Perspectives Workshop: Science of Design – High-Impact Requirements for Software-Intensive Systems
Seminar Outline and Working Group Summaries

Matthias Jarke[1], Kalle Lyytinen[2], John Mylopoulos[3], Gerti Kappel[4], Julio Leite[5],
Gloria Mark[6], Bala Ramesh[7], Dominik Schmitz[1], Alistair G. Sutcliffe[8]

[1] RWTH Aachen & Fraunhofer FIT
[2] Case Western Reserve University, Cleveland
[3] University of Toronto
[4] TU Wien
[5] PUC-Rio de Janeiro
[6] University California
[7] Georgia State University
[8] University of Manchester

Abstract. This document gives a motivation for this perspective seminar within the Science of Design initiative, as well as an outline of the participants, agenda, sessions, and presentations. Furthermore, the outcomes of the five working group sessions are summarized: multiple concepts of design, evolution and management of requirements, stakeholder issues, intertwining requirements and design, and requirements, architecture and complexity.

1. Introduction

The NSF-funded Science of Design (SoD) Initiative in North America has tried to establish principles of a science of design between the traditional natural science and social science methodologies. This is highly relevant in a scientific climate whose publications tend to accept formal results or formally conducted empirical studies of existing systems much more easily than design- and innovation-oriented research. It is therefore necessary to define more clearly what is "good" design research and, in particular, to align better the research strategies and the current and future needs of practice.

Within the design science initiative, two workshops in the US and Europe discuss the relationship between the practice and the research in *requirements engineering* with the aim of identifying "high impact requirements" research, i.e. areas which have high importance and relevance in current and future practice but have received little research interest in the past. Another goal is to bring together representatives of the broad variety of fragmented disciplines in which requirements play an important role, but where little communication exists.

The starting point of the workshops was a large-scale empirical study (Hansen et al. 2008) in over thirty organizations concerning the present relationships between research and practice in RE. The results were in part quite encouraging: Many RE research results have found their way at least partially into practice:

- The study found a wide-spread use of semi-formal models. Validation strategies for them are common at least at some level, and formal methods have found their way to some critical areas. It must be noted, however, that methods are largely defined and promoted by the *tools* that support them rather than by underlying *theory*.
- The need for multiple requirements elicitation and discovery methods is recognized (known as viewpoint approach in the RE literature) and sometimes mandatory in companies.
- With the deplorable exception of some public prestige projects, risk-driven development strategies with strong emphasis on rapid prototyping and risk-driven scoping of project stages are increasingly becoming standard in large-scale development projects.

But while uptake of scientific RE results has been more successful than often perceived, the transfer of new practice problems to research has been less successful. While the above-mentioned three RE results were derived from problems of the 80's, many new challenges have arisen in the meantime for which relatively little RE research exists. Moreover, isolated ideas from different disciplines have not yet found their way into coherent theories. It is in these areas, where RE research with high impact could emerge in the next few years.

The first workshop was held in Cleveland, Ohio, June 3-6, 2007. It brought together about 30 representatives from research and industry covering the following disciplines: software and IS development, requirements management, business information systems, behavioural and management issues, design theories and practices. The following main themes and conclusions for further research have been identified: business process focus, integration focus, system transparency, structuring distributed and layered requirements, and fluidity of designs.

These issues have been used as anchors for the second workshop to be held in Europe, namely Dagstuhl. The idea was to deepen the discussion on some particularly important challenges in the above five areas, but also to include more strongly the perspectives of European companies and researchers, such as the stronger focus on enterprise software architectures and formal semantics of service-oriented business software architectures, but also inter-cultural management aspects ranging from eInclusion aspects to offshoring. Accordingly, the Dagstuhl workshop has interleaved a number of plenary keynotes and panel discussions from various disciplines with working groups dedicated to special topics including, but not limited to the ones mentioned above.

The Dagstuhl personnel, as always, is to be congratulated for a smooth and friendly operation of all the organizational details surrounding this highly interesting perspective seminar.

Major publications in the context of the two workshops include a book mostly by participants of the first workshop (Lyytinen et al. 2008), a manifesto from the second workshop (Jarke et al. 2009), and a planned Special Issue of the journal Business & Information Systems Engineering / Wirtschaftsinformatik to appear in early 2010.

2. Participants

Bannon, Liam	University of Limerick, Ireland
Brooks, Fred	University of North Carolina – Chapel Hill, USA
Damerow, Valentina	DFG Bonn, Germany
Glukhova, Anna	RWTH Aachen University, Germany
Hansen, Sean	Case Western Reserve University, Cleveland, USA
Jarke, Matthias	RWTH Aachen University & Fraunhofer FIT, Germany
Kappel, Gerti	TU Wien, Austria
Leite, Julio Cesar	PUC-Rio de Janeiro, Brazil
Liu, Lin	Tsinghua University Beijing, China
Lyytinen, Kalle	Case Western Reserve University, Cleveland, USA
Mark, Gloria	University of California, Irvine, US
Mylopoulos, John	University of Toronto, Canada & Trento University, Italy
Oberweis, Andreas	University of Karlsruhe, Germany
Paech, Barbara	University of Heidelberg, Germany
Pillay, Sasi Kumar	NASA Glenn Research Center, USA
Ramesh, Bala	Georgia State University, USA
Reymen, Isabelle	TU Eindhoven, Netherlands
Robinson, Bill	Georgia State University, USA
Rossi, Matti	Helsinki School of Economics, Finland
Rumpe, Bernhard	TU Braunschweig, Germany
Schmitz, Dominik	Fraunhofer FIT, Sankt Augustin, Germany
Sutcliffe, Alistair G.	Univ. of Manchester, UK

3. Agenda

Wednesday	Thursday	Friday	Saturday
	Position statements (cont.) Panel session "Case studies from industry"	Panel session "Requirements and future business architectures"	Conclusions from different perspectives Planning of follow-up activities
Introduction, Review 1st Workshop Position statements	Working groups on "multiple concepts of design", "evaluation and management of requirements", and "stakeholders and economics" Joined session for sharing	Working groups on "intertwining requirements and design" and "requirements, architecture, and complexity" Social Event Trier	

Table 1. Schedule

Table 1 gives an overview of the agenda. The first half-day concerned picking up from the previous workshop in Cleveland. Matthias Jarke and Kalle Lyytinen gave presentations on the results as well as some intermediate case studies, identifying emerging RE challenges:

Business process focus	Requirements focusing on the business process; requirements for technological artifacts driven by business processes.
Systems transparency	Requirements driven by demand for a seamless user experience across applications.
Integration focus	Requirements efforts focus on integrating existing applications rather than development of new ones
Distributed requirements	Requirements process distributed across organizations, geographically, and globally.
Layers of requirements	Requirements iteratively developed across multiple levels of abstraction, design focus, or timing.
Packaged software	Purchase of commercial off-the-shelf (COTS) software rather than development – trend toward vendor-led requirements.
Centrality of architecture	Architectural requirements take a central role, and drive product and application requirements.
Fluidity of designs	Requirements processes accommodating the continued evolution of the artifact after implementation.
Interdependent Complexity	While some forms of complexity have been reduced, overall complexity has risen significantly.

This review was complemented by position statements on the basic assumptions of the workshop from the viewpoints of different disciplines.

Liam Bannon reported on his understanding of requirements (or design, respectively) from his background on human computer interaction (HCI), focusing on the importance of "the edge", i.e. the blurring boundaries of systems and the vanishing distinction between users and developers.

Andreas Oberweis talked about process-aware business information systems and emphasized the need for a synchronization of business and software requirements and their life cycles, respectively.

Isabelle Reymen reported on organization science from her engineering background and especially brought the background of effectuation theory into the discussion.

On Thursday, the plenary continued with a talk by Turing Award winner Fred Brooks entitled "'A Science of Design' is a Misled and Misleading Goal" where he strongly criticized the traditional notions of design sciences such as the waterfall model, and advocated the shift towards more realistic models of development, e.g. the spiral model for software development.

Lin Liu reported on culture-specific aspects of requirements engineering, using the Chinese culture as an example based on a broad field survey there.

In the panel session on "Case Studies from Industry", Sasi Pillay, CIO of NASA, talked about collaborative development methodologies and the importance and limitations of RE in such a context. Barbara Paech discussed quality aspects that arose in joined work with Siemens, Daimler, and SAP, as well as the emerging trend of blurred boundary between development time and run time. Sean Hansen presented two case studies highlighting challenges identified in their earlier field survey. The first one concerned an enterprise system in higher education while the second focused information sharing in law enforcement within Summit County in Connecticut.

Afterwards the participants split up into three separate working groups concerning *multiple concepts of design* (chaired by Gloria Mark), *evolution and management of requirements* (chaired by Bala Ramesh), as well as *stakeholder issues and economics of requirements* (chaired by Matthias Jarke). Details on these sessions are given below. A joined session in the evening provided summaries of the sessions as well as another discussion led by Fred Brooks on the distinction between requirements and design.

On Friday morning the seminar continued with a plenary session on "Requirements and future business architectures", chaired by Bill Robinson. Bernhard Rumpe presented his view on the impact of modeling on a science of design and especially emphasizes the decomposition problem as well as the need for simulation. John Mylopoulos talked about understanding a requirements model as a problem space and thus how to represent, identify, and support the customer's preferences in order to single out a solution. Afterwards, Matti Rossi presented is thoughts on the impact of new technologies such as clouds, stream processing, the service paradigm, and Web 2.0 enterprise applications. There was heavy debate on the role and relevance of modeling and model-driven approaches in complex, heavily context-dependent and rapidly evolving information systems of the kind identified in the workshop.

Afterwards the group split up again into two group sessions one on *intertwining requirements and design* (chaired by Gerti Kappel) and a joined session on *requirements and architecture* as well as *complexity* (chaired by Julio Leite and Alistair G. Sutcliffe). Another plenary session allowed again the sharing of the findings within a broader audience. The rest of the afternoon was devoted to a trip to Trier with an in-depth analysis of several aspects of historical and cultural context, including a vineyard.

On Saturday morning, two presentations by Gloria Mark and Alistair Sutcliffe summarized some of the seminar findings, e.g. by defining requirements engineering domain dimensions and by an even deeper interaction with the social sciences and with other, non software-related design sciences. In the following debate, several participants expressed their views on what were some of the most important results and challenges emerging from the workshop. Themes such as the "importance of the edge", the apparent paradigm shift from 20 years of process organizations towards the new model capability-based network organizations and platforms, and speculations about the real impact of service orientation and requirements models were among those most mentioned in this final debate.

Initial ideas for a follow-up workshop in Bejing in 2010 focusing more on the cross-cultural aspects were explored. The rest of the day was spent with working on the draft of a manifesto.

4. Working Group Session Summaries

4.1. Working Group Session "Multiple Concepts of Design"

Chair: Gloria Mark
Participants: Liam Bannon, Valentina Damerow, Sean Hansen, Gerti Kappel, Gloria Mark, Isabelle Reymen, Matti Rossi, Bernhard Rumpe

The session started with a presentation by Gloria Mark: "Emerging Forms of Distributed Collaboration: Designing for Who?"

We don't have one simple type of collaboration. Rather, collaboration takes multiple different forms (e.g. architecture of participation, "trivial" interaction, gaming and play; designing for teams vs. designing for network). The following items were elaborated:

- *Social worlds:* units of collective action, articulated by Strauss (1978). They offer a way to define *the boundaries of work practice.*
- *Design ecologies:* Political ecologies concern institutional structures and rules that principles draw on to determine sources and bases of power. Furthermore functional ecologies exist (Bergman et al., 2008).
- *A New Interaction Order:* People are participating in a multiplicity of social worlds, but this diversity must be managed and this leads to tensions. This issues concerns competing political and functional ecologies [Two examples from NASA]. A discussion of some challenges for distributed design followed; e.g., cyberinfrastructure vision (global sharing of data; does it occur? Not really)
- *Articulation:* is defined by "all the tasks needed to coordinate a particular task, including scheduling subtasks, recovering from errors, and assembling resources". In distributed collaboration, individuals and groups need to make their assumptions explicit. In practice we see significant *surface* articulation, but very little *deeper* articulation. We need to find ways of recontextualizing methods and terms across distance. Information bridges (i.e. facilitators) drive articulation, but articulation really should emerge from all participants
- *Information Integration:* "Sidebars" are sub-group discussions both intra- and inter-site and are the "heart" of design work; especially they are critical for resolving design issues. Distributed teams are moving toward collocated groups in terms of the sidebar participation patterns (e.g., network betweenness centrality).
- *Design Boundary Objects*: A boundary object is an artifact that is shared between two or more actors at the border of two social worlds. It can overcome gaps in design knowledge (functional ecology) and agreements (political ecology).

In the group discussion afterwards, the following questions were discussed:

What do we mean by "multiple concepts of design"? Multiple design domains being leveraged in a single broader effort; multiple concepts about what design is; multiple conceptions of design processes.

What is the difference between requirements and design? Proposals have been that requirements are a subset or facet of design, that requirements are the "vision generating" element of design, or that requirements are the pursuit of flexibility – the effort to ensure that one design does not preclude later development or modification. At the plenary discussion the following answers were given. The answer of the RE community is that requirements are the process of moving from vision to specification; design then is the movement from specification to creation of an artifact. Requirements reflects a more Lamarckian perspective on evolution.

Modularity of requirements. Have we given up on the pursuit of reusability and modularization of requirements? Perhaps the modularization has shifted to a different level of analysis. At NASA, they try to learn from previous project, but frequently the technology has changed so much that it is difficult to reuse. If we could modularize effectively, systems would remain essentially complex, but the projects would become smaller and smaller. If design processes could be perfectly modularized, then the multiple concepts of design would be resolved; but there are often different cultures that emerge around the use of the same tools.

Learning from Other Design Domains. There is a big *Design* literature out there. Do requirements researchers participate in that community? If not, do we care to learn from that literature? What are some fundamental design insights that could enhance or direct requirements research in the years ahead? In particular, what are some design environments that might have insights for the participants of this seminar: architecture, automotive design, software design, aerospace design, device design, graphical design, and instructional design. Good examples of cross-disciplinary learning are given by Alexander (1977, 1979).

4.2. Working Group Session "Evolution and Management of Requirements"

Chair: Balasubramaniam Ramesh
Participants: Frederick P. Brooks, Anna Glukhova, John Mylopoulos, Balasubramaniam Ramesh, William Robinson, Alistair G. Sutcliffe

The working group summarized their findings in a list of Ph.D. topics that should be worked on:
- Management of models
- Impact RE
- Understanding requirements evolution in different domains
- Traceable Requirements Engineering for Communities of Practice
- Monitoring for diagnosis
- Decision support for requirements
- Cultural support of requirements evolution

4.3.   Working Group Session "Stakeholder Issues"

Chair: Matthias Jarke
Participants: Matthias Jarke, Julio Leite, Lin Liu, Kalle Lyytinen, Andreas
                  Oberweis, Sasi Pillay, Barbara Paech, Dominik Schmitz

The working group merged two originally planned themes on "stakeholders" and "money and time: economics of requirements" but also expanded to the topics of "business processes" and "service orientation".

Kalle Lyytinen reported on a talk by John Henderson that challenged value-based modeling and then discussed innovativeness, aesthetics, and ethics in the context of requirements engineering.

Afterwards, Julio Leite presented the notion of "software transparency", mainly hinting on the need to make software better understandable for people so that they can trace what is happening with the information they provide.

Another discussion emerged around the question whether the view of management on requirements engineering has changed. The need for pilots for any larger software project was agreed upon. The earlier argument that an extensive requirements investigation is needed to avoid expensive errors is less strong nowadays since most software is written. Instead the focus now should be on better functionality and meeting customer expectations. In the end four themes were touched and some initial ideas elaborated:

1. changed **stakeholder** roles and demands
2. changed **management arguments** for RE (cost-benefit trade-offs)
3. changed meaning of **business (process) focus**
4. impacts of service orientation

How do the stakeholders in RE efforts interact today, and what strategic changes can be observed there? A move from "user" to "citizen" was identified with the resulting need for **transparency** of systems. Systems should inform what they do, attach requirements-level information to running system (extended traceability need). Furthermore, process automation may make business rules less transparent. In addition, one should consider (but didn't) the new kinds of End User Developers etc. Liam Bannon was mentioning in his position statement.

What are the impacts of changing contexts on the cost-benefit trade-offs in RE? Has the view of management on RE changed? How should it change, and what can we do about it? It was argued that rigorous Return-on-Investment (ROI) for large enterprise systems (validate by reasonable pilots, also for scalability) is important. The time horizons for ROI have reduced to 18-20 months (also because this has become feasible by massive reuse: COTS, reference models – via knowledge brokers). Furthermore, outsourcing/offshoring requires more explicit specifications as a basis for delegation (pilot cases even more needed in this case, due to cultural differences); RE and development cannot be fully separated. Protection against being sued has also been identified as an argument for RE (waste company vs. SAP case). Other arguments for RE concerned flexibility, business process, manage customer

expectation, create user buy-in, training costs, and finally understanding vendor's own capabilities – the RE process must be aligned with the reasons why you are doing it!

How do business process management and information systems management interact? What do we mean precisely by "business process focus"?   Move from process organizations to capability-based network/edge organizations (John Henderson critique of value-based modelling), accordingly from gap analysis to appreciative enquiry. Also the inclusion of "industrial design" goals such as innovativeness, ethics, aesthetics (user experience to the fore!) should be considered. Traditional "soft goals" are more related to software. Innovativeness in this regard is complementary to quality/time/cost; different uncertainty, cascading effects. But the implications for RE / SE process are not yet clear.

What are the implications of service orientation? It has been emphasized that RE must be carried out from the viewpoints of service provider, service client, and service broker. Especially this helps negotiate service level agreements (SLAs). Furthermore, we don't really know how to refine/decompose the requirements for a service-oriented solution to a (business) service problem, especially conflicts of non-functional requirements. Domain-specific XML standards are under development, but RE-level is still missing. How about architectural standards? It was also discussed under what circumstances ontologies will be useful tools as opposed to stifling innovation? And what are good properties of reference models, where are their limitations? Further input maybe be expected from the Architecture session?

4.4.   Working Group Session "Intertwining Requirements and Design"

Chair: Gerti Kappel
Participants: Liam Bannon, Fred Brooks, Anna Glukhova, Gerti Kappel, Gloria Mark, John Mylopoulos, Andreas Oberweis, Balasubramaniam Ramesh, Isabelle Reymen, Bill Robinson, Matti Rossi

Anna Glukhova started with a presentation on "Requirements Engineering for Social Software". Building also on input from other group members, several challenges concerning intertwining requirements and design were then discussed:

- *Social Software for Requirements Elicitation*   It should be further investigated if using social software and thus integrating the end user even more in the requirements elicitation process decreases the amount of necessary changes later on.
- *Community as Contextual Information*   The knowledge of the participating people should be taken into account in a more structured and formal way. For example, the work on "Community of Practice (CoP)" should be investigated in more detail. A related project in this area is CONTici (Context Adaptive Interaction in Cooperative Knowledge Processes, http://dbis.rwth-aachen.de/lehrstuhl/projects/contici/index.html).
- *Intertwining R&D might lead to Lazy Treatment of Requirements*   Since the possibility of handing in requirements late might lead to a certain laziness it is very important to have a very structured requirements elicitation process to stress its importance even more.

- *Intertwining R&D versus Contracting*   Intertwining R&D must lead to a rethinking of when and how to contract. Contract once versus contracting bit by bit are two options with various options in between. In this realm, the role of trust has to be investigated in more detail.
- *Learn from Architecture and Civil Engineering*   In architecture and civil engineering design competitions are a common practice to find out the best design. The best design or even a mixture of best designs is further developed. "Design first, contract afterwards" is another common practice in these areas (relates to contracting above).
- *Development of innovative products*   Innovative products have no or very few requirements beforehand. This is in contrast to incremental products. Intertwining R&D influences also innovation management, i.e., the process and supportive actions which should lead to innovative products.
- *Requirements and SW-architecture*   One challenging question is which kind of requirement tackles the SW-architecture. Is it possible to identify clusters of requirements and how they influence the SW-architecture? Related questions are "how do requirements and SW-architectures map to each other?" and "what are the dependencies between requirements and SW-architectures?".
- *Requirements birth control versus Requirements production* Certain requirements come late and might change the whole design (see also SW-architecture above). In this realm, one big question arises, namely, when does a new requirement or the change of an already stated requirement lead to a new system? Or to put it in other words, which requirement may not be intertwined with design easily but leads to a new design?

4.5.   Working Group Session "Requirements, Architecture, and Complexity"

Chair: Julio Cesar Leite, Alistair G. Sutcliffe
Participants: Matthias Jarke, Julio Cesar Leite, Lin Liu, Kalle Lyytinen, Andreas Oberweis, Sasi Kumar Pillay, Berhard Rumpe, Dominik Schmitz, Alistair G. Sutcliffe

Prior to the group meeting, each participant was asked to provide four major themes for discussion by the group. Five participants gave their list. Out of the 20 themes provided, the chair amalgamated the matching themes: four clusters where produced. Each cluster has a number of matches associated with it, which identifies the number of different respondents who listed any of the descriptors of the given cluster. The resulting list is as follows:
- Architecture Control/Stability/Modularity (**3**)
- Architectural Sytles/ Organization Principles (**2**)
- Validation/Prototyping (**2**)
- Consistency/Change Control/Sustainable/Granularity (**2**)

Three different presentations sparked the discussions. Inspired by Thomas Friedman's book "The World is Flat", Matthias Jarke talked about the importance of

considering software platform strategies for requirements engineering. The talk stressed the difference of these platforms from the product line approach, and cited the case of XML as a platform of wide acceptance by business organizations.

Alistair Sutcliffe stressed the importance of ecology in a broad sense encompassing the immediate environment, the wide environment, and the kinds of interaction that will happen in these contexts, including robots, or artificial agents.

Dominik Schmitz talked about the role of requirements engineering in embedded systems, stressing the importance of non-functional requirements. In this kind of environment, simulation is a driver force.

The group then discussed the concerns considered most relevant for further investigation. Contrary to the old understanding of requirements prior to architectures, the discussions showed the evident weaving of architecture and requirements. We aimed to better understand the challenges that lay ahead in the intertwined issues among requirements and architectures.

The topics that emerged from the discussion were the following ones:

- Complexity (New frontiers)
  - Very hard problem (layers of complexity)
  - Requirements from several levels (trade offs, granularity)
  - New types of interaction (robots)
- Platform Strategies (vs the usual Product Line)
  - Architectural Styles (different levels, different contexts)
  - Architectural Control (too open versus too strict)
  - Vertical versus Horizontal Integration
- Simulation at Different Stages (embedded systems)
  - Change Management
  - Non-Functional Requirements
  - Scalability

The topics above reflect, to some extent, the four clusters identified before the discussion, which helps to support the above list. We concluded that more research is needed for these topics, stressing that they should be made from the perspective of requirements engineering, as to better focus on the interplay of requirements and design.

References

Alexander, C., Ishikawa, S., and Silverstein, M. (1977), *A Pattern Language*. New York, NY: Oxford University Press.

Alexander. C. (1979). *The Timeless Way of Building*. New York, NY: Oxford University Press.

Bergman, M., Lyytinen, K., & Mark, G. (2008). Boundary Objects in Design: An Ecological View of Design Artifacts. *Journal of the AIS*, 8(11): 546-468, 2008.

Hansen, S., Berente, N., Lyytinen, K.J. (2008). "Requirements in the 21st Century: Current Practice & Emerging Trends". In: Lyytinen, K.J., Loucopoulos, P., Mylopoulos, J., Robinson, W. (eds.): *Design Requirements Engineering: A Ten-Year Perspective*. Springer LNBIP 14, pp. 44.87.

Hutchins, E. (1995). *Cognition in the Wild*. Cambridge, MA: MIT Press.

Jarke, M., Loucopoulos, P., Mylopoulos, J., Robinson, W.R. (2009). High-impact requirements for software-intensive systems: a manifesto. *Proc. Dagstuhl Perspective Seminar 08412* (revised version submitted for journal publication).

Lyytinen, K., Loucopoulos, P., Mylopoulos, J., Robinson, W.R., eds. (2008). *Design Requirements Engineering: a Ten-Year Perspective*. Springer LNBIP 14.

Norman, D. (1994). *Things That Make Us Smart: Defending Human Attributes in the Age of the Machine*. Cambridge, MA: Perseus Books.

Salomon, G. (1993). *Distributed Cognitions: Psychological and Educational Considerations*. Cambridge University Press.