Joint evaluation report

on

INTEGRATED ENGINEERING INFORMATION SYSTEMS (IEIS)

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1 Introduction

This report is based on a document proposing a research program, written by Prof. Tore Risch and a number of collaborators from Swedish universities, an oral presentation of the proposal by Profs. Tore Risch and Lennart Karlsson in front of the evaluators, and comments by a number of participants from industry on the significance of the proposed program for Swedish industry. The written proposal was identified to the evaluators as a program outline, which had deliberately left some aspects open. The oral presentation succeeded in answering many of the open questions to the satisfaction of the evaluators. The comments by industry provided concrete examples of the needs of industry for the work proposed.

2 Significance and importance of the Research Program

The availability of current information and knowledge is the key to international competitiveness of industrial companies. More and more the time from market- and customer-requirements to innovative products, which have to be developed simultaneously in distributed engineering networks, is the critical factor for economic success.

Today the volume of accessible information is rapidly increasing. Information systems are the necessary tools to reduce the engineering time and management of the product life cycle. There are different ways to represent the information to all participants in the engineering processes. But many specific applications are isolated systems and the companies lose a lot of time and efficiency because of the low level of integration of engineering information systems. Many standards and many information islands are available but basic product- and production-models for the exchange of information between the applications are a task for information engineering.

Information systems have to be adapted to the specific requirements of engineering processes and applications. The proposed program for “Integrated Engineering Information Systems” (IEIS) deals with fundamental research and development for the integration of methods and tools based on an architecture to access heterogeneous information in the distributed engineering processes. In particular, such a methodology should also be capable of dealing with the problem of legacy systems.

It is the goal of the program to develop the national competence of researchers and engineers within engineering information systems, an area that previously has not been established in Sweden. This development is crucial for the big manufacturers in all branches of industry as well important as for the smaller suppliers and the engineering consultants and services. It is evident, that engineers have to realize, adapt, and manage information systems in view of the rapid introduction of innovations based on information and communication technologies.

This program has an application focus in the main engineering area like the mechanical engineering and design, including the analysis and optimization by means of CAD/CAM and FE systems. Virtual reality is used for visualization. The kernels of the program are the “data integrator” and the “cooperative product development system” sub-projects. Both include specific applications for detail design, finite element analysis, simulation of the dynamic behavior and manufacturing processes. Other applications, which are of high importance, are covered in the complementary programs ENDREA, IVS and PROPER.

The originality and novelty of this program is in the basic modeling of the main engineering and analytic processes based on an innovative mediator architectural framework. It includes existing or evolving international standards and common application systems as well as access to proprietary simulation methodologies.

3 Strategic Focus

Much of the early discussion during the oral presentation centered around the question of what the intended strategic focus of the program was, so that it would provide long-lasting benefits to the scientific and industrial communities alike. It was agreed that the program was to aggressively pursue three objectives:

I. A generic solution on the information technological level to the management and integration of information in a distributed and heterogeneous environment with many interacting data sources, by providing the ”lower” part of a mediator layer (translators) that connects the information sources with the applications.

II. A generic solution on the application domain-specific level to the management and integration of information that is semantically heterogeneous, by providing the ”upper” part of the mediator layer (integrators).

III. Awareness of industry, in particular of management, of the complexity of the integration issues and the need for a mediation solution that may appear somewhat costly in the beginning but one where in the long term the benefits will outweigh the costs.

To pursue the first objective, a strong information technological solution must be developed that identifies the technical issues involved and provides the software tools to build a mediation layer architecture and its components, that can be tailored to the needs of a given application (its data and processes). It must overcome the many challenges caused by the heterogeneity and distribution of the sources, their technical and software platforms, and the communication and presentation standards they employ. This objective is the domain of Prof. Tore Risch.

Pursuit of the second objective is primarily an issue of providing the means for developing uniform models into which both the data of the sources and the data views of the applications can be translated, and vice versa. This implies choosing the proper representation system for the models, capturing the meta-data that allow the interpretation of the modeled data, and developing domain-specific models. This objective is primarily the domain of Prof. Lennart Karlsson.

The third objective is clearly an issue of education and is to be pursued by, on the one hand, a graduate program that fosters communication and mobility between academia and industry, and on the other, by collaborative projects between academia and industry.

4 Structure of the Program

On the face of it, the document does not seem to give equal weight to the three strategic objectives. However, the proposers convinced the evaluators that this had to do with the outline character of the document, and with the tedious negotiations with the application-oriented research partners who had to be convinced to submit their ”homegrown” insular system solutions to a more widely employable, generic approach. The proposers suggested during the oral presentation that at least 50% of the effort and expenses should be devoted to the two levels of the mediation layer and its associated scientific challenges, and that both Prof. Risch and Prof. Karlsson would take a strong personal hand in these efforts. They agreed that, as a consequence, project 11.1 should be refined into a number of projects that follow the lines of the issues identified under the heading of ”Scientific merits” below. It is to be expected, then, that the final version of the program will contain a number of projects that fall under the topic of ”mediation layer”.

The remaining projects 11.2 to 11.7 (or to the extent that they will be pursued, see ”Program management” below) contribute both to the second and third strategic objectives and thus are an important part of the overall program. For one, they offer essential test cases that allow the validation of the scientific hypotheses and technical solutions underlying the mediation layer. Second, they are the conveyor belt for the transfer of the results of the program to the industrial world. Care must be taken to specify these projects in such a way that they contribute well-defined test criteria to the evaluation of the mediation layer, and at the same time prove highly attractive as solutions to the problems at some of the industrial partners.

The graduate education program is another essential part of the program. Care should be taken that it serves not only the purpose of instilling the needed skills in university graduates but attracts industrial Lic. and Ph.D. candidates to spend considerable part of their time in the academic environment to stimulate new avenues of research there and to expose themselves to the much broader range of ideas commonly found at universities.

5 Scientific Merits

Integration of systems and information is a topic is of great technological interest, although no specific scientific basis for integration exists as yet. It is not unusual that 30% of project costs in IT and engineering systems is devoted to integration. Practitioners and educators in this field tend to come from the fields of databases, artificial intelligence, and systems engineering, but have to complement their past background with expertise in the complementary topics. Having a significant project which focuses on mediation as a generalizable method of integration in engineering systems is of high value, and should provide a foundation for academic and industrial understanding of an increasingly important segment of computer science and engineering.

The presentation stressed the need for partitioning and modularity of mediating software. Such modularity is needed to adapt the technology to the diverse needs of engineering projects, and also to achieve the scalability needed for industrial adoption. The presenters observed, correctly, that many projects demonstrating mediation, specifically in academia, used a single, centralized mediator, which may show the concepts, but would not be scalable or maintainable in a realistic industrial setting.

Specific topics for fundamental research in this project are:

- Meta-data management
  – will provide the foundation for information sharing of the participants and guidance for the implementers.
- Structural data integration
  – deals with differences in representation and is well understood in this proposal. New data structures will arrive as new applications and as new methodologies arise so that this aspect has to remain flexible.
- Semantic data integration
  - Issues of semantics arise once structural integration has to be performed and will become of greater importance as the project progresses.

- Efficient access
  – is an important concern in the industrial adoption, but may not be fully resolved during prototype development.
- Adaptation to standards
  – provides the means for interoperability and the proposers are well aware of the large number and aspects of standards development.
- Scalable, modular and distributed mediator architecture
  – The intent of mediator architecture is to be scalable. To achieve that objective a very careful partitioning is needed so that a single mediator does not require a committee for its maintenance.
- Security
  – will be important when tools are going to be used among multiple companies but is probably an issue whose implementation is best deferred to a later stage.
- Availability
  – Providing backup in the architecture for data and access paths will be important but again requires a maturity that will arise later in the program.
- Domain specialized database technology
  – Partitioning by domains is important to reduce semantic heterogeneity.
- Presentation data access
  – Good presentation is essential for the applications but not central to the mediators themselves.

The intermediate representation and transport mechanism for communicating among translators and mediators in this program. There is a wide choice of industrial and academic technologies, each with some benefits and demerits. None of them will be fully adequate. The choice will crucially affect progress, performance, and needed investment, but a single choice will have to be made.

Crucial to powerful mediation is the meta-data. The IEIS project descriptions focus on meta-data as found in database schemas, and in object-oriented models of data structures. We expect that as the project matures, the meta-data will have to be extended to include full ontologies, computational methods, and process control information. The presenters were aware of those areas, but had no definite approaches in mind. Their view is that the current-state-of-the-art makes it preferable to insert equivalent capabilities as programmed plug-ins into the mediators, and that is not an unreasonable approach at this point, although it will lead to some long-range maintenance concerns.

Since simulations are a component of many applications, it will be important to formalize the meta-data needed to drive simulations and extract data from them, at an early stage. Simulations have features, as uncertainty, indefinite result sizes, etc, that make them intrinsically different from databases, and require specific concerns.

With that background, the overall concept of domain modeling, as input to defining the role of mediators in the context of the diverse applications, remains weak. The power of ontologies, as presented, was limited to object-based structures. While object-oriented structures provide a useful foundation, they are not likely to remain adequate throughout. Object-oriented modeling is in practice restricted to hierarchies. Diverse applications will have their own hierarchies, so that an integrated model has to be able to handle a general network. At the articulation points, where the hierarchies intersect, semantic differences are likely to occur, and here term-capable ontologies were needed.

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Systems of many mediators will have many interfaces, and at each layer there will be a cost impact system performance. Optimization was listed as a need for these systems, and an expectation was expressed that interfaces could be composed that would show little loss. In general, optimization of complex, distributed systems with many black-box components is hard, if not impossible without innovative technology. Our advice here is to not expend much effort on optimization until the structural issues are solved.

Mediators can be seen as information resources shared by the applications. Such a view provides a criterion for deciding whether to associate certain functionalities with a mediator or an application system. We suggest that clear guidelines will be provided for application implementers where to assign given application functions. Extensible mediators with application plug-ins as proposed in the presentation may be one possible solution.

The major scientific benefit from the IEIS program will be an improved understanding on how to engineer effective information systems. Prototype tools and modules that carry out the functions will provide the means to demonstrate the science and technology to a wider audience. Having trained students that understand integration as a methodology will provide the principal means of technology transfer.

6 Scientific Synergy and Cooperation

Platforms for Integrated Engineering Information Systems need an interdisciplinary cooperation between Engineering, Information and Manufacturing departments. The central architecture framework and the cooperative engineering methodology are developed by Prof. Risch and Prof. Karlsson. Both are competent and familiar with the fundamentals of engineering data management and engineering methodologies as well as with different application systems. They have cooperated with each other for a long time and their presentation showed a strong sense of mutual understanding. Their developments are supported by selected application systems for engineering and manufacturing. This will make sure that different views of the architecture are taken into account.

The industrial requirements are supported as expressed in writing by different companies by their engineering departments and verbally during the presentation.

International cooperation is provided indirectly via relevant research contacts in other programs. It seems to be advantageous to find more contacts to international groups of researchers, which are involved in product and production modeling. The program is too small to independently sustain international co-operation efforts. This would be desirable though because there are major relatable efforts in Germany.

7 Multidisciplinary Scope

Information and communication systems have different scopes. The research scope of IEIS is mainly focused on the architecture and the structure of information and their presentation to different applications. From the application point of view there are the requirements of the engineering processes and the requirements of the real state of the art in the companies. This leads to the need of interdisciplinary cooperation between information, engineering and application departments. The proposed program includes all of these views in a beneficial way.

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8 Graduate Program

The program includes provision for graduate education. The intention is to provide a means for developing a number of new courses that are given at the participating universities. The courses will broaden the national knowledge for engineering of information systems in the area of product-development and production. The industrial development and engineering of information management systems for production has a strong and sustainable future for all manufacturing companies in Sweden and in the increasing global production.

The proposed program for graduate education is a means to transfer and concentrate the knowledge in the field of distributed and simultaneous engineering. Just at this time there is a highly demand in basic education of tools, methodologies and integration of engineering systems. It can be expected that students will find easy employment after obtaining degrees in the engineering departments as well as in the manufacturing near service companies like information and communication services or consultants.

9 Program Management

The proposal text did not define the program management, except to the extent that there would be a board. At the presentation it was made clear that the board has considerable leverage over policy setting. That board will meet several times per year. Important policies to be set are the relative investment, and start and termination dates of the various subprojects. These decisions must take into account dependencies among the projects, namely software that exists now, software being developed and needed by some subproject, and application data and testing resources needed to validate the correctness, breadth, and usability of the software.

It is clear that the principal provider of the mediating modules is project 11.1, at Linköping. To the extent that adequate software, specifically translators, already exists, other applications can start. However, having several applications (subprojects 11.2 – 11.7) depend on immature software will impose too high a burden on the software suppliers (11.1). It would also raise the danger of technical solutions that are again insular. Training, answering questions, assisting in debugging, and in order to perform those functions, understanding diverse requirements takes much time, and would impact crucial development efforts.

We recommend hence that initially only one or at most two applications be involved, preferable those that have already served as input to the systems models that the mediator technology is focusing on. When such applications have reached some stability and can be used to demonstrate the concepts, then other projects can be added to the portofolio of the IEIS program. There may be pressure from industry to focus on projects with great perceived needs. But such enthusiasm should be dampened with the realization that in the end a poorly performing or greatly delayed project will have a greater negative impact than no project at all.

In order to enable such management there must be milestones defined for the various software modules and application states. Those milestones can be set out along a timeline or PERT chart that makes the interdependencies clear. When a milestone is missed, as is sure to happen at times in a project of this breadth, the board must be willing to reallocate resources and defer impacted subprojects.

The role of the board, and an effective interaction between the board and the researchers will be essential to bring the research aspects of the IEIS program into a productive conclusion.

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10 Budget

The proposed budget is modest for a proposal of such a broad scope and wide participation.

At SEK 6 600 000 per year, adjusted only for annual inflation at 5%, it will only provide for fewer than 10 Ph.D. students, given current stipends that are mandated by the state, even with some University participation. No faculties are directly supported; that effort is presumably supported by their Universities. The faculty has, of course responsibilities to teaching and other projects, and the extent of their commitments should be recognized.

The overhead for VAT, administration and the board is SEK 1 200 000.-. We assume that this will also cover travel and communication cost for the remote institutions.

As the program is refined, and subprojects complete and start we expect that expenses will differ annually among them.

There are no costs budgeted for hardware and software. We were assured that other sources would provide the funding for hardware and software. Probably some software can be obtained by donations or discounts appropriate for academic institutions. For the teaching aspects of this program it will be important that hardware and software remain modern, so that the students' education and background remain as relevant as possible.

However, to install and maintain the many substantial pieces of software that are required for up-to-date research in this arena, some technician time will be required, and that cost did not appear in the budget either. It is doubtful that donated or purchased software would include such support.

11 Industry Relevance

By studying the supportive letters in the proposal and summing up what was pointed out by the industrial representatives in the presentations at the hearing, it is clear that the area of IEIS, as defined by the program proposal, is of key interest for the Swedish industry.

The support was mainly expressed as the need for:

- Graduate trained people that are able to handle and manage the issues raised by the increasingly heterogeneous and distributed environment evolving in the engineering field.
- New technologies to handle the integration of heterogeneous and distributed data sources and methods.

However these needs does not show up as commitments in the program proposal. We would like to see a substantial industrial commitment in the form of funding of projects, graduate students or equipment in the program budget, at least after the third year and ahead. This will enable the program to start up with a focus on research in the generic areas of IEIS and then migrate into an implementation phase where the results are implemented in joint industrial projects.

Given the importance of the mediation architecture it is highly recommendable that software companies to the extent that they exist in Sweden, are brought in.

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12 Conclusions

The reviewers are unanimous in approving the proposed IEIS program. The project is of high strategic relevance for the Swedish industry and must be solidly anchored within the academic environment.

Access to distributed information will be increasingly important for Swedish industry as it works in a global context.

The proposal is centered around two capable highly involved, enthusiastic researchers.

The proposed board should be convened immediately in order to develop the detailed program plan.

We highly recommend funding at the proposed level over the proposed time.

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