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Strategies for Research about Design: a multidisciplinary graduate curriculum

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Abstract

We are developing a graduate curriculum and summer school on design research intended to prepare graduate students to do research about the *nature of design* or research about a *class of designs*, including concepts, models, and methods for that class. We expect our summer school to advance the science of design of software-intensive systems by fostering an open community of design researchers, both in software design and in related disciplines, who are knowledgeable about design and design research methods and who are interested in advancing the field. The curriculum will create a common basis for discussion and identify core material to master, while the flexible format of the workshop will encourage the introduction of new ideas and new methods.

The goals of our course and summer school are to (1) develop an open community of graduate students, faculty, and industry researchers who are actively engaged in the advancement of software design research and (2) to associate this community with the larger community of researchers from related areas of design research who can contribute to the software design community and who can take ideas from software design back to their own research communities. We will offer a week-long summer school in May-June 2007, in which PhD students, who are just beginning to develop their research proposals, will have the opportunity to work closely with faculty and researchers who are on the forefront of software design research and related design fields.

Introduction

In 2003 the U.S. National Science Foundation held a workshop on the Science of Design. The Preliminary Report from the workshop says: "…workshop participants agreed … that we don't teach software and software-intensive system design well. The most significant problem is that we still don't understand the field well enough" (Sullivan 2003). The state of education for software design research methods is equally dismal. The report concludes (slightly rearranged): "The issue: *Can there be a science of design for software and software intensive systems, and, if so, what should it be?"* was resolved by tacit agreement that *science of design* could be interpreted to mean an organized body of rigorous knowledge about how to make things (software and software-intensive systems)."

To address these concerns we are developing a curriculum in design research methods to be offered initially as a summer school program in 2007. The summer school will recruit 2nd and 3rd year graduate students from computer science, engineering, architecture and interaction design who are planning design-related PhD theses. These students struggle with questions such as: What is a good research topic? How can I write a research plan when I don't have any answers yet? How will I evaluate my results? Everyone on my committee has a different idea of

what a thesis is – How can I write just one thesis that satisfies them all? Research methods classes are notoriously difficult to teach, but students who are struggling to write their thesis proposals are the most receptive audience, and this is the stage with the most leverage to influence the methods used in their research.

We draw on Shaw's experience with a course on software engineering research paradigms. Although that course does not specifically address *design* research, we have found most students are not aware of differences among research paradigms; and they must be guided to look for the *research argument* of a paper instead of simply reading for the result.

Our summer school curriculum will include an overview of design and design research issues, a discussion of research paradigms, suggestions for projects and exercises, and an annotated bibliography of resources that cover the disciplines represented by the students. Summer workshop participants will:

- read classic design literature;
- study design research paradigms in software and other disciplines;
- engage in discussions with researchers and designers from other fields such as engineering design, industrial design, architecture, and cognitive science; and
- propose, discuss, argue and develop their ideas with fellow students and with faculty.

We plan thereby to create a curriculum and related materials that have been hardened and tested so they can be widely disseminated in differing formats depending on local needs. Our Wiki on the Science of Design (http://science-of-design.org) is a vehicle for our curriculum planning and may form the basis for a larger on-line community. Our workshop plan has grown out of discussions in an existing interdisciplinary group at Carnegie Mellon who meet to talk about design research and design education; here we found that cross-fertilization of ideas across design fields is essential to advancing design research. Our group discussions have been enjoyable and intellectually stimulating and we hope to make this enthusiasm for design research an essential part of the environment of the workshop.

Frameworks for studying design

Initial course planning generated a list of topics, including:

- Why should we understand design processes (the argument for "research in design")?
- Design spaces: optimizing an objective function in a multi-dimensional constrained space.
- Coupling, clustering, and dependency: Identifying relationships between design decisions
- Organizing for design: Control hierarchies: design as a social negotiated act over time.
- Design for change: How to design for evolutionary lifecycle change?
- Pattern Language: structuring observed relationships into representation for future design.
- Involving end-users and other stakeholders in a participatory design process.
- End-user designing: role of end-users in innovation, how and when to support user innovation.
- Problem-seeking; "system-analysis"; from needs into requirements and specifications.

- Documenting; design rationale; representations of alternatives; communicating designs for implementers.
- Representations: for exploring and comparing alternatives, consequences of representations.
- Innovative vs routine (precedented vs unprecedented) designs.

We are refining this topic list to a pair of frameworks for studying design; both are works in progress. One, presented here, considers the tangible domains associated with designs in the style of problem frame analysis (Jackson 2000). The other focuses on the activities associated with creating designs. The domains associated with design include bodies of information and communities of people. Their relations are suggested in Figure 1.

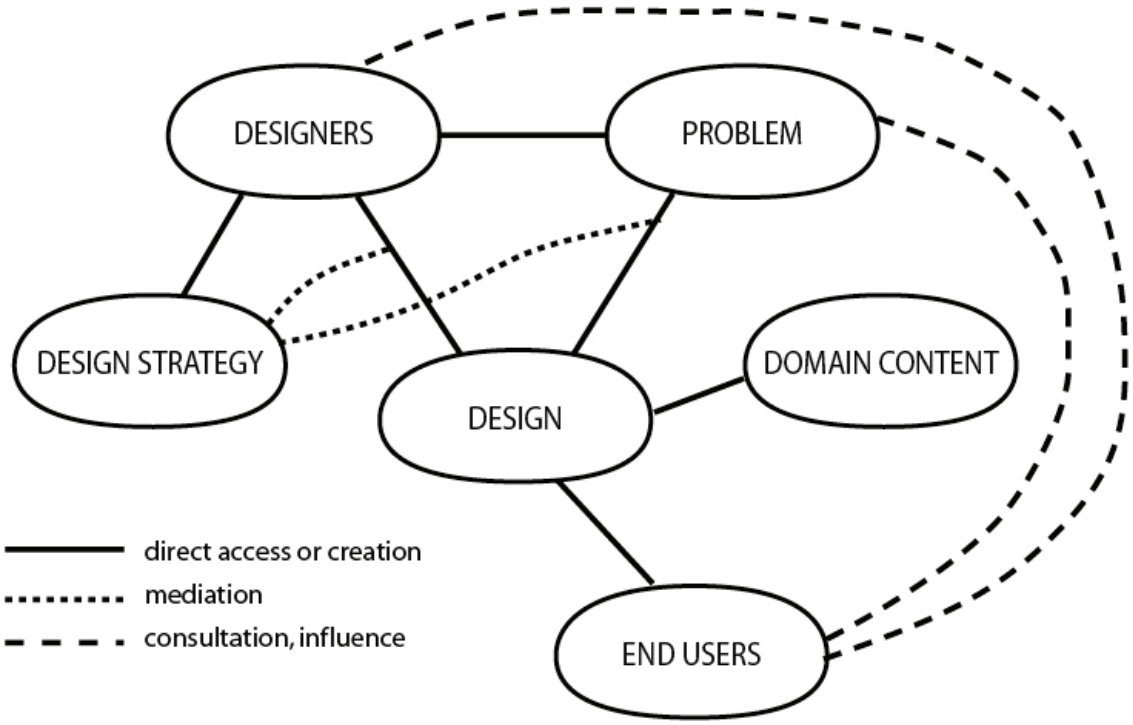

Figure 1: Our working model of problem frames in design.

The *design* is central in our model. It has a structure (its position in a design space, its hierarchy, its coupling, and its rationale), a representation, and variability (evolution through time plus co-existing alternatives) It is directly related in some way to each of the other domains.

The *problem* represents the design problem to be solved. It has a context and a structure (which often differs from the structure of the design). It is shaped by end users but we treat it as a separate domain. The *problem* connects to (is solved by) the *design*, and this connection is mediated by *design strategy*.

Designers are the people who create designs. This domain includes their social interactions and ways they learn from one other. The connection of *designers* to the *design* is mediated by *design strategies*. *Design strategy* is knowledge about how designers go about doing

design. Designers consult it, and it thereby mediates activities of *designers* as they produce *designs*, and it shapes how *problems* map into *designs*.

Domain content includes domain knowledge as well as underlying reality that may be implicit but nevertheless constrains which designs can be realized (like physics, but more broadly). Content of multiple *domains* is usually brought to bear on a design. *Domain content* is connected to the *design* as it constrains the space of feasible designs.

End Users are the people who will ultimately use the realization of the design (not just the next customer down the line in the hierarchy or value chain). They may participate in the design and they may extend designs, but in general they do not function as professional designers. *End users* are connected to the *design* as the recipient of the realization, and also through end user participation. Further, they are connected to the *problem* as the recipient of the realization.

Crossing our topics (above) with these frames yields some interesting observations. For example, the idea of design spaces probably belongs to *design strategy*, the specific design space for a given problem to the *domain content*, and the *design* is a point in a domain-specific design space -- or many points if we consider variability, or in many design spaces if we consider sets of goals from multiple domains. Similarly, the set of useful design representations are probably in *design strategy*, while the *design* itself is described in one or more of these representations.

Plan for the summer school

The first Design Research Summer School will be held at Carnegie Mellon in May-June 2007 (http://science-of-design.org/drss07). The curriculum for the summer school has been developed over the past semester in a graduate special topics course on design research strategies. Our goal for students in the summer school is two-fold: 1) to help them refine and hone their thesis topics through a deeper understanding of design research strategies and 2) to develop their ability to

Table 1 Research Argument Template

Short version:

- What question does the paper address?
- What do the authors do to answer the question?
- Does what the authors do address the question and support the conclusion?

Long version:

- What question does the paper address?
  - What *type* of question is it?
- What assumptions do the authors make in order to be able to answer the question?
- What approach do the authors take to answer the question?
  - What is the *type* of approach?
- What evidence is presented?
  - What is the *type* of evidence presented?
- What is the result reported in the paper?
  - What is the *type* of result?
- Does the conclusion follow from the evidence?
- Does the conclusion apply to the original question (or a subpart of the original

articulate and evaluate research strategies used in design research. We have developed a Research Argument Template (Table 1) that will be used to organize the discussions and presentations during the summer school. As the students will use the Research Argument Template throughout the summer school, we plan to use it to evaluate their ability to read a paper critically e.g., to identify the type of research strategy or to separate the evidence from the conclusion. This in turn will be used as an evaluation criterion of the success of the summer school.

A few weeks before the summer school, students will receive a packet containing the book *The Sciences of the Artificial* (Simon 1969) plus the papers "Design Science In Information Systems Research" (Hevner et al. 2004), "Writing Good Software Engineering Research Papers" (Shaw 2003), and "A preliminary analysis of the products of HCI research, using pro forma abstracts" (Newman 1984). The students will receive an additional set of four design research papers in the domain of building design. We will ask the students to complete the short version of the Research Argument Template (Table 1) for three of the four papers they receive. As an example of the desired result, we will provide a fifth paper for which we have completed the Research Argument Template. We are using the design of buildings as the example domain for discussing research strategies because it is a domain with which most people have a basic familiarity and in which none of our students are doing research. This will enable us to talk about design research strategies without spending time explaining the domain and without becoming bogged down in the particular details of a research field.

Table 2 gives the plan for the summer school program. The curriculum is designed to maximize the interactions among the faculty and the students. The curriculum is a balance between developing general knowledge about design research and providing particular feedback on the student's research question.

Conclusion

The design research curriculum is designed to give students the intellectual underpinnings they need to do thesis work that will expand the body of rigorous knowledge about the design of things, and in particular, the design of software-intensive systems. In the summer workshop, students will develop a deeper understanding of how their research is informed by the state of the art in software design research and by design research in other disciplines. Including other design disciplines is important for several reasons. One is that other disciplines inevitably come into any real-world software system design. Another is that research approaches in other fields may be applicable to research questions in software design, much as the use of Pattern Language in software design borrows from prior research in (building) architecture.

Acknowledgements

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Table 2: Summer school plan

Tuesday	Wednesday	Thursday	Friday
- Introductions - Scope and goals of summer school - Design ice breakers	- Design research strategies: Students present results of their research argument analysis	- Small group discussions with faculty on thesis topics; feedback on presentation drafts	- Student presentations and discussion
Break			
- Short student presentations on research topics	- Design research strategies: continued	- Small group discussions with faculty: students and faculty shuffled from earlier groups	- Student presentations and discussion
Lunch			
Talks by the faculty: - What is the field of design research? - Design research strategies - Design research papers	- Faculty design research presentations: faculty present their own work using the research argument template	- Outside speaker: discussion of design research in another field	- Student presentations and discussion
Break			
- How to read a design research paper: Research Argument Template (Table 1)	- Faculty design research presentations: continued	- Fun, hands-on design learning activity	- Wrap up discussion - Summer school feedback and evaluation
Dinner			
Assignment: - Complete long Research Argument Template for three design research papers on building design	Assignment: - Prepare first draft of research topic presentation	Assignment: - Prepare final research topic presentation - Prepare final research argument templates	