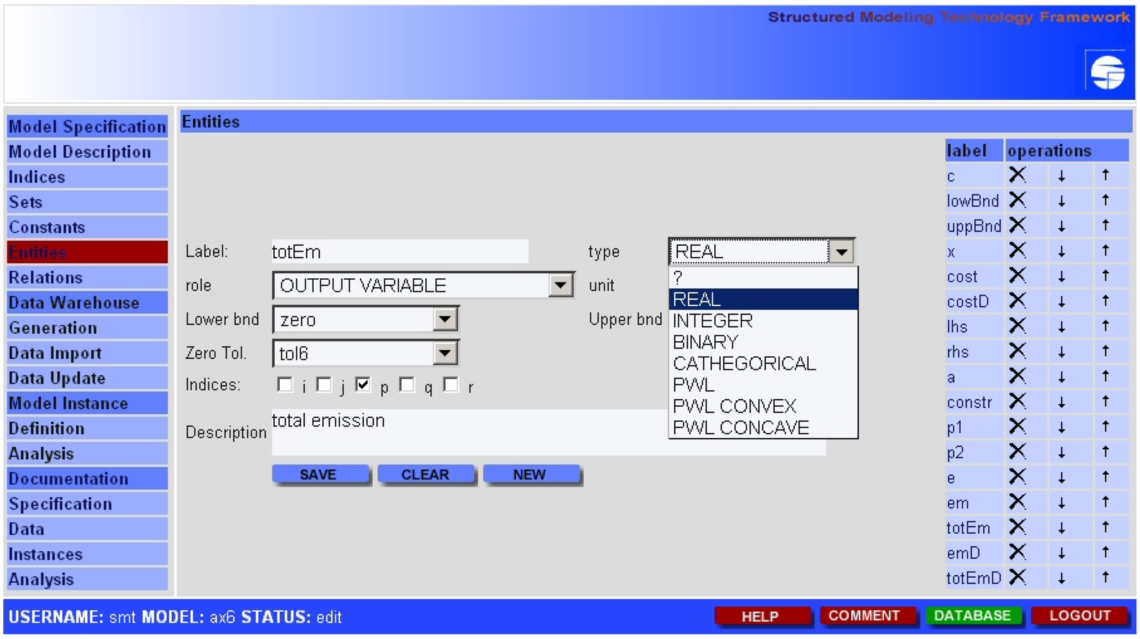

Figure 4: User interface of SMT (the displayed form serves for the specification of entities).

structured modeling process which are outlined below.

A more detailed presentation of SMT can be found in [4]. Here we only outline basic features of three SMT components.

2.1 Model Specification

Model specification is a symbolic definition of the model composed of variables and algebraic relations between them. In order to efficiently handle large and complex models the specification exploits the power of OOP combined with core concepts of SM, such as sets, relations, hierarchy, primitive and compound entities. Primitive entities have attributes and functions common for the derived types, namely parameters, variables, and constraints (representing parametric relations between variables), each possessing additional attributes specific for each of them. Compound elements of the specification are composed of collections of indexed primitive entities. Two types of indices are currently supported: sequential, and collection. Indices are organized into sets; sets can also be indexed (i.e. a composition of members of a set may be different for various values of the index (or a set of indices) that index such a set); this provides a powerful way for specification (and later instantiation) of complex problems in a compact and transparent way.

In other words, model specification provides parametric definitions of all variables, constraints, indices, and sets; it is equivalent to a commonly used symbolic definition of a problem by a specification of variables and constraints, in which all distinct collections (symbolically defined by sets) of variables and constraints are declared. The sets of indices needed for the instantiation of collections are only declared (they are defined later by specification of sets and their updates, which are in turn used whenever model instances are needed); this makes it possible to generate a complete representation of each model instance from a definition that is rather small also for a large model.

2.2 Data

Data for large models comes from different sources (also as results from analyses of various models), and larger subsets of data are maintained by teams. SMT exploits the concept of *Data Warehouse* (DW) for supporting persistency and efficiency of data handling. The data structures of a DW are generated automatically from the model specification. This not only assures consistency between the declarations of the parameters (including indices and sets) in the model specification and the data used for their instantiations, but also saves substantial resources that would otherwise have been needed for preparing and maintaining data structures for any complex model. Moreover, SMT supports import of data from DBs, and from files having a simple, self-documenting format.

For the sake of efficiency the persistency of all data modification is achieved by defining a base dataset, and supporting incremental modifications of this set (which allows avoiding duplications of large amounts of data needed in more traditional approaches requiring the storage of complete datasets even when only a small fraction of the data is modified). Efficient data structures are also used for definitions of sets; this is especially important for large models that use indexed sets because the number of sets in such models can be counted in thousands, and each set can have a large number of elements.

The DW handles not only data used for the computation of values of model parameters, but also all other persistent elements of the whole modeling process, including:

- Administrative data (about users, developers, administrators, access rights, etc.);
- A tree structure of updates defining various modifications of data;
- The specifications of elements of the modeling process, such as model specification, a selection of data (defined by a selection of updates), definitions of model instances;
- Results of various analyses of model instances.
- The documentation of the modeling process.

Although SMT uses XML for data, it does so in a way that is different from that used in commonly known XML-based applications, which typically document each data item separately. SMT uses XML only for meta data, which contains all the necessary information about the data structure (including types and units of each data element) and documentation; sparse or dense data structures are used depending on the sparsity characteristics of the corresponding data items. Therefore, the actual data is stored without any redundant information. Moreover, if necessary (e.g., for huge amounts of data) more efficient ways (e.g., based on BLOB or HFD) can be used to combine the advantages of a standard use of DBMSs with efficient handling of large amounts of numerical data.

2.3 Model analysis

Model analysis is probably the least-discussed element of the modeling process. This results from the focus that each modeling paradigm has on a specific type of analysis. However, the essence of model-based decision-making support is precisely the opposite; namely, to support various ways of model analysis, and to provide efficient tools for comparisons of various solutions.

The basic function of a model-based *Decision Support System* (DSS) is to support the user in finding values for his/her decision variables that will result in a solution of the problem that best fits his/her preferences. A countless number of actual applications show that to meet such requirements a well-organized model analysis phase of the modeling process is composed of several stages, see e.g., [5], each serving different needs. Thus, not only are different forms of preferential structure typically used for the same problem, but also different instances of each of these forms are defined upon analyses of previously obtained solutions.

A typical decision problem has an infinite number of solutions, and users are interested in those that correspond best to their preferences represented here by a *preferential structure* of the user. Various specifications of the preferential structure support diversified analyses of the decision problem aimed at:

- Suggesting decisions for reaching specified goals;
- Analyses of trade-offs between conflicting goals; and
- Evaluations of consequences of decisions specified by the user.

A preferential structure typically induces partial ordering of solutions obtained for different combinations of values of inputs, and in a well-organized modeling process is not included in the model, but is defined during the model analysis phase, when users typically modify their preferences substantially.

The analysis of the model instance is composed of a sequence of steps, each of which consists of:

1. Selection of the type of analysis, and the definition of the corresponding preferential structure, which takes different forms for different methods of model analysis, e.g., for:
   - Classical simulation, it is composed of given values of input variables;
   - Soft simulation, it is defined by desired values of decisions and by a measure of the distance between the actual and desired values of decisions;
   - Single criterion optimization, it is defined by a selected goal function and by optional additional constraints for the other (than that selected as the goal function) outcome variables;
   - Parametric optimization, it is defined as a sequence (possibly composed of thousands elements) of single criterion optimizations;
   - Multicriteria model analysis, it is defined by an achievement scalarizing function, which represents the trade-offs between the criteria used for the evaluation of solutions.
2. Selection of a suitable solver, and specification of parameters that will be passed to a solver.
3. Generation of a computational task representing a mathematical programming problem, the solution of which best fits the user preferences.
4. Monitoring the progress of the computational task, especially if it requires a substantial amount of computing resources.
5. Translation of the results to a form that can be presented to the user.
6. Documenting and filing the results, and optional comments of the user.

A specialized utility called *Scheduler* has been developed for an efficient handling of possibly large number of computational tasks (e.g., a parametric optimization of a large model may require dozens of thousands of optimization runs). The scheduler maintains queues of computational tasks and dispatches them for execution on workstations available on a LAN (Local Area Network).

2.4 Documentation

SMT exploits the XML capabilities for handling the documentation. XML is a data format for storing structured and semi-structured text, originally designed for publications on a variety of media. However, it can also be used for self-documenting various types of information that is exchanged between applications.

In SMT an XML document type is defined to enable a single-source model symbolic specification that can be used for all relevant tasks of the whole modeling process. The documentation of other elements of the modeling process is done on different levels of detail. The basic information (such as date, user name, options requested for each object to be used) is automatically stored in the DW by each

SMT application. Additionally, a user accessing a DB with privileges for data creation or modification is asked to write comments, which are logged. A more advanced documentation (e.g., automatic logging of changes in a way that allows for documenting the complete history of modifications, and optional undoing of the changes) can be included in applications that manipulate data.

3. Conclusions

Development of models for complex problems does, and will, require various elements of science, craftsmanship, and art (see, e.g. [6] for a collection of arguments that supports this statement). Moreover, development and comprehensive analysis of a complex model require a substantial amount of time and other resources. SMT has been developed to provide a modeling environment which supports the whole modeling process, thus increasing the quality of modeling work and reducing the amount of the needed resources. While some features of SMT are already present in various modeling systems, SMT is probably the only modeling system that is fully integrated with DBMSs, and can actually be used for collaborative development and for the distributed use of complex models.

Thus, SMT effectively supports collaborative modeling (both model development and exploitation) by interdisciplinary teams working at distant locations. In particular, SMT supports the development of models with complex structures and huge amounts of data, and diversified analyses of such models; moreover, it provides automatic documentation of the whole modeling process. Moreover, SMT promotes modeling quality and transparency, which are critically important for model-based support of decision-making, especially in environmental policy.

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Mobile Clinical DSS: Providing Support at the Point of Care

WOJTEK MICHALOWSKI

School of Management, University of Ottawa, Canada

ROMAN SLOWINSKI

Institute of Computing Science, Poznan University of Technology, Poland

SZYMON WILK

Institute of Computing Science, Poznan University of Technology, Poland

Keywords: decision support systems, "lean" computing client, model- based design, ubiquitous decision support, mobile decision support

Healthcare professionals normally need to conduct several activities while evaluating a patient. For example, physicians first have to complete initial assessment, then establish diagnosis, and finally control and adjust an appropriate treatment plan (often called "clinical pathway"). Moreover, a physician who is following a treatment plan while managing patient's health needs to revisit and re-evaluate this plan when patient's condition changes in an unexpected manner. Finally, the need for support in clinical decision making arises at a time when a decision is being made for example in the Emergency Department of a hospital. In order to meet these decision support requirements a new class of clinical decision support systems (CDSS) has to be created, so they are truly capable of dealing with complex triage and diagnosis problems in a variety of decision situations. We propose a concept of an *anytime and anywhere* CDSS that relies on an enhanced architecture of a decision support system (DSS), combined with the most recent advances in design of ubiquitous computer systems.

Figure 5 presents the classical architecture of a DSS proposed by Sprague in early 1980's. According to this design, a DSS consists of a database subsystem (storing problem data and generated results), a model subsystem (combining decision models and appropriate solvers), and interface and dialog subsystems (controlling interactions with other subsystems and managing interaction with an end-user). Such a design is not flexible in terms of possible adjustments to the type of an end-user (his/her needs) and the type of a decision problem. Moreover, possibilities of distributing system's functions are limited to the client-server paradigm, where a client acts as a front-end for entering data and presenting results, while a server is responsible for complete processing. Such a DSS works correctly in strong-connectivity conditions (with reliable and permanent connection between a server and clients), that are typical for web-based systems, but are not appropriate in other settings requiring pervasive decision support.

Figure 6 presents our proposal for an *anytime and anywhere* CDSS or a mobile CDSS (m-CDSS). This proposal is derived from the classical DSS architecture, enhanced with expanded functionality aimed at providing ubiquitous support. It relies on recent advances in general system design (model-based approach for designing system components including user interface), DSS design (separation of decision models and generic solvers), and design of mobile and distributed systems (extended client-server paradigm). A ubiquitous DSS has to be accessible "at the point of care", making it imperative that it is available anytime and anywhere to a physician. Thus, we believe it should be accessible not only through networked desktop systems, but first of all through portable devices, ranging from mobile phones to tablets and notebooks. Such implementation means that an m-CDSS should adjust to the specificity of

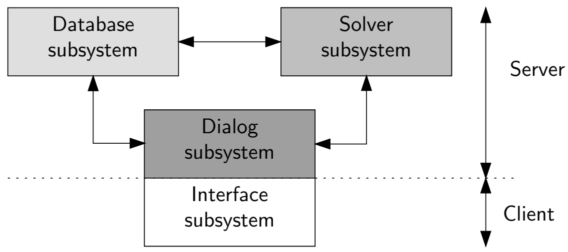

Figure 5: Sprague's architecture of a DSS

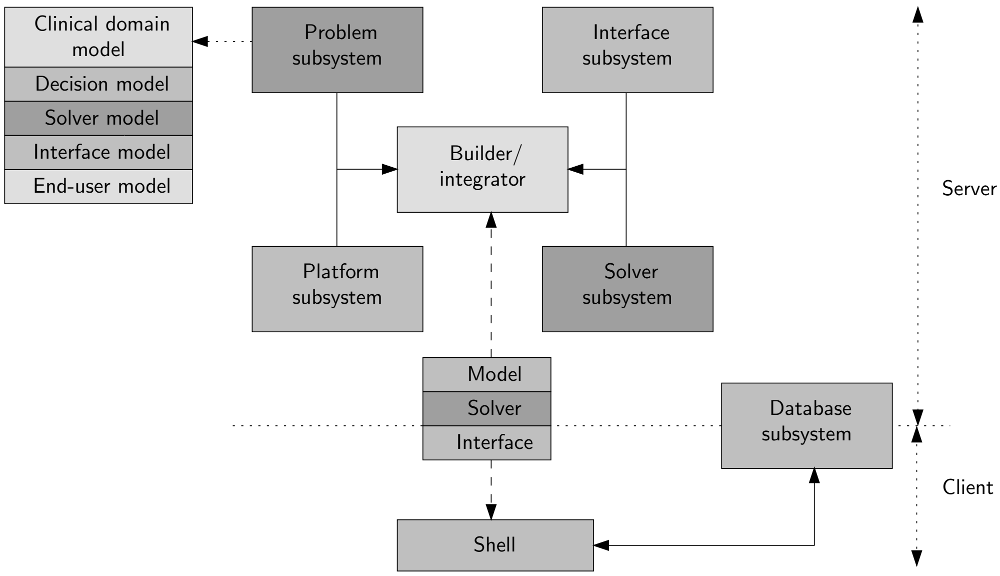

Figure 6: Architecture of an m-CDSS

a target platform (computing and interaction capabilities) and the quality of connection with a computer network. Finally, it is important to recognize that an m-CDSS should offer an extensive flexibility of customization to evolving needs of an allied health professional and new clinical problems.

The proposed m-CDSS design fulfills modularity and granularity requirements that are essential for providing ubiquitous support. It is possible to illustrate basic concepts behind this design using the example of Lego blocks. Let us use the following metaphor for an m-CDSS session on a "lean" computing platform. Assuming that one wants to build a small red house from the Lego blocks in such a way that it fits into limited space, then one would consult an assembly instruction, get appropriate blocks (color and shape) from a pile, and finally assemble the house. In the m-CDSS terms interface and solver subsystems can be considered as a set of different Lego blocks, clinical problem and computing platform subsystems can be seen as an instruction how to assemble the house, the house itself will correspond to an identified clinical decision problem and a specific support task, and finally the limited space will reflect limited computing capabilities of a "lean" target computing platform. To provide ubiquitous support, an appropriate problem and platform models are selected in order to provide "instruction" for selecting blocks from the solver and interface subsystems. A "package" is then assembled and transferred to a lean client where it is transformed into a *DSS in use*. If a clinical problem changes and support is no longer required, appropriate components are "purged" (equivalent to destroying the Lego house) to free necessary "space", and a new support environment can be requested. Thus, an m-CDSS designed in such a way is capable of handling complex triage and diagnosis problems on "lean" target platforms, and it can operate within a changing decision environment and according to changing needs.

The proposed m-CDSS expands the classical DSS paradigm by enriching its context. According to our proposal, the problem subsystem contains rich problem models for different clinical presentations. Each problem model is composed of a clinical domain model (describing a problem domain), a decision model (containing "knowledge" necessary to triage and manage a clinical problem), a solver model (specifying which generic solver should be used with a decision model and what its specific parameters are), an interface model (defining a platform-independent user interface), and an end-user model (representing characteristics associated with a specific class of allied health professionals, including their behavioral and support requirements). Such a definition of the problem subsystem makes it easy to add and modify problem models as they are no longer embedded into other subsystems, and an m-CDSS can be easily adjusted to handle new or revised clinical presentations and end-user requirements. Introduction of the end-user model to problem models was inspired by research on the role of information about an end-user (allied health professional in a case of the m-CDSS) in the overall system design. It follows research by Wierzbicki and his group from IIASA, where it was proposed that the classical DSS paradigm should be augmented with a decision maker model to better reflect intertwined character of provision of support and a request for support.

The platform subsystem on m-CDSS contains enhanced models of computing platforms that describe the characteristics of specific target clients (display size, input devices, available storage, etc.). Similarly to the problem subsystem, such a design solution makes it is easy to add instances for new platforms, or to modify characteristics of existing platforms if their capabilities change (this information is no longer hard-coded into the system design).

The problem and platform models are used by the builder/integrator component to construct a *DSS in use* (handling a specific clinical decision support problem) and to customize it to a specific platform. When the builder/integrator receives a request for a decision support function coming from a specific access platform, it retrieves a model of a clinical problem, and a model of a requested platform. With this information, the builder/integrator is capable to extract necessary building blocks from the interface and solver subsystems, to customize them to a target platform and allied health professional needs, and finally to assemble them into a *DSS in use* to be executed on a client. The customization includes crafting a user interface to interaction capabilities of a platform and behavioral requirements of an end-user, and selecting a solver suited to computational power of a target device (platform-independent models are turned into platform-specific runtime components).

A *DSS in use* is transferred to and executed on the client side by a shell that supplies appropriate run-time environment and manages *DSS in use* operation on a client. The shell constantly monitors communication channels with a server and self-adjusts client's behavior accordingly. If a server is available, a client is used to host an interface, while all processing and operations on the database subsystem are performed on the server side. However, if a communication channel is closed, all computations are done locally on the client side, and data are stored in the local database subsystem (transmitted to the server database system as soon as a communication channel becomes open). Such a solution increases the robustness of an m-CDSS. Moreover, it offers a possibility of using different solvers for local and remote use (local solvers can offer only basic functionality limited by lean access platforms, while remote solvers can be much richer, as they run on a powerful server).

The concept of an m-CDSS has been successfully implemented as the Mobile Emergency Triage (MET) system (a CDSS for supporting triage of a patient in the Emergency Department of a hospital) and partially verified in a clinical trial in a hospital, demonstrating the capabilities of the MET system in providing ubiquitous support.

Algorithms for generating clusters with nonlinear boundaries

Sadaaki Miyamoto

Department of Risk Engineering, University of Tsukuba, Japan

Keywords: cluster analysis, fuzzy c-means, competitive learning, kernel-trick

Many data clustering algorithms have been proposed among which the c-means techniques are most well-known and widely used. The c-means algorithms in a broad sense are classified into four major categories:

1. The crisp c-means algorithms,
2. The method of fuzzy c-means clustering and its variations,
3. The statistical model of mixture distributions, and
4. a family of competitive learning algorithms for clustering.

Basic algorithms in these four categories can produce clustering rules that divide the data space into Voronoi regions with linear boundaries, while data in real worlds have more or less nonlinear clusters; in some cases mild nonlinearities with boundaries specified by open surfaces that can be continuously transformed into linear boundaries and in other cases strong nonlinearities that cannot be continuously transformed into linear boundaries.

In this study we overview current methods of generating clusters with these mild and strong nonlinearities. Mostly we consider methods in the three categories of the crisp c-means, fuzzy c-means, and the competitive learning. The methods include new algorithms of the author's. Mild nonlinearities are handled by introducing additional variables for clustering, while strong nonlinearities are dealt with by employing the kernel-trick in support vector machines.

Illustrative and real-world data are tested; effectiveness and efficiency of the proposed algorithms are compared.

Roles of Knowledge Science in Technology Creation

YOSHITERU NAKAMORI

School of Knowledge Science, Japan Advanced Institute of Science and Technology, Ishikawa, Japan

Keywords: knowledge science, technology

This presentation introduces a research program on theory and practice of technology creation based on knowledge science. The goal of this program is to create a world-class center of excellence in the following areas:

- Theoretical Research: With a final target of strategic research and the development of scientific technologies, we will study knowledge fusion and development in important scientific fields, and then establish a theory of scientific knowledge creation.
- Practical Research: As we develop theories, we will apply them in scientific laboratories and improve them by feedback from practice. Repeating this task, we will improve the theory and promote the creation of useful scientific technologies.

At the same time, we will train graduate students in this environment, and teach them to become knowledge coordinators or knowledge creators.

This program will establish an interdisciplinary research field called the Study of Scientific Knowledge Creation. The new research field of Knowledge Science is the basis of this program, which models the process of knowledge creation and supports knowledge management. The School of Knowledge Science, established in 1998 at Japan Advanced Institute of Science and Technology (JAIST), is the first school established in the world to make knowledge a target of science. At this graduate school, knowledge management research is already producing results in areas such as knowledge conversion theory, knowledge systematizing methods, and methods for the development of creativity in the field of management science.

Knowledge science should help researchers produce creative theoretical results, not only in management science, but also in important natural sciences. For that purpose, it is necessary to design an environment, including time, place, people, context, etc. that supports the development and practice of knowledge creation theory: $Socialization \Rightarrow Externalization \Rightarrow Combination \Rightarrow Internalization$ in technology research. This research program is a vehicle to integrate theory and practice, to combine knowledge in social science and knowledge in natural science, to produce new theories, and finally to create a new research field called the study of scientific knowledge creation.

The results of our research will be methodologies and techniques for knowledge creation; data, information and models for knowledge integration; systems to support creativity; and new technologies created as practical results. The most valuable result will be the theory of scientific knowledge creation, as developed by all project members:

- Integration of social information: Methods for knowledge discovery, knowledge modeling, road mapping, representational models of knowledge, databases of scientific knowledge, and road maps.
- Development of support systems for knowledge creation: Knowledge systematization support, creativity support, awareness support, knowledge creation support, and visualization of complex phenomena.
- Creation of scientific knowledge: Applied technology of living functions, super-molecule biomaterial technology, applied technology of useful proteins, new materials with highly efficient characteristics, environmental protection technology, energy saving plastics, functional conductor technology, advanced sensitivity information technology, high reliability software, and ultra high-speed distributed

networks.

- Creation of an ideal environment for theoretical research and practice: Theory of knowledge-creating systems, theory of environmental design to promote scientific creativity, and theory of scientific knowledge creation.

This introduces the detail plan of this program followed by a systems methodology under development that could help the success of this program. One of the important research topics in knowledge science is to develop systems methodologies for trans-disciplinary knowledge exchange utilizing information and communication technologies. By the name of knowledge science, we are developing methodologies and methods related to information environment with which we can convert subjective, implicit or individual ideas into justifiable or hopefully reliable ones. This is not necessarily implies the utilization of information technology only. The methods and ideas in knowledge science should be those that guarantee justifiable trans-disciplinary knowledge exchange. The role of systems science is crucial for development of knowledge science.

Optimization of Anti-seismic Elements for In-service Structure Using Computational Intelligence

HIROTAKA NAKAYAMA

Konan University, Dept. of Info. Sci. & Sys. Eng.

KOICHI INOUE

Mitsubishi Heavy Industries, Ltd., Steel Structural and Civil Engineering Laboratory

YUKIHIRO YOSHIMORI

Ryosen Engineers, Co. Ltd., Technical Analysis Center

Keywords: seismic design, structural optimization, computational intelligence, black-box objective function

There are many in-service structures that require to be improved their anti-seismic property. It is practical in them to be installed a number of small anti-seismic elements taking into account strength and/or space. In this problem, the form of objective function is not given explicitly in terms of design variables, but the value of objective function is obtained by some analysis such as structural analysis and seismic analysis. Since those analyses are usually expensive, it is necessary to make the number of analyses as few as possible. To this end, the authors already proposed a method using computational intelligence in which optimization is performed in parallel with predicting the form of objective function.

In this paper, radial basis function networks (RBFN) are employed in predicting the form of objective function, and genetic algorithms (GA) in searching the optimal value of the predicted objective function. We made an attempt to apply the method to a problem in which we investigate the efficient arrangement of additional mass for cables to control the motions of a cable-stayed bridge. The results show that the proposed method can find fair solutions within 1/10 or less times of analysis than conventional optimization techniques.

Optimization Models for Fair Resource Allocation Schemes

WŁODZIMIERZ OGRYCZAK

Warsaw University of Technology, Institute of Control & Computation Eng., Warsaw, Poland

Keywords: multiple criteria optimization, resource allocation, fairness, equity

The problem we consider may be generally viewed in terms of resource allocation decisions as follows. There is given a set of m services (clients). There is also given a set Q of allocation patterns (allocation decisions). For each service j a function $f_j(\mathbf{x})$ of the allocation pattern $\mathbf{x}$ has been defined. This function, called the individual objective function, measures the outcome (effect) $y_j = f_j(\mathbf{x})$ of the allocation pattern for service j. The outcomes can be measured (modeled) as service quality, service amount, service time, service costs as well as in a more subjective way (client's) utility of provided service. In typical formulations a greater value of the outcome means a better effect (higher service quality or client satisfaction). Otherwise, the outcomes can be replaced with their complements to some large number. Therefore, without loss of generality, we can assume that each individual outcome y_j is to be maximized which results in a multiple criteria maximization model MCM:

$$\max \{ \mathbf{f}(\mathbf{x}) : \mathbf{x} \in \mathbf{Q}\}$$

where $Q \subseteq R^n$ is a feasible set and $\mathbf{f}(\mathbf{x}) = (f_1(\mathbf{x}), \ldots, f_m(\mathbf{x}))$ is a vector of real-valued functions $f_j : Q \to R, j = 1, 2, \ldots, m$, where $\mathbf{x} = (x_1, x_2, \ldots, x_n)$ is a n-vector. We refer to the elements of the criterion space as outcome vectors. An outcome vector $\mathbf{y}$ is attainable if it expresses outcomes of a feasible solution $\mathbf{x} \in Q$ (i.e., $\mathbf{y} = \mathbf{f}(\mathbf{x})$). The set of all the attainable outcome vectors is denoted by Y.

The multiple criteria maximization model only specifies that we are interested in maximization of all objective functions f_j for $j \in M = \{1, 2, \ldots, m\}$. In order to make model operational, one needs to assume some solution concept specifying what it means to maximize multiple objective functions. Simple solution concepts are defined by achievement functions $\theta : Y \to R$ to be maximized.

The most commonly used achievement function maximizes the mean (or simply the sum) of individual performances, thus defining the so-called maxsum solution concept. This solution concept is primarily concerned with the overall system efficiency. As based on averaging, it often provides solution where some services are discriminated in terms of performances. An alternative approach depends on the so-called max-min solution concept, where the worst performance is maximized:

$$\max\{ \min_{j=1,\ldots,m} f_j(\mathbf{x}) \; : \; \mathbf{x} \in Q \}$$

The max-min solution concept was widely studied in the multi-criteria optimization methodology. The max-min solution concept is regarded as maintaining equity. Indeed, in the case of a simplified resource allocation problem, the max-min solution $\max\{\min_{j=1,\ldots,m} y_j \; : \; \sum_{j=1}^m y_j \leq b \}$ takes the form $\bar{y}_j = b/m$ for all $j \in M$ thus meeting the perfect equity requirement $\bar{y}_1 = \bar{y}_2 = \ldots = \bar{y}_m$. In general case, with possibly more complex feasible set structure, this property is not fulfilled. Nevertheless, the following assertion is valid (Ogryczak, 2001). If there exists a nondominated outcome vector $\bar{\mathbf{y}} \in Y$ satisfying the perfect equity requirement $\bar{y}_1 = \bar{y}_2 = \ldots = \bar{y}_m$, then $\bar{\mathbf{y}}$ is the unique optimal solution of the max-min problem $\max\{\min_{j=1,\ldots,m} y_j \; : \; \mathbf{y} \in Y \}$. Hence, the perfectly equilibrated outcome vector is a unique optimal solution to the max-min problem if one cannot improve any of its individual outcome without worsening some others. Unfortunately, it is not a common case and, in general, the optimal set to the max-min aggregation may contain numerous alternative solutions including dominated ones. While using standard algorithmic tools to identify the max-min solution, one of many solutions is then selected randomly.

Actually, the distribution of outcomes may make the max-min criterion partially passive when one specific outcome is relatively very small for all the solutions. For instance, while allocating clients to service facilities, such a situation may be caused by existence of an isolated client located at a considerable distance from all the location of facilities. Maximum of the worst service performances (equivalent to minimization of the maximum distance) is then reduced to maximization of the service performances for that single isolated client leaving other allocation decisions unoptimized. This is a clear case of inefficient solution where one may still improve other outcomes while maintaining fairness by leaving at its best possible value the worst outcome. The max-min solution may be then regularized according to the Rawlsian principle of justice. Rawls (1979) considers the problem of ranking different "social states"; that is different ways in which a society might be organized taking into account the welfare of each individual in each society, measured on a single numerical scale. Applying the Rawlsian approach, any two states should be ranked according to the accessibility levels of the least well–off individuals in those states; if the comparison yields a tie, we should consider the accessibility levels of the next–least well–off individuals, and so on. Formalization of this concept leads us to the lexicographic max-min concepts.

The lexicographic order may be used to refine the max-min solution concept according to the Rawlsian theory of justice. Let $\langle \mathbf{a} \rangle = (a_{\langle 1 \rangle}, a_{\langle 2 \rangle}, \ldots, a_{\langle m \rangle})$ denote the vector obtained from $\mathbf{a}$ by rearranging its components in the non-decreasing order. That means $a_{\langle 1 \rangle} \le a_{\langle 2 \rangle} \le \ldots \le a_{\langle m \rangle}$ and there exists a permutation π of set M such that $a_{\langle i \rangle} = a_{\pi(i)}$ for $j = 1, \ldots, m$. Comparing lexicographically such ordered vectors $\langle \mathbf{y} \rangle$ one gets the so-called leximin order. The approach called the Lexicographix Max-Min or the Max-Min Fairness (MMF) problem depends on searching for solutions maximal according to the leximin order.

$$\operatorname{lex}\max \{(\theta_1(\mathbf{f}(\mathbf{x})), \ldots, \theta_m(\mathbf{f}(\mathbf{x}))) : \mathbf{x} \in Q\}, \quad \text{where } \theta_j(\mathbf{y}) = y_{\langle j \rangle}.$$

The MMF approach is a refinement (regularization) of the standard max-min optimization, but in the former, in addition to the smallest outcome, we maximize also the second smallest outcome (provided that the smallest one remains as large as possible), maximize the third smallest (provided that the two smallest remain as large as possible), and so on. Note that the lexicographic maximization is not applied to any specific order of the original criteria.

The (point-wise) ordering of outcomes causes that the lexicographic max-min problem is, in general, hard to implement. Nevertheless, for convex problems it is possible to use iterative algorithms solving a sequence of properly defined max-min problems by eliminating some blocking criteria. In general, it may does not exist any blocking criterion allowing for iterative max-min processing. In this paper we discuss optimization models allowing to form lexicographic sequential procedures for various nonconvex (possibly discrete) MMF problems.

The first model takes advantages of the equivalent formulation of the lexicographic optimization with cumulated criteria $\bar{\theta}_k(\mathbf{y}) = \sum_{i=1}^{k} y_{\langle i \rangle}$ expressing, respectively: the worst (smallest) outcome, the total of the two worst outcomes, the total of the three worst outcomes, etc. However, the optimization problem defining the cumulated ordered outcome can be dramatically simplified since for any given vector $\mathbf{y}$, the cumulated ordered value can be found as the optimal value of the following LP problem:

$$\begin{aligned} \bar{\theta}_k(\mathbf{y}) \quad &= \quad \min \sum_{j=1}^{m} y_j u_{kj} \\ &\quad\ \text{s.t.} \quad \textstyle\sum_{j=1}^{m} u_{kj} = k, \ 0 \le u_{kj} \le 1 \text{ for } j = 1, \ldots, m. \end{aligned}$$

Exactly, the above problem is an LP for a given outcome vector $\mathbf{y}$ while it begins nonlinear for a variable $\mathbf{y}$. This difficulty can be overcome by taking advantages of the LP dual

$$\begin{aligned} \bar{\theta}_k(\mathbf{y}) \quad &= \quad \max \ k r_k - \sum_{j=1}^{m} d_{kj} \\ &\quad\ \text{s.t.} \quad r_k - y_j \le d_{kj}, \ d_{kj} \ge 0 \text{ for } j = 1, \ldots, m. \end{aligned}$$

or in a more compact form $\bar{\theta}_k(\mathbf{f}(\mathbf{x})) = \max\ \{kr_k - \sum_{j=1}^m (f_j(\mathbf{x}) - r_k)_+ : \mathbf{x} \in Q\ \}$ where $(.)_+$ denotes the nonnegative part of a number and r_k is an auxiliary (unbounded) variable.

For some specific classes of discrete, or rather combinatorial optimization, problems, one may take advantages of finiteness of the set of all possible values for the functions f_j on the finite set of feasible solutions. The ordered outcome vectors describe a distribution of outcomes generated by a given decision $\mathbf{x}$. In the case when there exists a finite set of all possible outcomes of the individual objective functions (or we may focus on some fuzzy approximation), we can directly deal with the distribution of outcomes described by frequencies of several outcomes. Let $V = \{v_1, v_2, \ldots, v_r\}$ (where $v_1 < v_2 < \cdots < v_r$) denote the set of all attainable outcomes (all possible values of the individual objective functions f_j for $\mathbf{x} \in Q$). We introduce integer functions $h_k(\mathbf{y})$ expressing the number of values v_k taken in the outcome vector $\mathbf{y}$. Having defined the functions h_k we can introduce cumulative distribution functions: $\bar{h}_k(\mathbf{y}) = \sum_{l=1}^k h_l(\mathbf{y})$. The function $\bar{h}_k$ expresses the number of outcomes smaller or equal to v_k. Since we want to maximize all the outcomes, we are interested in the minimization of all the functions $\bar{h}_k$. Indeed, one may express the lexicographic max-min solution concept in terms of the standard lexicographic minimization problem with cumulated frequencies objectives $\bar{h}_k(\mathbf{f}(\mathbf{x}))$. Taking advantages of possible weighting and cumulating achievements in lexicographic optimization, one may further simplify the objective functions. For this purpose we introduce:

$$\hat{h}_k(\mathbf{y}) = \sum_{l=1}^{k-1} (v_{l+1} - v_l)\bar{h}_l(\mathbf{y}) = \sum_{j=1}^m (v_k - y_j)_+ = \sum_{j=1}^m \max\{v_k - y_j, 0\}.$$

The lexicographic problem:

$$\operatorname{lex\,min}\ \{(\hat{h}_1(\mathbf{f}(\mathbf{x})), \ldots, \hat{h}_r(\mathbf{f}(\mathbf{x}))) : \mathbf{x} \in Q\}$$

provides us with an alternative computational model for the MMF solution.

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Application of EDGE software and Monte Carlo methods for pricing catastrophe bonds

MACIEJ ROMANIUK

Systems Research Institute, Polish Academy of Sciences (SRI PAS), Warszawa, Poland

TATIANA ERMOLIEVA

International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria

Keywords: catastrophe bonds, financial instruments pricing, simulations

During the last two decades the losses from natural and human–made catastrophes increased significantly (see e.g. [2], [9]). For example, between 1989 and 1995 total insured losses were 50 % higher than in the preceding 38 years (see [5]). For many countries, even developed ones, losses caused by these events considerably affected insurance industries, national economy and governmental budgets.

The increasing amount of losses from catastrophes triggered ideas for developing new financial instruments — *catastrophe bonds*, in abbreviation *cat bonds*. The catastrophe bond is very similar to normal bond issued by a government or an enterprise (see e.g. [8]). The structure of payments of the catastrophe bond depends on the occurrence of specified type of natural catastrophe in the specific region and time interval. This event defines so called *triggering point*, which changes the schedule of future payments of the cat bond (see [5], [7], [10], [11]). Examples of catastrophes may be floods, earthquakes, hurricanes, etc.

The catastrophe bonds may be a very important new financial instruments for insurers and governments. Especially in the developing countries these instruments may stabilize economic growth. In developed countries they may be also significant for national economy and private sector (see eg. [10]). These instruments transfer *risk* from *insurance markets* or *governmental budgets* to *financial markets*, which are more *liquid* and have more *capacity* than other markets or budgets (see e.g. [4], [5], [7]).

An important problem is to evaluate the price for cat bonds, i.e. to answer for question "how much should we pay *now* for this financial instrument?". In the language of economics *what is the present value of catastrophe bond?*

As an answer for this problem we present the application of EDGE software and Monte Carlo simulations.

The software package EDGE, an Earthquake and Damage Generator / Estimator for Toscana, was developed at IIASA (see [1], [13]). This software consists of two main parts. The first part is a generator of catastrophes (earthquakes), and the second is an estimator of damages arising from generated catastrophes.

The generator of catastrophes simulates earthquakes. From input calibrated to specified region it generates scenarios of possible earthquakes for this region. These scenarios include a variety of important data, i.e. locations of earthquake occurrences, their magnitudes, affected areas, etc. (see [1]).

These scenarios are then used in the second part of the software. Using additional input, the estimator creates distributions of possible losses and samples of losses for different locations in the whole region. These outputs may be used, e.g., by insurers or more generally by risk managers to design loss–reduction or loss–spreading programs (see e.g. [1], [3], [10]).

Monte Carlo methods are used to simulate the set of possible trajectories of underlying asset behaviour $S = \{S_1, S_2, \ldots, S_m\}$. To generate these trajectories we use adequate iterative stochastic equation, eg. Euler scheme for geometrical Brownian motion with constant drift (see eg. [6], [14]).

Using EDGE software we acquire the set of possible scenarios of catastrophe $X = \{X_1, X_2, \ldots, X_m\}$, eg. values of earthquake magnitudes. Joining these two sets S and X we may calculate *fair price* for given type of catastrophe bond, ie. discounted expected value of its future cash flows.

During the presentation we illustrate examples of cat bonds discussed in [12] with obtained simulations results. These examples include cat bonds depending on earthquake magnitude value for different schedules of payments. We also present generalizations of the EDGE–Monte Carlo method to the case of dependency between trajectories of underlying asset behaviour and scenarios of catastrophes. Moreover, we discuss application of methods for accelerating and simplifying calculations known for other types of financial instruments (see eg. [6]) to the case of cat bonds pricing.

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Handling of Fallout Processes from Nuclear Explosions in the Severe Nuclear Accident Program (SNAP)

JØRGEN SALTBONES *and* JERZY BARTNICKI *and* ANSTEIN FOSS

Norwegian Meteorological Institute

Keywords: radioactive air pollution, decision-making support

Nowadays, the possibility of terrorist attacks is a serious threat all over the world. Such terrorist acts may even involve nuclear detonations. Taking this fact into account, national decision makers need a tool (model) able to simulate atmospheric transport/deposition of the radioactive debris released during the nuclear detonation.

SNAP is the Norwegian Meteorological Institute (met.no) operational real-time dispersion model for decision support use by the National Emergency Management Organization "Kriseutvalget" in case of nuclear accidents. A new operational version of SNAP has been developed at met.no in 2003. This version includes new parameterization of important physical and meteorological processes for real-time simulation of the atmospheric dispersion, transport and fallout of radioactive particles emitted into the atmosphere as a result of a nuclear explosion.

Concerning source term and initial conditions, we have assumed that the radioactivity is mainly transported as particles of different size. We have considered two shapes of the radioactive cloud shortly after the explosion: cylinder and mushroom type shape. In both cases, parameters of initial shape and activity depend on the explosive yield. We have also used data presented in open military publications.

The effect of large variation of the particle size in the initial cloud, represented by 10 discrete classes with characteristic particle radius ranging from 2 micron to 200 micron, resulting in different gravitational settling velocities, has been tested with regard to transport distances and deposition patterns.

As an overall conclusion, we have shown that including particles with their hygroscopic properties, will give quite different deposition pattern compared to what has previously been shown to be of interest in military calculations of the fallout pattern from nuclear detonations.

Structuring multidisciplinary knowledge for model-based water management: the HarmoniQuA approach

HUUB SCHOLTEN

Information Technology Group, Department of Social Sciences, Wageningen University, the Netherlands

AYALEW KASSAHUN

Information Technology Group, Department of Social Sciences, Wageningen University, the Netherlands

JENS CHRISTIAN REFSGAARD

Geological Survey of Denmark and Greenland, Denmark

Keywords: model-based water management, knowledge base, ontologies, guidelines, glossary

Introduction

Mathematical models have been applied for several decades in solving problems in many domains of water management. With the requirements imposed by the EU Water Framework Directive the trend to base water management decisions to a larger extent on model studies and to use more sophisticated models is likely to be reinforced. At the same time insufficient attention is generally given to documenting the predictive capability of the models. In the last decade a growing need for Quality Assurance (QA) has emerged among professionals in this field [Refsgaard, 2002]. Quality Assurance is defined by [NRC, 1990] as the procedural and operational framework used by an organisation managing the modelling study to assure technically and scientifically adequate execution of all tasks included in the study and to assure that all modelling-based analysis is reproduced and defensible.

Refsgaard [2002] gives a summary of reasons for the growing interest in quality assurance:

- Ambiguous terminology and a lack of mutual understanding between key-players;
- Malpractice (careless handling of input data, inadequate model set-up, insufficient calibration/validation and model use outside of its scope);
- Lack of data or poor quality of available data.
- Insufficient knowledge on the processes hindering ecological (biota) modelling.
- Miscommunication of the modeller to the end-user on the possibilities and limitations of the modelling project and overselling of model capabilities;
- Confusion on how to use model results in decision making;
- Lack of documentation and transparency of the modelling process, leading to projects, which hardly can be audited or reconstructed.
- Insufficient consideration of socio-economic, institutional and political issues and a lack of integrated modelling.

As a result of these problems, the credibility of the models is often questioned, and sometimes with good reason [Refsgaard, 2002]. Recommendations made mostly focus on scientific/technical guidance in how the modeller should carry out the various steps of the modelling work in order to achieve the best and most reliable results.

Existing modelling guidelines, mostly nationally based, focus on a single domain in contrast to multi-domain and integrated models [Refsgaard, 2002]. Furthermore, these guidelines vary throughout Europe. The resulting models and decisions based on them are therefore often: not transparent, irreproducible, non-auditable and not fully comparable between different countries.

The Water Framework Directive (WFD) provides European policy at the river basin scale. It explicitly states that water resource models should be applied. The EU- financed project HarmoniQuA aims at improving the quality of model based water management at catchment and river basin scales by providing guidance throughout the modelling process and by supporting all persons involved (water managers, modellers, auditors, stakeholders and concerned members of the public) in their activities. The guidelines are based on accepted and common methodology and practices of experienced modellers. This knowledge is collected, completed, improved and made available in the form of a Knowledge Base, using state-of-the-art knowledge engineering technology with an ontological approach. MoST, the software tool of HarmoniQuA, provides guidance from the Knowledge Base it supports monitoring of the modelling activities and reporting to various audiences. In the future MoST will use expertise collected in previous modelling studies to advise on how to perform the model study at hand. This paper focuses on how HarmoniQuA handles and improves existing knowledge on modelling for water management.

The knowledge base

The HarmoniQuA approach to develop a knowledge base with guidelines made use of the experiences in realising the Dutch GMP Handbook [Scholten *et al.*, 2001], [Van Waveren *et al.*, 2000]. Furthermore it was based on other water management related guidelines, especially on the Murray-Darling groundwater flow modelling guideline in Australia [Middlemis, 2000] and the Bay-Delta modelling protocol for water and environmental modelling in Californian [BDMF, 2000].

HarmoniQuA will support model based water management in general [Refsgaard and Henriksen, 2004]. We had to decide whether to realise support at a very generic level only or to aim at serving all key players, covering a wide range of water management domains, suited for various purposes and for modelling jobs of different complexity. We have chosen for the latter way and therefore the knowledge has been dedicated to a specific modelling study and to the roles of its key players. The term 'domain' refers here to the disciplines of water management, making water management a multidisciplinary topic as is required by the WFD. The following domains / disciplines and other dedication aspects are distinguished:

- *Domains*: groundwater, precipitation-runoff, hydrodynamics, flood forecasting, surface water quality, biota (ecology) and socio-economics;
- *User types*: modeller (e.g. consultant), water manager (e.g. client), auditor, stakeholders and (concerned members of the) public;
- *Application purpose*: planning, design and operational management;
- *Job complexity*: basic, intermediate and comprehensive.

A major design criterion in the development of the modelling knowledge base is the granularity of the decomposition. Three decomposition levels are distinguished. At the highest level the modelling process has been divided in *steps*, which are groups of *tasks*. To perform a *task* one or more *activities* have to be performed. An *activity* is related to the actor, being the smallest 'doing' in the process. A *task* related to what has to be done and it refers therefore to the modelling process. By performing *activities* a *task* will be completed. *Steps* are logical groups of *tasks* and have only an organisational purpose for human actors involved in the process.

Besides making an appropriate choice in the granularity of the decomposition, several other design criteria are relevant for the KB:

- Explicit structure of the modelling process;
- Easy to update by web based access;
- Easy to maintain;
- Flexible structure;
- Authorisation management for knowledge editors;

• Operating platform independent;
• Other, normal software engineering criteria.

To deal with most of these criteria we chose for an ontological approach in the design of the KB. The most used definition in knowledge engineering of the term 'ontology' is of [Gruber, 1993, 1995]: an ontology is an explicit specification of a conceptualisation, referring to what can be represented in terms of concepts and the relationships among them. [Borst, 1997] added to this definition that there should be consensus of the concepts and the relations between them, resulting in the following definition: an ontology is a formal specification of a shared conceptualisation.

Uschold *et al.* [1998] distinguishes three groups of uses of ontologies: *communication* (of structured knowledge between people and between organisations), *interoperability* (understanding knowledge between machines and between men and machines) and *systems engineering* (for software systems and knowledge based systems, facilitating re-use and making knowledge explicit).

Developing an ontology is a part of a process to build a knowledge base for some purpose. This process is typically composed of the following steps:
1. An *ontological structure* is made which is the frame of the intended knowledge base;
2. A tool based on this ontology is used for *knowledge acquisition*;
3. The acquired knowledge is stored *as instance of the ontology* in a knowledge base;
4. A *software application* is developed which uses this knowledge base.

An ontology can be seen as a framework that represents the data structures for a certain domain, in a formal, machine processable way. In order to describe the data structures, ontologies must provide one or more standard vocabularies, defining the terms (*concepts*) and *relations* that are used to describe this specific knowledge domain (subject area). To describe a certain piece of knowledge an ontology contains sentences describing the *concepts* and *relations* between them. *Concepts* can be discussed and have to be represented. The term *concept* has thus a broader meaning than 'entity' and it encompasses abstract and concrete things, but also processes, tasks and ambitions or goals. *Concepts* are used to define and explain terms. *Relations* organise *concepts* in a hierarchical or in some self- defined structure. Often ontologies contain other elements e.g. *properties*, *functions*, *axioms*, but these are not essential to understand what ontologies are. *Instances* are also parts of an ontology, as they contain the actual knowledge. If *task* is a concept in an ontology, the instances of *task* can be *go shopping*, *cook a meal*, *eat the meal*. A comprehensive and clear introduction on what ontologies are and why we need them is given in [Chandresakaran, *et al.*, 1999].

In HarmoniQuA we use Protégé2000 as tool to build the ontology and to include the collected knowledge as instances of the ontology. The functionality of Protégé2000 has been extended by building a plug-in for XML-export, according to a predefined interface for the tools that have to co-operate with the KB.

In a small group of 5 modelling experts with know-how in knowledge engineering techniques and/or experience in the development of one of the existing guidelines, of the modelling process has been decomposed. In this first draft the modelling process has been divided in 5 *steps* and at a lower decomposition level into 45 *tasks*. Each task was further decomposed in the following *task describing components*: name, definition, explanation, one or more activities (most with one or more associated methods), references, software aspects, links to other tasks and some other aspects. This first draft consisted of *structure diagrams*, which determined the order of the task and *spreadsheets* with rows for the task determining components, a column to fill these in and columns to indicate relevance of each task determining component for various types of users, domains, job complexity and application purpose. In the decomposition three types of tasks are distinguished: *normal tasks*, *decision tasks* (to decide on advancing to the next task or going back to a previous one) and *review tasks* (i.e. special decision tasks emphasising the negotiating interaction between water manager and modeller).

In the second stage, a modelling expert for each of the 7 domain filled in spreadsheets for the 45 tasks and indicated the relevance for the user types, application purpose and job complexity. Two parties, not involved in providing the knowledge, assessed the quality of the knowledge. All HarmoniQuA partners discussed their findings and proposed improvements. In a third step most of these comments were incorporated in the spreadsheets, resulting in a first, spreadsheet based, prototype, which was not very suited to be used in actual modelling studies. The 315 spreadsheets were imported in Protégé2000 as instances of the ontology structure for the KB with a tool developed in the project.

Spreadsheets were also the preliminary front-end interface in the development of a glossary for the terminology in model based water management. The domain experts delivered a prototype glossary of almost 1000 entries, which has been included in the Protégé2000 KB.

A series of tools has been built in HarmoniQuA to work with the KB. As extra front-end for experts in model based water management, a web based knowledge editor and a glossary editor assist in completing and improving the modelling knowledge and the glossary. The major tool, especially for end-users, provides guidance, supports monitoring of the modelling activities and helps in reporting to various audiences. In the future it will give advice based on previous modelling studies. A more detailed description of the tool can be found in [Kassahun *et al.*, 2004] and in another contribution to this workshop.

The knowledge base is too large to be discussed here in detail. It consists of the following *steps*: (1) model project plan, (2) data and conceptualisation, (3) model set-up, (4) calibration and validation and (5) simulation and evaluation. The first step (model project plan) focuses on the interaction between the water manager and the modeller (or the modelling team). This step starts with a series of tasks for water manager in the following order: *describe problem and context*, *define objectives*, *identify data availability*, *determine requirements*, *prepare terms of reference*. In the next task (*proposal and tendering*) there are roles for the water manager, the modeller and the auditor. The last task in this step is the review task *agree on model project plan and budget*, where water manager and modeller have to discuss how the model study has to be continued. If the parties come to an agreement, one has to continue with the 'data and conceptualisation' step. Here the first task *describe system and data availability* is typically a modeller's task.

The tasks briefly presented here do not consist of activities, which have complex methods to be used, as is the case for the complex task *parameter optimisation and evaluate model performance* being a task in the step *calibration and validation*. This task consists of several activities to do and a number of methods to use. The HarmoniQuA guideline recommends to 'use expert knowledge' or - in case the modeller is not familiar with the model code - to 'do a sensitivity analysis' to select optimisation parameters. For a sensitivity analysis several methods are recommended, including, but not restricted to analytical sensitivity analysis, manual sensitivity analysis, Response Surface Methods, Monte Carlo Methods. Furthermore, the guidelines give short introductions of the suggested methods.

Conclusions

The end-user part of the HarmoniQuA system is called MoST (Modelling Support Tool) and it provides guidance, it monitors modelling activities and it helps in reporting. The HarmoniQuA suite for model based water management is completed with training material in the form of multi-medial courseware for students and workshop-ware for professionals.

The guidance to all involved in model-based water management is provided by a knowledge base (KB), which contains expert knowledge on many facets of modelling, including specific knowledge on seven domains of water management and of a glossary with many entries from the jargon used in water management. Substantial efforts are made to ensure that the knowledge in the KB is accepted by a wide group of key players. Furthermore, the KB has been designed and implemented using an ontological approach, which is a state-of-the-art knowledge engineering technology. This approach has been chosen to guarantee that design criteria are met. These include a proper choice of the level of detailing, easy maintenance and updating of the structure and the content of the KB. Furthermore, the knowledge has been made as explicit as possible and specific for seven *domains*, five *user types*, three *application purposes* and three level of *job complexity*. This approach allows providing guidance specific for a model study and the persons involved. In this way HarmoniQuA intends to contribute a methodological part to an infrastructure for implementing WFD and for model based water management in general.

The achievements of our approach so far suggest potentials for a wider use, such as for modelling in multidisciplinary problem solving projects in general.

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HarmoniQuA's support tool for model-based water management

HUUB SCHOLTEN

Information Technology Group, Department of Social Sciences, Wageningen University, the Netherlands

AYALEW KASSAHUN

Information Technology Group, Department of Social Sciences, Wageningen University, the Netherlands

GEORGE ZOMPANAKIS

Department of Water Resources, Hydraulic & Maritime Engineering, School of Civil Engineering, National Technical University of Athens, Greece

COSTAS GAVARDINAS

Department of Water Resources, Hydraulic & Maritime Engineering, School of Civil Engineering, National Technical University of Athens, Greece

Keywords: model-based water management, modelling support toolbox, process monitoring, guidelines

Introduction

There is an apparent need for quality assurance of the modelling process. This need is discussed in [Scholten *et al.*, 2004] and in another contribution to this workshop. The overall approach, chosen in the project HarmoniQuA, is process based and starts with defining the modelling process. This definition is subsequently stored in an ontological knowledge base and can be re-used for providing guidance to all involved in the modelling process. HarmoniQuA focuses on model-based water management, but this simulation- oriented approach is extendible to other paradigms and other application areas.

In this contribution we discuss how to use the ontological knowledge base and how to support modelling projects.

Outline of the HarmoniQuA approach

The software system, provided by the HarmoniQuA project to support model-based water management, is multifaceted and can be summarised as follows. The backbone is the ontological structure. Instances of this ontology are used for storing the knowledge on the modelling process, dedicated for the types of users, the purpose of the modelling project, the domains of water management involved in this study and the complexity of the job to be done. HarmoniQuA uses Protégé2000 for building the ontology and the knowledge base. To facilitate maintenance and improving of the knowledge base by modelling experts without experience in knowledge engineering a web based knowledge base editor has been developed, which enables direct editing of the Protégé2000 knowledge base. HarmoniQuA's Modelling Support Tool (MoST) provides the functionality to guide all involved in the modelling process and monitors what is done in a project and stores this in so called model journals. A set of model journals is filed in a model archive. Model journals can be reported in different ways by MoST and MoST can also use the model archive to advise users what or how to do their work.

Model projects can be rather complex as often many water management domains are involved. MoST support multi-domain projects, in which teams work at different speeds and redo many tasks or activities. Further it provides an authorisation functionality to permit read/write access effectively to all involved. Finally the system facilitates auditing by providing an audit trail with its monitoring functionality and evaluation by scoreboards.

Handling knowledge on modelling

The knowledge handling process has been discussed in [Scholten *et al.*, 2004] and in another contribution to this workshop. The knowledge base consists of a Protégé2000 ontology, which provides a structure for the knowledge and stores the modelling process knowledge. The knowledge base editor is web tool that allows experts to view and edit the contents of the knowledge base. We developed a knowledge base editor that reflects the ontology developed for the knowledge base. When the ontology changes, the editor is adjusted to the new ontology. Because the editor is aware of the dedication aspects, the editor allows experts to enter information only in their own field of expertise. The authorisation mechanism of the editor minimises conflicting updates and errors.

Besides modelling knowledge the knowledge base is also used for a glossary on model-based water management. This glossary consists of hundreds of terms and can be edited by the knowledge editor as well.

The knowledge editor is supposed to be used beyond the lifetime of the HarmoniQuA project, since modelling guidelines have to reflect new insights and new developments. In this perspective the knowledge base editor provides all interested individuals the possibility of providing their comments and suggestions.

All tools are built in Java and therefore operating system independent. All functionality has been built, except for the advisor part.

MoST: Modelling Support Tool

Model project set up

MoST can be used as desktop application in case of a single modeller project. If a team of modellers is involved the desktop application interacts as client with a server application. A model project has to be set up by defining subprojects, water management domains, tasks to do per subproject/domain, users (their role and authorisation) and the criteria for reviews and auditing the model project.

Guiding

The guideline screen of MoST provides guidance based on a shared view on modelling methodology for water management. A copy of the guidelines is kept at the client computer. MoST allows users to update the guidelines by requesting the knowledge base server for the most recent version of the guidelines.

To use the guideline functionality users need to specify their personal profile. The user profile is a combination of all dedication aspects that user specifies as applicable to his work. These include the role of the users, the purpose of the model project, the domain and the job complexity [Scholten *et al.*, 2004]. Three different views on the guidelines are presented to the users. The left-hand side window is called the *tree view*, showing the modelling process as a tree structure. The top right window is called the *flowchart view*, showing the flowchart complete with feedback loops as a flow diagram. The lower-right window shows the detailed information of the task and is called the *task view*. All views enable users to browse through the tasks of the modelling process and the associated guidelines.

Monitoring

The monitoring part of MoST is the heart of the system, as it monitors what has been done. In the project screen users (including managers) can monitor what they do and keep track of the tasks and activities performed during a model study. Here the system records tasks and activities that are executed or skipped, decisions that are made and methods and data that are used. In many ways it looks like workflow management tools.

The project screen is composed of three resizable windows. The left- hand side window is called *navigation view*, showing the sequence of model tasks that are already completed, under construction or skipped. All irrelevant tasks are shown if they fit in a user profile and in the project initialisation aspects, otherwise they are greyed. The lower-right window shows detailed information on the task and is called the *task view*. This information is the same information that is shown in the task view of the guideline screen.

The top-right window is called *activity view*. This view shows the list of activities for the task selected in the navigation view. It shows which activities are completed activities, skipped or under construction. Clicking on an activity takes us to the *journal view*. The journal panel is where users actually record model journal information. This panel also provides the possibility of attaching log files or relevant project documents.

Reporting

MoST's reporting functionality facilitates providing reports in a format adapted to the wishes of water managers, modellers, auditors, stakeholders and public. The benefit of the audit trail recorded by the monitoring part will be severely restricted if there is no tool that can filter the myriad of recorded decisions made, methods and data used and other information such as the time a specific task is finished to the level of detail users need for a specific goal. The reporting functionality has been designed like the other parts, i.e. it is sensitive for the actual dedications aspects. Thus it will be aware of the context of the information elements in the model journal and will be capable of generating the right information for a given audience.

Other features

The advising functionality aims at using model journals in model archive to provide advise to users. In its most simple form it shows how a problem is solved in a previous project. In a more sophisticated form it selects previous projects that resembles the present one in its characteristics and deduces what should be done in the project at hand. This advise feature is not implemented yet, and its design is hardly started, so it will probably not implemented in HarmoniQuA.

Training and helping

The HarmoniQuA suite for model based water management will be completed with web based training material in the form of multi- medial courseware for students and workshop-ware for professionals. Instructions on how to use the software will be presented as screen recordings with oral instructions. The training material will be completed with presentations and with exercises, which will the knowledge base and MoST to give trainees hands-on experience in a training project. All training material will be web based and specified for audiences.

Supporting modelling in distributed teams

Through its client-server design MoST enables modelling by teams at distributed locations. It facilitates multi-domain and integrated model-based water management projects and it allows asynchronous execution of projects. Each tem member can do his job and - if authorised - see what the others are doing and which parts are completed and with what result. The work of team members is merged and synchronised with what others did to a single model journal for the whole project.

Conclusions

The HarmoniQuA modelling support tool gives guidance to water managers, modellers, auditors, stakeholders and interested public. It also enforces that the modelling activities are monitored and stored, leaving an audit trail of the modelling project. A reporting facility allows users to generate reports on projects that are completed or in progress, which is particularly useful for water managers and auditors.

MoST and its KB have dedication aspects specifying guidelines and tasks to perform for different types of users, domains, job complexities and application purposes in water management studies.

A substantial part of the HarmoniQuA resources are spent to two rounds of testing the tool and the KB. The first round of testing, mostly done by modellers and some water managers, showed that users found the tool and the KB useful. The present guideline functionality was very satisfactory according to the test. The monitoring functionality received also very positive reactions but also lots of feature requests, which indicates that modelling support tools are valuable in modelling studies. Most of the wishes of the testers are implemented in the present version.

Our choice for an ontology-based implementation of the knowledge based has also paid dividends. The guideline procedures have undergone its first review process that resulted in some modification to the structure of the knowledge base. That resulted in only minimal modification to the knowledge base and the tools.

Finally while the knowledge base is at present rather stable, the development of the toolbox is under construction for the second test series next winter.

Our experience with the KB and the tools so far, suggests that the HarmoniQuA approach to support the modelling process for water management may also be useful to support other process oriented work.

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Optimization of Flight Networks for Freight Transportation

HANS- JÜRGEN SEBASTIAN

Deutsche Post Endowed Chair for Optimization of Distribution Networks, Aachen University (RWTH)

Keywords: optimization, transportation networks

In freight transportation one important problem of the strategic/tactical planning phase is the design of service networks. Such networks provide the services to ship quantities of goods from origin to destination locations. Here, we focus on networks which provide air-transportation of freight (so-called flight networks) taking into account that such flight networks are always combined with ground-feeding and ground-distribution networks. There are different network types in air transportation such as e.g., direct flight networks, one-hub networks, mixed direct- and hub flight networks (using one or multiple hubs). For the case of networks consisting of direct, non-stop flights only the DFP (Direct Flight Problem) we develop the optimization model which aims to minimization of costs under service quality and other constraints. The DFP is proven to be NP-hard. Therefore, a Meta-Heuristic which combines Tabu Search with Branch and Bound was developed and successfully applied to the Night-Airmail Network Design Problem of the Deutsche Post World Net [1]. The main idea of this method is the enumeration of terminated flights and the solution of a modified warehouse location prolem.

Irnich [2] developed an exact solution method for the DFP and also for the MFP (Mixed Flight Problem). This method is based on Dantzig-Wolfe Decomposition of the DFP and the MFP models (decomposition with respect to the services, in this case to the flights). Irnich uses Column Generation to construct an intial solution of a Restricted Master Program RMP and a Branch and Price and Cut Method in order to generate integer solutions for the DFP and the MFP as well. Finally, we will present numerical results for 6 groups of instances of DFP's and MFP's. Some of these instances represent large-scale real world examples taken from the Night- Airmail Network Design Problem of the Deutsche Post World Net.

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Coevolution of environment and behavior in social dilemmas

SIGRID STAGL

School of the Environment, University of Leeds, United Kingdom

DALE S. ROTHMAN

Macaulay Institute, Craigiebuckler, United Kingdom

Keywords: common pool resources, social dilemma, co-evolution, learning

Many real-world situations are characterized as social dilemmas. Accordingly, these situations have been studied for many years. In a recent paper, Gotts, et al. (2003) provide an extensive review of agent-based simulation in the study of social dilemmas. This also provided a basic summary of key insights from game theory and empirical evidence from experimental studies of these dilemmas.

In their wording, social dilemmas are described as follows:

In a social dilemma, two or more participants must each choose between following their own immediate interests, or the common interest of all participants. For each participant, choosing the 'selfish' option is immediately advantageous, whatever the other participants do, but if enough participants take this option, all end up worse off than if enough had made the 'altruistic' or 'cooperative' choice (p.4).

They highlight the Prisoner's Dilemma as the most commonly studied two- player game and the (somewhat misnamed) Tragedy of the Commons and Public-Goods games as the most studied multi-person games. In each of these cases, a situation is described in which individuals must make choices that affect not only their own well-being, but also that of the other players. In a two person game, the payoffs are generally represented in a simple payoff matrix. In a multi-person game, these are more often represented by a formal equation.

One thing that is striking about their review is the relative lack of examples of studies that have looked at situations in which the actual payoffs change over time as a result of the choices made by the players. By this we specifically mean situations in which the entries in the payoff matrix for a two-person game or the formal equations describing payoffs in a multi-player game change over time. These payoffs in a sense represent the physical environment in which the players are operating, as opposed to the social environment, which is represented by the other players. The changes in the underlying payoffs represent the impact of the players' choices on this physical environment over time. Gotts et al. (2003) refer to these as "system-level consequences" (p.68). This can be seen as being somewhat distinct from recent work on dynamic fitness landscapes (see for example Yi and Wilke 2004), which considers fluctuating environments, but in which the fluctuations are caused by factors exogenous to the system. Our surprise at the lack of examples of evolving landscapes in the research literature is in part related to our familiarity with the early work by Epstein and Axtell (1995), in which they were very careful to distinguish between the agents and the environment in which they existed, and to our interpretation of the metaphor of the Tragedy of the Commons, where it is really the physical environment that is changing.

Gotts et al. (2003) do review several examples in their section on The Environmental Context: Simulations of Common-Pool Resource Dilemmas that begin to address this broader environment. Even here, though, very few of the studies actually represent changes in the physical environment, with most presenting this as an important, but a fixed backdrop. Those that do include a changing environment tend to be "relatively 'thick' models . . . (that) are difficult to summarise and relate to each other, in part because of their very specificity" (Gotts et al 2003, p.68).

This opens the door to the possibility of developing fairly simple models that try to include the effect of changing underlying payoffs in the exploration of social dilemmas. Several new areas of interest come up when one starts considering this aspect of social dilemmas. Three of these that will be explored in this paper can be captured in the following questions: how can/should you represent changing payoffs, how does this change the game that is being played, and how do the players learn about these changes.

The first question focuses on how specific payoffs change over time, e.g. how do the actions of individuals translate into system-level consequences. In the case of a two-person game, these changes would be reflected in entries in the payoff matrix; in a multi-player game, they would be reflected in changes in the structure or parameters of the formal equations.

Given the changes in specific payoffs, the second question focuses on the relationships between the payoffs for different choices at any point in time. In the general study of social dilemmas, it is this structure that in many ways defines the game that is being played (see Heckathorn 1996, p. 258 for the standard payoff matrices for five distinct games). Shifts in the specific payoffs will change the nature and, perhaps, even the fundamental structure of the game. A slight shift in the payoffs, for example, could change a Prisoners' Dilemma situation into one of Chicken, which is known to exhibit different behavior. Changes in the structure thus raise the possibility that the game that is being played at any point in time may change over time.

The third question centers on how the actors perceive and learn about the changing nature of the game and their influence upon it. This represents a different and complementary type of learning to that which is traditionally explored in the literature on social dilemmas. The latter focuses primarily on learning about the behavior of other players. Here, the learning of agents about the state of their (physical) environment and changes in this also becomes significant. Agents may have an imperfect understanding of the environment due to a personal or more general lack of information or precise knowledge about its structure. The possibility of a changing structure only serves to compound this uncertainty.

As we see this as a relatively unexplored area in the study of social dilemmas, our goals for this paper are three-fold:

Further exploration of the literature: It will be important for us to establish if and how others may have tried to address the questions we have posed here. Although Gotts, et al. (2003) do provide a fairly extensive review of the literature, it should not be assumed that their work is exhaustive, at least not for our purposes. As just one example, the Journal of Artificial Societies and Social Simulation produced a special issue on agent-based modelling, game theory and natural resource management issues that should be considered (see Bousquest, et al. 2001).

Develop a generic analytical framework for approaching these problems: As pointed out above, the studies Gotts et al. (2003) do cite that include a changing environment tend to be relatively 'thick' models with very specific features, which makes comparability difficult. Thus, assuming we do not find anything in the literature, we will need to develop a more generic analytical framework to allow us to look at this class of problems. This will include methods for representing how the payoffs change, how the players' learn about these changes, and how they change their behavior accordingly. The changes in specific payoffs will almost necessarily be developed as abstractions of more complex models. An important aspect of this will be to look at how the payoffs would need to change in order to make transitions between fundamentally distinct games, and whether these changes make sense. In terms of learning and agent behavior, we will draw upon existing work in game theory and social simulation. We will assume that in all situations some kind of feedback about the environment is available to the agents and that there is some sort of interaction between agents. This will involve distinguishing between (a) different qualities of information (degree of true representation of reality), (b) certitude of knowledge (certain, risky, uncertain), and (c) the timing of the feedback from the environment to the agents (immediate, constant delay, variable delay). We plan to compare several different learning algorithms. Our present intention is to look at: a) Bayesian learning, where the learning agent updates their probability estimates within a given and immutable set of categories, which constitute a partition of the real world; b) instance-based learning, such as nearest neighbor learning, which is an instance based method and takes a long time until general, explicit descriptions of the situation are constructed; and c) reinforcement learning which is learning in response to different (possibly delayed) rewards given by some trainer or institution.

Test simple examples: Finally, using the analytical structure developed, we will test a few simple examples using standard techniques of agent- based social simulation. Given our interest in the co-evolution of the (physical) environment and behavior, we will look not only at the evolution of the agent population, but also that of the (physical) environment itself.

It is our intention that this paper will be just a first step toward further work on what we see as a key gap in this field of research.

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On a Descriptive Model of a Measurable Value Function under Uncertainty for Complex Decision Analysis

HIROYUKI TAMURA

Faculty of Engineering, Kansai University, Osaka, Japan

Keywords: value function, uncertainty, decision analysis

The expected utility model has been widely used as a normative model of decision analysis under risk. But, various paradoxes have been reported for the expected utility model, and it is argued that the expected utility model is not an adequate descriptive model.

In this presentation a descriptive extension of the expected utility model to account for various paradoxes is proposed using the concept of strength of preference. We deal with the case where probability of occurrence for each event is unknown. When we describe the degree of ignorance and uncertainty by the basic probability of Dempster-Shafer theory, the problem is how to represent the value of a set element to construct a measurable value function under uncertainty based on this concept. For identifying a value function under uncertainty, we need to find the preference relations among set elements, which is not an easy task. If the number of elements contained in the set element contains considerable number of elements, it is not practical to find the value function as a function of the set elements. To cope with this difficulty we use some appropriate axiom of dominance.

Incorporating the Dempster-Shafer probability theory in our descriptive model of a value function under uncertainty, we could model the lack of belief that could not be modelled by Bayes' probability theory. As the result our descriptive model could resolve the Ellsburg paradox.

Recent increase of carbon dioxide concentration around the globe is getting serious and it is said that the resulting greenhouse effect and global warming may cause serious damages in our life. Therefore, we need to restrict the emission of carbon dioxide and other greenhouse gas somehow. By using a value function under uncertainty we could deal with a set element of like {1), 2)}, where:

1) to get damage caused by unusual weather due to global warming,

2) to get damage caused by unusual weather which is not related with global warming.

Actually, when we get damage caused by unusual weather, we do not know whether it is due to global warming or not. Basic probability could be assigned to such a set element {1), 2)}. Then, we could construct a measurable value function under uncertainty for evaluating the alternative policies to decrease the emission of carbon dioxide for avoiding global warming. The measurable value function under uncertainty could also evaluate the preference of various type of decision makers; ordinary, pessimistic or optimistic ones.

The approach described in this presentation may contribute to value judgement for evaluating sense of security in various fields.

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Meta-synthesis Approach to Exploring Constructing Comprehensive Transportation System in China

XIJIN TANG *and* KUN NIE

Institute of Systems Science, Chinese Academy of Sciences, Beijing, P.R. China

Keywords: meta-synthesis, group argumentation, multi-agent system, simulation, transporation

Proposed by a Chinese system scientist Qian Xuesen (Tsien HsueShen) and his colleagues in 1990, meta-synthesis system approach (MSA) is regarded as an effective method to deal with open complex giant systems problems. The typical characteristics of an open complex giant system (OCGS) are, 1) there are more than hundreds of subsystems of different categories; sometimes the number of subsystems may be over one billion; and there are the communications between subsystems; 2) there are continuous exchanges in material, energy and information between the system together with its subsystems and external world; 3) the structure of subsystems are evolving with the system evolution. Usually OCGS is simplified as complex system. MSA approach emphasizes "confident hypothesis, rigorous validation", i.e. quantitative knowledge arises from qualitative understanding.

In 2002, Chinese Academy of Engineering (CAE) initiated a consulting project on "constructing comprehensive transportation system in China", whose purpose is to explore the possibility of developing a national integrative transportation system in order to meet the continuously increasing demands from the national socioeconomic development, especially the national strategic goal for comparatively well-off living standards for whole population, i.e. the per capita income is over 1000 US dollars. Currently 5 available transportation modes, railway, highway, airway, waterway and pipes, are independently managed by different government departments who have formed their own strategic plan for each mode. There are a number of problems in the current national transportation framework. One of the serious problems is structure conflicts, which bring uncertainties toward the development of each transportation mode. How to construct a national comprehensive system to overcome those problems is the principal focus of the CAE project. Actually the focused system is a complex system. Thus meta-synthesis approach is applied to the project development.

For better research, the CAE project has 6 subprojects on different goals. One subproject is on theory, directions and methods about comprehensive transportation system construction, and expected to provide guidelines and coordination for other 5 subprojects. A mix of different domain people from different organizations attend the "theory" subproject. Those participants include 3 kinds of people, system researchers, management researchers and representatives from 3 major transportation modes, railway, highway and airway. Here we focus on the work of this subproject.

During the beginning period, project members held many discussion meetings to exchange opinions and define the pathway toward the project goals; even there are many discussion about the definition and contents of a so-called comprehensive transportation system, which is obviously different from an aggregation of current independent transportation systems of 5 transportation ways. Such kind of brainstorming meetings facilitate those participants to think of many original diverse ideas about the focused topics and move outward into a variety of perspectives. Moreover, participants learn from each other during such a divergent thinking process which is an efficient way of knowledge acquisition. Our developed Group Argumentation Environment (GAE) is utilized here to provide augmented support for expert discussions and trigger idea generation and incubation. Gradually, some principal topics are attained or consensus is built about project pathway. The results of such a divergence-convergence process is to transfer a messy problem into a structured problem for quantitative modeling, which is regarded as qualitative meta-synthesis.

As the major problems are fixed after several rounds of group discussions, different modeling work is undertaken based on qualitative meta-synthetic results. One of them is modeling by rules. An agent-based model is constructed to analyze competitive relations in passenger traffic between railway and highway. Simulations are undertaken using a multi-agent system (MAS) platform Starlogo developed by MIT to testify some qualitative hypothesis about passenger traffic based on different conditions about the traffic system and passenger behaviors. Here MAS simulation is expected to provide useful information for quantitative understanding about passenger traffic system behavior based on qualitative rules and helpful for further research about comprehensive transportation system development.

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Knowledge Network System Approach to the Knowledge Management

ZHONGTUO WANG

Research Center of Knowledge Science and Technology, Dalian University of Technology

Keywords: knowledge management

This paper introduces the concept of Knowledge Network System as a new approach to knowledge management, especially to knowledge integration and creation. Knowledge Management has become a hot topic in the later years of 1990s. The term knowledge management had immediate and vast appeal and, at the same time, spawned strongly felt criticism. The major criticisms are:

1. It implies that knowledge can be managed, but in real life, the tacit knowledge can't.
2. It describes knowledge management as a sequence of processes as: "creating-capturing-storing-sharing-applying-reusing", which is too mechanistic and ignore the complex cognitive process of human being.

To overcome the difficulties of understanding the term of knowledge management, we can think of knowledge management as building and enhancing knowledge systems and embedding work systems within these knowledge systems, rather than managing something as nebulous as knowledge per se. From this point, we can understand knowledge management as developing and managing integrated, well-configured knowledge systems and increasingly embedding work systems within these knowledge systems.

The author of this paper suggests to model the structure of knowledge system as a network system. The knowledge network system is composed of a set of networks, both technical and social in different aspects and at different levels. The notion of network implies nodes and links. Nodes can be either documents, models , or individuals, teams even organizations. Nodes are the focal points for activity or organizational processes. The links are various connecting and coordinating mechanisms, such as workflow procedures or meeting. As information flows across the links, new knowledge is created at the nodes and on the links, which can then be applied to meet the needs of the organization. When people think about some things or events, all the concepts (nodes) are connected by some relations or laws (links) to formulate a network. The network can be used as a thinking or knowledge presentation tool. For a working group, the concepts of all members with different expertise will be integrated as large network.

In the last decade, the National Science Foundation of U.S. set up an initiative of knowledge networking. Knowledge networking focuses on the seamless integration of knowledge and activity across content domains, space, time, and people. Modern computing and communications systems are beginning to provide the infrastructure. The creation of new knowledge in groups, organizations, and scientific communities requires additional advances beyond the ability to collect, process, and transmit large amounts of data. Both technological capability and human interaction in the overall scientific process must evolve if knowledge networking is to reach its full potential. The members of knowledge network share information, experience and insights. The members are also part of the network, because they have tacit knowledge that is valuable for the organization.

Knowledge networking approach looks knowledge as process (knowing) while knowledge network approach looks knowledge as objects. 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. Knowledge networks focus on the members' knowledge exchange. They are social networks, which can be defined as " specific sets of linkages among a defined set of actors, with the additional property that the characteristics of these as a whole may be used to interpret the social behavior of the actors involved." A central part of knowledge networking is its focus on the relationships between organizational members, and the impact of these relationships on knowledge creation and utilization. We put forward the concept of "Knowledge Network System" to integrate the approach of knowledge networking and approach of knowledge network. People often consider knowledge network only as tool. If we think of the roles of the network not only a communication and repository tool, but also as an environment for knowledge processing and creation, we will not concentrate only on the nodes and links of the network, but also comprehend the network in its entirety and its environment as well as their interactions. It means that a new paradigmatic approach must be adopted.

A human-centered knowledge network system will include the following constructs: Cultural constructs, invisible connections. Organizational constructs, formal and informal connections. IT constructs. Knowledge network may be organized in different levels:

- Individual level,
- Group (team) level,
- Organization (firm in the business world) level,
- Association or corporate alliance level.

Knowledge networks at each level may be constituted by integrating of sub-networks at the same level. At the higher level, the integration may consist of networks at lower levels. The integrated results constitute a knowledge network systems. In this type of system, the technical networks are interwoven with the social networks.

The crucial issues are interfacing. For the effective processing the knowledge, the concept of knowledge node is introduced. A knowledge node is a kind of high level processing unit. It has three main functions: Dissemination of information on request or automatically channeled. Two way communication and feedback capacities through multimedia interfaces. Access to a local knowledge bank and possibly meta knowledge about other knowledge nodes. The most crucial task for the knowledge management is knowledge conversion and creation.

A typical approach is put forward by Nonaka and Takeuchi. They assumes that knowledge is created through the interaction between tacit and explicit, individual and organizational knowledge, and proposes four modes of knowledge conversion. Corresponding to the above four modes, Nonaka proposes four types of ba (means a place or a sphere). There are other scholars they do not agree with the knowledge conversion explained by Nonaka and Takeuchi. Cook and Brown point out the difference between knowledge that is possessed by its owner and knowing that is demonstrated and enacted as part of action. They distinguish the epistemology of practice (knowledge) and the epistemology of practice (knowing). inseparable from practice and interaction with the world. They see explicit knowledge and tacit knowledge as two distinct forms of knowledge. Each form of knowledge does its own work that the others can not do. In the practice people are not performing on their tacit knowledge that turns it into explicit knowledge; people are using the tacit knowledge to generate the explicit knowledge. Each of the forms of knowledge (individual and group, explicit and tacit) is brought into play by knowing when knowledge is used as a tool in interaction with the world. within this interaction, lies what they have called the generative dance. Through these actions, organizations create both products (or/and service) and knowledge.

The knowledge network system serves to integrate these two approaches. The author of this paper has pointed out, the knowledge systems in the organization is an intelligent complex adaptive system. In the system they are two types of states : ordered and chaotic. The ordered state exists in the routine work or structure procedures both in the organization and technical systems. The chaotic state exists in the process of tacit knowledge exchange and creation. In the knowledge creation and innovation processes, the individual mental process and brainstorming cannot in ordered state. It is in the chaotic state, some new ideas will be emerging. The knowledge network system will bridge the two states.

Knowledge network system is a kind of complex network. As the system growing up, and the numbers of nodes and links increasing to a large figure, there are some issues in network itself. There are some interesting characteristics in the complex network like Internet, World Wide Web; is in uncontrolled and decentralized growth; new lines and routers are added continually. People thought it may be a random network with degree of distribution P(k) as bell type. But experience on Internet and WWW shows that the P(k) is significantly deviate from random It can be described by a power law and in logarithmic scale, it is a straight line. Since power law is free of a characteristic scale, so this type of network is called scale free network.

This type of network has two generic features:

1. It is open system that grows by the addition of vertices.
2. Preferential attachment, which favors attachment to vertices with high degree, rich gets richer. The vertices with high degree are called hubs.

Other two features are the connectivity of scale free network is robust, it contains a giant cluster compromised of most of the nodes even after a removal of a fraction of its nodes. At the same time it is fragile, if the hubs are removed. The description above will help us to understand and design the complex network like knowledge network system.

Finding the Pareto front with Particle Swarm Methods

JAAP WESSELS

EURANDOM, Eindhoven, The Netherlands

NATALIA ROSCA

Eindhoven University of Technology, Eindhoven, The Netherlands

GUIDO SMITS

DOW Benelux, Terneuzen, The Netherlands

Keywords: Pareto optimality, particle swarm methods

Since 1995, the field of optimisation has been enriched by a new type of methods, viz. Particle Swarm Methods (compare [1]). The idea of these methods is that every particle from a swarm tries to find the optimum in its own way, but using some of the information obtained by the other particles. The basic idea seems to be even more natural for characterising the Pareto front of a multi-objective problem. Such a characterisation might play a role in an interactive procedure for multi-objective analysis. The approach that was chosen seems to be more natural and efficient than earlier approaches from the literature (see [2], [3], [4]). As far as the authors know, this is the first approach based on Particle Swarms that works efficiently for three objectives.

In the presentation, it will be indicated how the approach works and how it differs from earlier attempts. Experimental results will be shown for two and three objectives.

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Systems Approach to Knowledge Theory: Creative Space and Creative Environments

ANDRZEJ P. WIERZBICKI

Center for Strategic Development of Science and Technology, Japan Advanced Institute of Science and Technology, Ishikawa, Japan and *National Institute of Telecommunications, Warsaw, Poland*

YOSHITERU NAKAMORI

Center for Strategic Development of Science and Technology, Japan Advanced Institute of Science and Technology, Ishikawa, Japan

Keywords: knowledge discovery

This paper develops further the themes presented in recent publications on multiple criteria decision making and systems approach versus knowledge theory. It was shown in these publications that modern advances in systems science and informational sciences (computational science, computer science, etc. – including multiple criteria decision support) indicate the necessity of reconsidering philosophic ontology and epistemology. There are at least three reasons for that. First, we observe the change from the reduction principle to emergence principle, brought about by studying nonlinear systems dynamics and resulting complexity: catastrophe, deterministic and nondeterministic chaos, computational complexity etc. Secondly, we are at the beginning of new civilization era and we change also other aspects of perceiving the world. Mechanistic perception of the world of industrial civilization era, with its stress on inevitability, reduction, binary logic, is replaced by systemic and chaotic perception of the world of informational and knowledge civilization era, with stress on diverse possibilities, emergence, multivalued logic. Third, traditional ontology and epistemology were directed only towards knowledge validation and verification, while recently several new theories of knowledge creation were developed - Sawaragi and Nakamori *Shinayakana Systems Approach,* Nonaka and Takeuchi *SECI Spiral,* Motycka *Regress Theory,* Wierzbicki *Rational Theory of Intuition* and others. Until we reconsider methodological - ontological and epistemological - aspects of knowledge theory in all these respects, we will not have fully balanced methodology of knowledge science.

The Rational Theory of Intuition is recalled to show its relation with the concept of tacit knowledge and of knowledge creation. Epistemological conclusions of the rational theory of intuition are outlined. The postulate of a new reconsideration of epistemology and the philosophic theory of knowledge on the basis of these developments coincides with recent postulates of philosophers (e.g. Searle, Motycka). However, also basic ontological issues have to be reconsidered in this respect. All this leads to the concept of *Creative Space* which can be considered either as a generalisation of the *SECI Spiral* of Nonaka and Takeuchi, or as a generalisation of the creative *I5 System* model of Nakamori, or as a further development of *Shinayakana Systems Approach* of Sawaragi and Nakamori and of Wierzbicki *Rational Theory of Intuition*.

The creative space has many dimensions, starting with the rational-irrational (explicit-tacit) and individual-social (individual-group) dimensions used in the *SECI Spiral*. However, other dimensions are stressed by the *I5 System*, while the *Rational Theory of Intuition* indicates that on each dimension we should rather use three-valued logic and consider at least three ontological entities than the two-valued logic and two ontological entities underlying the *SECI Spiral*. The concept of *Creative Space* leads in a natural way to the discussion of *Creative Environments* - systems of modern tools that support diverse transitions in the creative space.

The paper indicates new directions of research on such creative environments, undertaken in the 21st Century Center of Excellence *Technology Creation Based on Knowledge Science: Theory and Practice* and the related *Center for Strategic Development of Science and Technology* of the Japan Advanced Institute of Science and Technology (JAIST) in Tatsunokuchi, Ishikawa.

List of Participants

Prof. Tatsuo Arai
1-3 Machikaneyama-Machi
Toyonaka 560-8531
Japan
email: `arai@sys.es.osaka-u.ac.jp`
URL: `www-arailab.sys.es.osaka-u.ac.jp`
telephone: (81-6)-6850-6365
fax: (81-6)-6850-6365

Prof. Masao Arakawa
Dept. Reliability-based Information System Engineering
Faculty of Engineering
Kagawa University
2217-20 Hayashicho
Takamatsu, Kagawa 761-0396
Japan
email: `arakawa@eng.kagawa-u.ac.jp`
URL: `www.eng.kagawa-u.ac.jp/˜arakawa`
telephone: (81-87)-864-2223
fax: (81-87)-864-2223

Prof. Adrie J.m. Beulens
Wageningen UR
Social Sciences Group/
Information Technology Grup
Dreijenplein 2
6703 HB Wageningennn
Netherlands
email: `Adrie.Beulens@wur.nl`
telephone: (31-317)-484460
fax: (31-317)-483158

Prof. Joao Climaco
Faculty of Economics and INESC-Coimbra
University of Coimbra
Av.Dias da Silva
3000 Coimbra
Portugal
email: `jclimaco@inescc.pt`
telephone: (351-239)-851040
fax: (351-239)-824692

Dr Tatiana Ermolieva
IIASA
Schlossplatz 1
A-2361, Laxenburg
Austria
email: `ermol@iiasa.ac.at`
URL: `www.iiasa.ac.at`
telephone: (+43-2236)-807.581

Mr Michael Flechsig
Potsdam Institute for Climate Impact Research
P.O.B. 60 12 03
14412 Potsdam
Germany
email: `flechsig@pik-potsdam.de`
telephone: (49-331)-288.2604
fax: (49-331)-288.2600

Dr Wesley Foell
Resource Management Associates
35 Bagley Court
Madison, Wisconsin 53705
USA
email: `wfoell@attglobal.net`
telephone: (1-608)-238-8834

Dr Motohisa Funabashi
Systems Development Laboratory,
Hitachi, Ltd.
1009 Ohzenji, Asao-ku
Kawasaki 215-0013
Japan
email: `funa@sdl.hitachi.co.jp`
URL: `www.sdl.hitachi.co.jp`
telephone: (81-44)-959 0215
fax: (81-44)-966 4673

Dr Robert Genser
OeGART
Malborghetgasse 27-29,6/6
1100 Vienna
Austria
email: `rgenser@aon.at`
telephone: (+43-1)-6074187
fax: (+43-1)-6074187

Prof. Manfred Grauer
University of Siegen
Information Systems Institute
Hoelderlinstr. 3
57068
Germany
email: `grauer@fb5.uni-siegen.de`
URL: `www-winfo.uni-siegen.de`
telephone: (0049-271)-740.3269
fax: (0049-271)-740.2372

Dr Kiyotada Hayashi
National Agricultural Research Center
3-1-1 Kannondai
Tsukuba, Ibaraki 305-8666
Japan
email: hayashi@affrc.go.jp
telephone: (81-29)-838-8874
fax: (81-29)-838-8515

Dr Keith Hipel
Department of Systems Design Engineering
University of Waterloo
200 University Avenue West,
Waterloo, Ontario, N2L 3G1
Canada
email: kwhipel@uwaterloo.ca
URL: www.systems.uwaterloo.ca/Faculty/Hipel/
telephone: (1-519)-888 4567.2830
fax: (1-519)-746 4791

Dr Andrzej Jaszkiewicz
Poznan University of Technology
Institute of Computing Science
Piotrowo 3A
60-965 Pozna
Poland
email: jaszkiewicz@cs.put.poznan.pl
URL: www-idss.cs.put.poznan.pl/~jaszkiewicz/
telephone: (48-61)-6652371
fax: (48-61)-8771525

Prof. Stefan Kaden
WASY Gesellschaft fuer wasserwirtschaftliche Planung und Systemforschung mbH
Waltersdorfer Strasse 105
12526 Berlin
Germany
email: SO.Kaden@wasy.de
URL: www.wasy.de
telephone: (49-30)-679998.0
fax: (49-39)-679998.99

Prof. Janusz Kindler
Warsaw University of Technology
Faculty of Environmental Engineering
Institute of Environmental Engineering Systems
ul. Nowowiejska 20
00-653 Warsaw
Poland
email: Janusz.Kindler@is.pw.edu.pl

Dr Norihisa Komoda
Osaka University
Department of Multimedia Engineering
Graduate School of Information Sicence and Technology
2-1, Yamadaoka
Suita, 565-0871
Japan
email: komoda@ist.osaka-u.ac.jp
URL: www-komo.ist.osaka-u.ac.jp
telephone: (81-6)-68797825
fax: (81-6)-68797827

Dr Pete Loucks
Civil and Environmental Engineering
Cornell University
Hollister Hall
Ithaca, New York 14853
USA
email: DPL3@cornell.edu
telephone: (001-607)-255 4896
fax: (001-607)-255 9004

Mr Michal Majdan
IIASA
Schlossplatz 1
A-2361 Laxenburg
Austria
email: majdan@iiasa.ac.at
telephone: 43-2236-807.0

Dr Marek Makowski
IIASA
Schlossplatz 1
A-2361 Laxenburg
Austria
email: marek@iiasa.ac.at
URL: www.iiasa.ac.at/~marek
telephone: (43-2236)-807.561
fax: (43-2236)-71.313

Dr Wojtek Michalowski
School of Management
University of Ottawa
136 Jean-Jacques Lussier St.
Ottawa, Ontario K1N 6N5
Canada
email: wojtek@management.uottawa.ca
URL: www.management.uottawa.ca/wojtek/
telephone: (1-613)-562-5800.4955

Prof. Sadaaki Miyamoto
Department of Risk Engineering
School of Systems and Information Engineering
University of Tsukuba
1-1-1Tennodai
Tsukuba, Ibaraki 305-8573
Japan
email: miyamoto@risk.tsukuba.ac.jp
telephone: (81-29)-853-5346
fax: (81-29)-853-5207

Dr Yoshiteru Nakamori
School of Knowledge Science
Japan Advanced Institute of Science and Technology
Tatsunokuchi
Ishikawa, 923-1292
Japan
email: nakamori@jaist.ac.jp
telephone: (81-761)-511755
fax: (81-761)-511149

Prof. Hirotaka Nakayama
Konan University
Dept. of Information Science and Systems Engineering
8-9-1 Okamoto, Higashinada
Kobe 658-8501
Japan
email: nakayama@konan-u.ac.jp
telephone: (81-78)-435-2534
fax: (81-78)-435-2540

Prof. Wlodzimierz Ogryczak
Warsaw University of Technology
Institute of Control & Comp. Engg.
Nowowiejska 15/19
00-665 Warsaw
Poland
email: ogryczak@ia.pw.edu.pl
URL: www.ia.pw.edu.pl/˜wogrycza
telephone: (48-22)-6607862
fax: (48-22)-8253719

Mr Maciej Romaniuk
Systems Research Institute,
Polish Academy of Sciences
Newelska 6
01 - 447 Warszawa
Poland
email: mroman@ibspan.waw.pl
URL:
http://www.ibspan.waw.pl/˜mroman/
telephone: (48-22)-8373578.393
fax: (48-22)-8372772

Mr Joergen Saltbones
Norwegian Meteorological Institute
P.O.Box 43 Blindern
0313 Oslo
Norway
email: jorgen.saltbones@met.no

Mr Huub Scholten
Wageningen University
Information Technology Group
Dreijenplein 2
6703 HB Wageningen
Netherlands
email: huub.scholten@wur.nl
telephone: (31-317)-484631
fax: (31-317)-483158

Prof. Hans-Juergen Sebastian
Deutsche Post Endowed Chair of
Optimization of Distribution Networks
Templergraben 64
52062 Aachen
Germany
email: sebastian@or.rwth-aachen.de
URL: www.or.rwth-aachen.de
telephone: (+49-241)-8096185

Dr Sigrid Stagl
School of the Environment
University of Leeds
Woodhouse Lane
Leeds LS2 9JT
UK
email: sts@env.leeds.ac.uk
URL: www.env.leeds.ac.uk/˜sts
telephone: (0044-113)-343.6787
fax: (0044-113)-343.6716

Prof. Hiroyuki Tamura
Kansai University
Dept. of Electrical Eng. & Computer Sci.
Faculty of Engineering
3-3-35 Yamate-cho
Suita, Osaka 564-8680
Japan
email: tamura@ieee.org
URL: hwww.asdel.ee.kansai-u.ac.jp/
˜tamura/index-e.html
telephone: (81-6)-6368-0829
fax: (81-6)-6368-0829

Dr Xijin Tang
Institute of Systems Science
Academy of Mathematics and System Sciences
55 Zhongguancun Dongdu
Beijing 100080
China
email: xjtang@amss.ac.cn
telephone: (86-10)-62553291

Prof. Zhongtuo Wang
Institute of Systems Engineering,
Dalian University of Technology
116024 Dalian China
Lingshuihe 2'
116024 Dalian
China
email: wangzt@dlut.edu.cn
URL: www.dlut.edu.cn
telephone: (+86-411)-4708495
fax: (+86-411)-4707425

Prof. Jaap Wessels
EURANDOM
P.O.-Box 513
NL 5600 MB Eindhoven
Netherlands
email: wessels@eurandom.tue.nl
URL: www.eurandom.tue.nl
telephone: (31-40)-2478110
fax: (31-40)-2478190

Prof. Andrzej P. Wierzbicki
Center for Strategic Development of Science and Technology
Japan Advanced Institute of Science and Technology
Asahidai 1-1
Tatsunokuchi, Ishikawa 923-1292
Japan
email: andrzej@jaist.ac.jp
URL: www.jaist.ac.jp
telephone: (+81-761)-511786