CALL FOR INDUSTRY PARTICIPATION

INFORMATICS iCORE CIRCLE OF RESEARCH EXCELLENCE

Intelligent Support for Better Software

The Laboratory for Software Engineering Decision Support at the University of Calgary is seeking industry partners for collaboration on software engineering decision support.

Software is important

Software is increasingly complex and large scale, and is used pervasively in business. Whether applied directly or indirectly to develop products and services, the software affects the resulting quality and value.

However, there are many decisions that can affect software quality. Right or 'good' decisions are essential for achieving better software, especially under budget, time and quality constraints. These tend to be very complex decisions, beyond the capacity of any individual.

How can improved decisions be made in software engineering?

An integration of human and computational intelligence is needed. The combination of information, modeling and knowledge, with a sound methodology, can lead to better decisions.

Research team leader: Dr Guenther Ruhe
Team members: 15 researchers (professors, postdocs, PhDs, grad students)
Mandate: To provide research excellence and breakthrough solutions for individual software engineering decision support problems

Who qualifies?

We are seeking to partner with industry organizations.
We would like to hear from you if your organization:

- is developing or maintaining software
- has strong needs to improve maturity of their software projects
- understands software engineering decision-making capabilities as of crucial concern for business success
- is open to mutually beneficial collaboration between industry and academia

Current offerings

- focus on early stages of software development
- release planning tool for incremental development
- support tool for requirements negotiations
- support for requirements-centric selection of components-off-the-shelf (COTS) software products

FOR ADDITIONAL INFORMATION, CONTACT:

Dr Guenther Ruhe, iCORE professor, at ruhe@ucalgary.ca, with a one-page brief on the company and its software engineering challenge.

http://www.seng-decisionsupport.ucalgary.ca/

DR GUENTHER RUHE

SOFTWARE ENGINEERING DECISION SUPPORT

iCORE Professor
Computer Science and Electrical and Computer Engineering
University of Calgary

Dr Guenther Ruhe is an iCORE Professor leading the Software Engineering Decision Support Laboratory, established in the department of computer science and department of electrical and computer engineering at the University of Calgary. iCORE has committed $350,000 per year for five years, for a total of $1.75 million dollars to establish this research group.

EXECUTIVE SUMMARY

The discipline of Software Engineering Decision Support integrates human and computational intelligence to facilitate better decisions during the software life cycle. This is a highly interdisciplinary enterprise using concepts from other disciplines such as computational intelligence, cognitive science, and knowledge engineering where empirical evaluation is a fundamental principle.

The main achievements over the last year have been the development of novel approaches and tools supporting early life-cycle decisions. The most successful results were achieved in the area of software release planning under resource and budget constraints. Computational efficient evolutionary algorithms have been designed and implemented, providing a set of most promising solutions. The final decision-maker can chose out of those solutions, taking into account further implicit and time-dependent constraints. First steps towards developing a commercial product out of these results have been conducted. In addition, a new approach called Soft Requirements Negotiator has been developed that initially uses qualitative, and later quantitative information to provide decision support.

The reported results are part of a broader effort to develop an integrated decision support system with intelligent components for knowledge retrieval, analysis and reasoning, multi-criteria decision aid, simulation and negotiation. Assuming a process-sensitive and web-based 'Intelligent Decision Guide', the system will proactively support process decisions in software development and evolution, to mitigate project risks and to generate the most promising solution alternatives taking into account different stakeholder interests, project parameters and business constraints.

During the reporting period, further progress has been achieved in creating a core team of researchers and in establishing or enhancing dynamic national and international collaborations. The team has started to prepare the 16th International Conference on Software Engineering and Knowledge Engineering, taking place in Banff in June 2004. This will be an excellent opportunity to present research excellence to both academia and industry.

RESEARCH GOALS AND OBJECTIVES

Background and Motivation

Software Engineering Decision Support is of critical interest to both research and industry. Decisions must be made during all iterations of the software life cycle. Currently, many of those crucial decisions are made in an ad hoc manner, based on simplistic rules of thumb, and without links to best knowledge, models, or experience. The impact of poor decisions on the quality of our software becomes more pronounced the earlier in the lifecycle those decisions are made. The main characteristics of decision-making during early lifecycle phases are that (i) the quantity and quality of information available at this stage is typically low, (ii) that the processes and available decision parameters are dynamically changing, and (iii) that a number of conflicting stakeholder interests with different objectives and constraints must be balanced and optimized.

Intelligent decision support is mainly required in situations characterized by the following factors: complexity, uncertainty, presence of multiple stakeholders, large quantities of (organization-specific) data, and/or rapid changes in problem parameters and related information. Support, here, means providing access to information that would otherwise be unavailable or difficult to obtain, facilitating generation and evaluation of solution alternatives and prioritizing alternatives by using explicit models that provide structure for particular decisions.

Only a few examples of software engineering decision support systems exist presently. None of them is specialized to characteristics mentioned above. Additionally, existing systems typically consider decision support as static, not as a continuous problem-solving activity. What is missing is an understanding of decision-making as a crucial part of the processes of evolutionary software development, the existence of active links to human and computational intelligence, and reusing prior decisions, knowledge, and experience.

Research at the laboratory for Software Engineering Decision Support is oriented towards excellence related to two focus areas of the strategic iCORE research strategy: "Software Systems" and "Intelligent Information Systems". To achieve novel research results, we propose an interdisciplinary approach using concepts and results from other disciplines such as computational intelligence, cognitive science, knowledge engineering, management science, and optimization. In more detail, the following objectives are aimed:

(i) To develop a hybrid methodology "Intelligent Support for Evolutionary Software Development" integrating and enhancing methods and techniques from related disciplines. Special emphasis is on:

- uncertainty and incompleteness of information;
- involvement of different stakeholders;
- conflicting objectives and constraints;
- dynamically changing project, process and process parameters.

(ii) To instantiate and adapt the proposed methodology in the context of seven classes of problems of evolutionary software development:

- release planning;
- soft requirements negotiations;
- trade-off analysis for requirements selection;
- requirements-centric selection of COTS products;
- design decisions for evolvable systems;
- simulation-based decision support for software quality assurance;
- scheduling and resource planning for software project management.

The long-term goal of the project is to provide a prototype intelligent decision support system. Assuming a process-sensitive and web-based "intelligent decision guide," the system will proactively support process decisions in evolutionary development, to mitigate project risks and to generate the most promising solution alternatives taking into account actual project parameters and constraints.

Software release planning under budget and resource constraints

There is a growing recognition that an incremental approach to software development is often more suitable and less risky than the traditional waterfall approach. This preference is demonstrated by the current popularity of agile methods, all of which adopt an incremental approach to delivering software rapidly. In the incremental software process model, requirements are gathered in the initial stages and, taking technical dependencies and user priorities into account and the effort required for each requirement, the system is divided into increments. These increments are then successively delivered to customers. It is often true that any given requirement could be delivered in one, several or even all releases. Consequently, there is a need to decide which requirements should be delivered in any given release. Since there are likely to be many different users all with different viewpoints on what the user value of requirements is, this decision is potentially very complex. Exacerbating this is the fact that there is a range of constraints, one of which is the desired maximum effort for any given increment. In addition to this factor, risk is an important consideration. A given project may have a risk referent. This is a level of risk which should not be exceeded. In an incremental delivery model this means that a given release has also a risk referent.

In response to these issues we have developed an evolutionary and iterative approach called EVOLVE+ that offers quantitative analysis for decision support in software release planning. The model is extended from and takes into account:

- priorities of the representative stakeholder groups with respect to requirements;
- effort estimates for implementing each requirement and effort bounds for each release;
- precedence constraints, where one requirement must occur in a release prior to the release for another requirement;
- coupling constraints where a group of requirements must occur in the same release;
- resource constraints where certain requirements may not be in the same release; and
- a risk factor estimate for each requirement and a maximum risk referent value, calculated from this for each release.

Soft requirements negotiations

Soft requirements negotiator (SRN) is a decision support method for requirements selection under incompleteness and uncertainty. Given a set of requirements, the decision maker needs support in the process of gradually reducing, evaluating and prioritizing the candidate sets of requirements. In our new approach SRN, the initial data are used under consideration of their incompleteness and uncertainty. SRN explicitly considers the fact that the available information is always incomplete and uncertain, but gradually becomes better and better during the negotiation process. The approach is initially based on a simple three-point scale for all the involved attributes. Later on, quantitative information is used to determine trade-offs between the supposed value (or priorities) of selected requirements, and the estimated effort to realize them.

We do not compute the results from the given data but use these data as a guide to assist the decision maker in the exploration of the solution space and in the construction of the results. As a final result, we propose a set of the most appropriate solutions. Our approach is soft in the sense that it does not depend on a rigid model and does not make strong assumptions about the available information. It was inspired by the paradigm of multi-criteria decision aid, in particular the concordance/non-discordance principle.

Trade-off analysis for requirements negotiation

Evaluation, prioritization and selection of candidate requirements are of tremendous importance and impact for subsequent software development. Effort, time as well as quality constraints have to be taken into account. Typically, different stakeholders have conflicting priorities and the requirements of all these

stakeholders have to be balanced in an appropriate way to ensure maximum value of the final set of requirements. Trade-off analysis is needed to proactively explore the impact of certain decisions in terms of all the criteria and constraints.

The proposed method called Quantitative WinWin uses an evolutionary approach to provide support for requirements negotiations. The novelty of the presented idea is four-fold. Firstly, it iteratively uses the analytical hierarchy process (AHP) for a stepwise analysis to balance the stakeholders' preferences related to different classes of require-ments. Secondly, require-ments selection is based on predicting and rebalancing its impact on effort, time and quality. Both prediction and rebalancing is based on the simulation model prototype GENSIM. Thirdly, the alternative solution sets offered for decision-making are deve-loped incrementally based on thresholds for the degree of importance of requirements and some heuristics to find a best fit to constraints. Finally, trade-off analysis is used to determine non-dominated extensions of the maximum value that is achievable under resource and quality constraints. As main result, quantitative WinWin proposes a small number of possible sets of requirements from which the actual decision-maker finally can select the most appropriate one.

Requirements-centric selection of COTS products

As the use of COTS components becomes more and more prevalent in the creation of large systems, the need for assistance for the selection of suitable components in the early stage of the software life cycle grows. COTS-based Software Development (CBSD) focuses on building large software systems by integrating previously existing software components. CBSD's success depends on the successful evaluation and selection of COTS software components to meet customer requirements. However, this process is faced with several difficulties: uncertainty, incom-pleteness and even incon-sistency of the information available, instability of proposed system requirements, as well as a great variety of objectives and constraints for the actual development process and the final product. Objectives can be related to usability, correctness, compliance to requirements, stability, or performance. Con-straints can be related to time, cost or fitness to architecture and dependencies between software components.

TRADE-OFF ANALYSIS IS NEEDED TO PROACTIVELY EXPLORE THE IMPACT OF CERTAIN DECISIONS IN TERMS OF ALL THE CRITERIA AND CONSTRAINTS.

A number of methodological proposals have been formulated to improve effectiveness of the individual selection of COTS components based on the fitness to requirements. However, even more benefits can be expected if we look for multiple COTS components to be integrated from a global evaluation perspective. The problem is to support the selection of a combination of components. As we are encountering typical trade-off relationships, support here means the generation of a set of most promising solution alternatives, from which the decision maker can finally select the best fit considering also implicit and subjective aspects.

In a large software system, components depend on each other and should not be evaluated individually. The domination procedure usually used in single and local COTS selection can easily lead to sub-optimal solutions from a global perspective. Since many interacting factors influence the global selection, these factors should be considered in final solution sets. The global perspective is also needed in order to avoid the interference of a new component selected for a subsystem with other components previously selected for other subsystems, and to avoid undesirable restrictions for further selections. We are then facing a problem that goes beyond a decision among several alternatives, but rather an optimization problem where an optimal combination of COTS products has to be found.

Simulation-based decision support for software quality assurance

Software development companies have real constraints for competitive market edge and

delivery of a quality product. Decision processes are the driving forces to organize a corporation's success. To achieve quality processes and practices there are permanent trades-offs to the different aspects related to the final quality of the product. In today's markets, these trade-offs are forced by the pressures of constraint management (e.g. budget, schedule and resources).

The development of a simulation model based on information about current or past reality helps understand why system states that are of interest behave in the observed way given certain start conditions and exogenous influences are in place. The simulation models reproduce current or past behaviour of reality, systematic variation of model parameters (i.e., sensitivity analysis or inclusion and exclusion of model structures) and help in understanding system behaviour. In particular, the nature of trade-off relationships between system states can be investigated this way.

We consider software development from a system theoretic perspective and assume the existence of global (business) goals when studying systems. Starting from an initial understanding of the system under consideration, the most critical and worst understood parts of the overall system are most promising candidates for an in-depth investigation. This investigation can be done by designing and implementing a GQM-based measurement program with the goal derived from the subsystem under investigation. The results from this program are used to better understand system structure and system behaviour at this point. This process can be iterated several times, where not only one measurement program needs to be considered at each step. The application of this interactive (between SD and GQM) and evolutionary (models, results, and insights are evolving and relying on each other) process results in:

- a sequence of SD models with increasing accuracy and validity in describing reality;
- a sequence of GQM plans (including existing results) derived from the global improvement goal(s) and the perspective of the whole system;
- a means to incrementally improve the validity of both the SD models and the GQM models by checking their respective consistency;
- a method to combine the results of GQM with the power of SD to show how different individual/local goals fit together; and
- a method that combines experiments in a virtual world by conducting simulation runs with experiments in a real world by performing goal-oriented measurement.

Based on descriptive modeling of existing processes, products and quality related attributes, simulation will be used to better understand and predict the impact of the different verification and validation activities. The process models themselves will be initially based on the unified process and will be later tailored to customers' specific processes.

RESEARCH TEAM

TEAM LEADER	TITLE
Guenther Ruhe	iCORE Professor, Software Engineering Decision Support

COLLABORATORS	TITLE
Dr Maurer	Associate Professor at Department of Computer Science
Dr Denzinger	Associate Professor at Department of Computer Science
Dr Walker	Assistant Professor at Department of Computer Science
Dr Eberlein	Associate Professor at Department of Electrical & Computer Engineering
Dr Far	Associate Professor at Department Electrical and Computer Engineering

OTHER TEAM MEMBERS	TITLE
Amandeep	Research Associate Department CS
Jinfang Sheng	Visiting Researcher, Department of ECE
Kornelia Streb	Adminstrative Assistant

POSTDOCTORAL FELLOWS	TOPIC
An Ngo The	Computational Intelligence, Department of Computer Science
Des Greer	Release Planning, University of Belfast
Dietmar Pfahl	Software Process Simulation, Fraunhofer Institute Experimental Software Engineering

PHD CANDIDATES	TOPIC
Abdallah Mohamed	Bayesian Belief Networks
Jingzhou Li	Decision Support Processes
Michael Ochs	COTS Selection
Liang Zheng	Evolutionary Modeling Intergating Measurement and System Dynamics

MSC CANDIDATES	TOPIC
Zhizhong Li	Requirements Management using Rough Set Analysis
Joseph Momoh	Decision Support for Software Project Management
Wei Shen	Trade-off Design Decisions
Yuhang Wang	Decision Support for Perspective-based Software Inspections
Qun Zhou	Effort Estimation for COTS-based Software Development

COLLABORATIONS

RESEARCH COLLABORATIONS

Fraunhoder IESE and Fraunhofer-Center Maryland
In accordance to the Academic Cooperation Research Exchange between the University of Calgary and the Fraunhofer Institute for Experimental Software Engineering ("Fh IESE"), the Laboratory for Software Engineering Decision Support and Fh IESE agreed to a collaborative research and personnel exchange. On this basis, Dr Dietmar Pfahl will visit the laboratory for three months. Collaboration with Fraunhofer-Center Maryland has just started after a visit in Fall 2002.

University of New South Wales
A similar agreement as signed with Fh IESE is in preparation to be signed with the research group of Dr Ross Jeffrey at University of New South Wales. It intends to conduct joint research and exchanging PhD students based on that.

INFORMAL COLLABORATIONS

Informal collaborations were launched especially with the groups of Dr Lionel Briand (Carleton University, Canada), Dr Khaled El-Emam (NRC, IIT), Dr Jens Jahnke (University of Victoria, Canada), Dr David Raffo (University of Portland, USA), and Dr Goivanne Cantone (University of Rome, Italy).

COLLABORATION WITH INDUSTRY

Brycol
An NSERC CRD proposal titled "Simulation-Based Decision Support Software Quality Assurance" was initially submitted to CSER, the (Canadian) Consortium for Software Engineering Research. Created in 1996, CSER is a multi-party, industry-led research program, geared toward solving selected industrial problems in software engineering. The project called SimQuali aims to benefit the collaborators, their students and the Canadian economy in various ways. As a small company, Brycol Consulting cannot afford to support a research department. This project provides the opportunity for Brycol to benefit from the collaborative research results embedded in an interaction/argumentation device when discussing trade-off in software quality improvements and outcomes. The intelligent decision support tool will provide the capability to evaluate the outcomes of feasibility alternatives based on standard variables for verification and validation techniques.

Motorola
A proposal for funding of one PhD student was submitted to the University partnership program of Motorola. The project is devoted to develop a new and innovative methodology to support analysis and decisions in software system development. In our new approach, the initial data are used under consideration of their incompleteness and uncertainty. Instead of computing the results from the given (uncertain) data, our new approach provides the decision-maker "a guided tour" in the solution space and assists him/her in the construction of the final selection. The support tool will

supplement the Motorola's use of the Decision Driven(tm) design methodology and its existing Motorola DecisionLink tool for building and maintaining decision networks for the stage of software analysis and designs.

Corel

Collaboration with Corel is devoted to release planning. Their main interest is to provide plans that fit to resource and budget constraints. No commercial product for that purpose is available on the market. Corel has contacted the lab based on a self-running demo that is provided at http://www.releaseplanner.com. In accordance to discussions conducted with Inno-Center and University Technologies Inc. (UTI), the strategy is to have Corel as a reference customer for a later product development. For access to business relevant real-world data, a disclosure agreement as signed.

Nortel Networks and Alterna Technologies

Two non-academic organizations have joined the proposed NSERC Strategic Project Grant: Alterna Technologies Group Inc. (Calgary) and Nortel Networks (CDMA Base-station Development, Calgary). The CDMA wireless group of Nortel Networks is presently supporting three releases in the application field, plus three releases in develop-- ment and one release in the planning phase. The base transceiver station is primarily driven by software. Each release, the software team adds more functionality to its application code. Release planning and requirements negotiation is of crucial importance for business success.

Alterna provides and integrates a full suite of internet-based global e-finance solutions allowing customers to maximize their visibility to liquidity, improve productivity, reduce costs, and increase shareholder value. Evolutionary development processes are an essential means to better react to changing markets and policies.

With both partners, we have extensively discussed the project goals and how these match with their priorities and current demands. In their letter of support, each expresses its strong commitment for in-kind contributions to achieve project goals.

ALBERTA SOFTWARE ENGINEERING RESEARCH CENTER (ASERC)

ASERC is composed of faculty and graduate students from the University of Alberta and the University of Calgary that are engaged in applied research in software engineering and partner companies that currently participate or intend to participate in collaborative research with the academic members.

MULTIDISCIPLINE OR MULTI-INSTITUTIONAL PARTNERSHIPS

Alberta Software Engineering Research Center ASERC

The Alberta Software Engineering Research Consortium ASERC is composed of faculty and graduate students from the University of Alberta and the University of Calgary that are engaged in applied research in software engineering and partner companies that currently participate or intend to participate in collaborative research with the academic members.

International Software Engineering Research Network (ISERN)

The software engineering research group at the University of Calgary successfully applied to become a member of the International Software Engineering Research Network ISERN. This gives us excellent opportunities to further extend collaboration with leading researchers and research institutions all over the world. For a list of the 33 member organizations, see http://www.iese.fhg.de/network/ISERN/pub/isern.list_of_members.html.

FUNDING

Current funding is based on the iCORE research grant ($350,000 over a period of five years), and an existing NSERC grant 'Decision Support for COTS-Based Software Development' with an annual funding of $24,000 over a period of four years.

The proposal for an Alberta Research Center for Innovative Software Engineering Technologies (AISET) including 24 researchers from six departments located in three Alberta Universities was asking for funding of about $2 million over a period of five years. The Alberta Ingenuity Science and Engineering Advisory Council finally evaluated the proposal in the category B (second best in a four point scale). This means, the proposal did not receive funding but may advance to full proposal stage in future competitions, with help from Ingenuity and institution. SEAC especially recommended continued support from Alberta institutions and iCORE.

Three more proposals have been submitted:

(i) NSERC Strategic Project Grant asking for about $180.000 over a period of three years plus in-kind contributions from Nortel Networks and Alterna Technologies.

(ii) NSERC CRD Grant asking for about $100.000 including in-kind contributions from Brycol Consulting.

(iii) Funding for one for PhD student was submitted to Motorola's University Partnership Program requesting $25.000 over a period of three years.

INTELLECTUAL PROPERTY

Current commercialization is focused on a tool for software release planning. No commercial product for that purpose is available on the market. In accordance to discussions conducted with Inno-Centre and University Technologies Inc. (UTI), the strategy is to further conduct research in this context to incrementally develop a powerful support tool and to use Corel as a first reference customer for a later product development.

For access to business relevant real-world data, a disclosure agreement was signed. Currently, software release planning is widely done ad hoc and without tool support. A comprehensive analysis of existing software solutions and pending patents in this area was conducted by UTI Calgary. The results have shown that no competitive products or results are currently available for this dynamic and complex task.

PUBLICATIONS

Accepted publications by refereed journals

1. G. Ruhe, A. Eberlein, and D. Pfahl, "Trade-off analysis for requirements selection," International *Journal on Software Engineering and Knowledge Engineering* (in press).
2. D. Pfahl, O. Laitenberger, G. Ruhe, J. Dorsch, and T. Krivobokova, "Evaluating the Learning Effectiveness of Using Simulations in Software Project Management Education: Results from a Two Times Replicated Experiment," *Information and Software Technology* (in press).

3. D. Pfahl and G. Ruhe, "IMMoS: A New Framework for Integrated Measurement, Modelling, and Simulation," *International Journal of Software Process: Improvement and Practice* (in press).
4. D. Pfahl, O. Laitenberger, G. Ruhe, and J. Dorsch, "An Externally Replicated Experiment for Evaluating the Learning Effectiveness of Using Simulations in Software Project Management Education," *International Journal on Empirical Software Engineering* (in press).

Refereed Conference Papers

1. G. Ruhe and D. Greer, "Quantitative studies in release planning under risk and resource constraints," appears in: International Symposium on Empirical Software Engineering, 2003.
2. G. Ruhe, "Intelligent Support for Selection of COTS Products," Net.ObjectDays, Erfurt, Springer, 2003, pp. 34-45.
3. G. Ruhe, A. Eberlein, and D. Pfahl, "Quantitative WinWin - A New Method for Decision Support in Requirements Negotiation," 14th International Conference on Software Engineering and Knowledge Engineering, Ischia, Italy, July 2002, pp. 159-166.
4. I. Grützner, D. Pfahl, and G. Ruhe, "Systematic courseware development using an integrated engineering style method," World Congress Networked Learning: Challenges and Solutions for Virtual Education (NL 2002), Berlin, Germany, 2002.

Books

1. G. Ruhe, "Software Engineering Decision Support - Methodology and Applications," *Innovations in Decision Support Systems*, ed. Tonfoni and Jain, International Series on Advanced Intelligence Volume 3, 2003, pp. 143-174.

Workshop on Software Engineering Decision Support

The first International Workshop on Software Engineering Decision Support was held in conjunction with the 14th International Conference on Software Engineering and Knowledge Engineering SEKE'2002 in Ischia, Italy. The workshop was a great success, and the iCORE Chair was asked to organize a successor event in 2003 again. Ten high quality papers were finally accepted after a peer review process. A special issue of the *Journal on Software Engineering and Knowledge Engineering* will be edited with advanced and improved versions of the four to five best papers of the workshop.