Abstract

We characterize Design Thinking as a major form of Collective Work, in which the pursuit of multiple objectives of team members can be tracked and semantically related by a supporting computer system. This has the advantages of not only providing pro-active coordination of the design team, but also of capturing the design process, which will enable post-analysis of Design Thinking in ways not previously possible.

The approach is to use Logical Spreadsheets modified to perform functions of a previously-developed tool, Redux', in conjunction with a large vocabulary of design terms derived from existing Computer-Aided Design tools and previous research performed by the CDR. This new CAD tool will be used by a design team member trained to perform process documentation. Not only the tracking and analysis of design decisions are research issues in this project: we also investigate new modes of design capture with modern PDA-like devices and Web2.0 tools, ideally based upon the new Apple iPhone.
Design Thinking as Collective Work

1 Introduction

Creative Design Thinking in groups developing novel solutions has been well-characterized in terms of process and methodologies that produce end designs that are judged to be successful. Such teams, especially when distributed, are also well-supported by computer tools that facilitate the sharing of information when initiated by a human.

However, these teams have no support for the coordination of their actual design activities. We propose a computer support of Design Thinking teams that will facilitate their coordination by actively searching for semantic links among design decisions, using modern web and communication technologies.

This research project will develop design coordination tools based upon existing technologies from previous projects, augmented with modern communication devices, such as the Apple iPhone. We will more allow individual design decisions to be be captured, as they emerge, which will not only aid the designers, but also allow the design activity to be analyzed, post-design.

2 Problems to be Addressed:

- Lack of support for Design Thinking may cause thrashing at design time.
- Lack of support for Design Thinking means lack of post-design-time analysis.

One hypothesis is that because such support is lacking, the individual design decisions interact so as to cause unnecessary conflicts and even thrashing, that delays prototyping. We may not be able to detect this quickly enough at design-time to help in a particular project, but this is the kind of analysis we would like to be able to at least detect and analyze for future projects. In addition, we would like to be able to measure:

- how many design options were attempted per design decision,
- how many sub-goals resulted from a decision, and
- capture the rationale for each decision so as to identify cases of thrashing.

We propose to perform such capture and analysis, as well as some design-time notification with the combination of a formal model and a dedicated human as interface to the model.

3 Collective Work and Design Thinking

In Collective Work[Petrie’08], multiple designers pursue different but related objectives, and are supported in their work by an underlying computer platform that observes the design decisions, finds connections among them, and appropriately notifies the affected designers of the joint decision effects.

Typically, possibly distributed engineers may work together on a single project, divided into components and special engineering disciplines, such as mechanical, thermal, electrical, and chemical, as illustrated in Figure 1.
It has been previously demonstrated that even in some simple tasks, two designers can lose track of the interactions of design decisions [Pareto’95]. Active computer support of designers is even more important when they are in distributed teams and may not be communicating often. Figure 2 illustrates a similar case in designing a bicycle, as might be done by a student team.

One specific model for supporting distributed designers is Redux’[Petrie’93]. The Redux model to be used is not a constraint propagation model. Indeed, constraint violation detection is just one kind of dependency used in this model. And constraint propagation is suitable only for the simplest type of design in which all of the possible variables and constraints can be enumerated prior to design.

Perhaps more important, Redux allows the creation of new design goals and ways of achieving them, as well as new constraints, at any time during the design process, and thus is more appropriate for the documentation of creative design than would be simpler formal systems such as constraint satisfaction algorithms.

However, there are some known issues with Redux based upon previous experience, so we will identify possible changes in the Redux model that may make it more suitable for Design Thinking capture and analysis, including development of the HI, adding some semantic filters, developing additional analysis tools, and developing a “look-ahead” capability. A major problem has been the complexity of the model. In addition, all approaches to providing real design coordination have the problem of providing semantics for a specific design.

4 Approach 1: Student Design Amanuensis

Previous uses of Redux involved capture of design decisions from software[Pareto’95]. However, especially in student design, sophisticated computer-aided design tools are rarely used. Instead, the approach this time will be to add one process documentation student to each team location to perform the job of process capture with the Redux model. This approach was tried in a modest fashion with the MADEFAST[Madefast’96] project and showed promise, but experience shows that dedicated team member is required to be present at all all team discussions, trained in both design and in use of the Redux model. Each such student will be called a Design Amanuensis.

We propose to identify and train students within the Design Division, who are already being trained in Design Thinking, also on the computer science aspects required to perform the experiment. (The filtering issue is further addressed by having the documentation students be the interface to the project designers.) These students, allocated
one to a design project team, will themselves be a Design Capture Design Team.

We propose to add these students to teams working on projects within ME310\(^1\). A key research element of this experiment will be to identify the most general common semantics that will be useful in documenting the design process in a computer-readable form. The students will also be trained in basic semantics and the faculty and academic staff will help them in this regard. This experiment will be particularly valuable when the students are located in different places so that the documenting students must agree upon the design terms used in the design decisions, rationales, assumptions, and constraints sufficient to derive value from the documentation.

5 Approach 2: Design Capture with Previous Technologies

The students we identify must have good tools for capturing design decisions. Though we will investigate use of Redux directly, we know that this is difficult. So, we will investigate how the existing Logical Spreadsheet[PrediCalc] tools, developed in the CS Logic Group, can be modified to provide most of the Redux capability. This technology is already in use in the Stanford Computer Science Department. Versions of it are also in use in the SAP-sponsored POEM project\(^2\). One example of such a modification is to add a “goal” object to these tools.

While Redux allows free form strings, one element of a good design tool is a good vocabulary of design terms, because this tactic will reduce the cognitive burden of the Design Amanuensis, as well as reduce mistakes. We will begin with a vocabulary that we we build up from existing Computer-Aided Design tools as well as previous research by the CDR. We will also perform other experiments to derive such terms that will provide design semantics.

\(^1\)http://engineering310.stanford.edu/07-08/index.php

\(^2\)http://logic.stanford.edu/poem
One experiment will be to use simple tags (as in many Web 2.0 sites) and have the students propose multiple tags for each design object, and see what matches, how much work matching takes, and whether methods can be developed to facilitate such matching.

6 Approach 3: Design Capture with New Technologies

We will investigate specifically how new Internet and cellular-based devices can be used to capture design elements during the time of their creation. Additionally, how Web2.0 tools can be used to document the information captured, in a way that would permit Redux, and perhaps other analysis tools, to be used.

In particular, we will use the new communication tools now on the market, such as the Apple iPhone. Since this device is a full unix-style operating system, it can already run the existing Logical Spreadsheet tools. Together with other new applications being developed for this device, we will explore an exciting new space of design capture capabilities.

Finally, the designs captured need not be mechanical designs, but ultimately may be software designs, perhaps composed of web services, which increases some of the difficulty, but which also builds upon the concept of the semantic web and semantic web services. However, our objective in this experiment will be to use the simplest technologies possible that makes the design documentation useful.

7 Use of ME310 as a Design Research Testbed

We propose that the students assigned to capture the process with the design teams have as a design project, the development of tools for the capture and documentation of design decisions, using the latest devices, software tools, and semantic web technologies. This will be a strong component of the research. Thus The Design Capture Design Team will not only operate to capture design, but also work on all of the development to improve the design capture interface and analysis.

The actual working process will need to be decided and require close supervision by both the design and computer science faculty and academic staff to adjust both the software, the human performance, and the methodology in order to optimize the value of the process capture. This project has the potential for important developments both in the computer science used for the formal documentation, and for analysis and support of the design process, especially for distributed teams.

The fundamental measure of success of this project will be whether we can detect examples of thrashing in student design projects and show that we can eliminate them by use of the tools. This success will in turn depend upon our success in developing tools that the students can and will actually use to document their design projects.

4 http://en.wikipedia.org/wiki/SemanticWebServices
8 References:


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FORMAL EDUCATION

Sc.B., Physics, M.I.T., Cambridge, MA
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BIOGRAPHICAL SKETCH

Michael Genesereth is an associate professor in the Computer Science Department at Stanford University. He received his Sc.B. in Physics from M.I.T. and his Ph.D. in Applied Mathematics from Harvard University. Genesereth is most known for his work on Computational Logic and applications of that work in Enterprise Management and Electronic Commerce. He is one of the founders of Teknowledge, the premier company commercializing Artificial Intelligence; he is a co-founder of CommerceNet, the premier organization for electronic commerce on the Internet; and he is a founder of Mergent Systems, an early vendor of technology for integrated catalogs on the World-Wide Web. (Mergent was sold to Commerce One in 2000, which in turn was sold to Perfect Commerce in 2006.) Genesereth is the current director of the Logic Group at Stanford and research director of CodeX (the Stanford Center for Computers and Law).

PUBLICATIONS RELEVANT TO THIS PROGRAM


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FORMAL EDUCATION

1978 B.S.M.E., University of Rochester, Rochester, NY  
1982 M.S.M.E., Carnegie Mellon University, Pittsburgh, PA  
1985 Ph.D., Mechanical Engineering, Carnegie Mellon University

BIOGRAPHICAL SKETCH

Mark Cutkosky joined Stanford in 1985, after working in the Robotics Institute at Carnegie Mellon University and as a machine design engineer at ALCOA, in Pittsburgh, Pennsylvania. His research activities include computational support for robot design, tactile sensing and the design and fabrication of biologically inspired robots. He has graduated 30 Ph.D. students and published extensively in these areas. He has consulted with various companies on robotics and human/computer interaction devices and holds several patents on related technologies. His work has been featured in Discover Magazine, The New York Times, National Geographic, Time Magazine and other publications and has appeared on the CBS Evening News, Next@CNN, ABC news and other popular media. Cutkosky’s awards include a Fulbright Faculty Chair, a Charles M. Pigott Professorship at Stanford and an NSF Presidential Young Investigator award.

PUBLICATIONS RELEVANT TO THIS PROGRAM


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FORMAL EDUCATION
1969, B.S., Mathematics, Louisiana State University, Baton Rouge, Louisiana.
1986, M.S., Computer Science, The University of Texas, Austin, Texas
1991, Ph.D., Computer Science, The University of Texas, Austin, Texas

BIOGRAPHICAL SKETCH
Charles Petrie is a Senior Research Scientist working in the Stanford CS Logic Group. His research topics are concurrent engineering, enterprise management, and collective work. Dr. Petrie was a Founding Member of Technical Staff of the MCC AI Lab, Founding Editor-in-Chief of IEEE Internet Computing, and Founding Executive Director of the Stanford Networking Research Center. He is the Founding Chair of the Semantic Web Services Challenge. A more complete biography is available at http://www-cdr.stanford.edu/~petrie/bio.html

PUBLICATIONS RELEVANT TO THIS PROGRAM


9 Project Timeline - 1st Year

- Month 1 - identify team members, develop kernel of design vocabulary.

- Month 2 - train member on Redux and Logical Spreadsheets, identify design projects, refine design vocabulary.

- Months 3-6 - try out tools in design sessions, refine as necessary.

- Months 7-8 - analyze data collected, provide feedback to students and tool developers.

- Months 9-10 - perform documentation of design sessions, gather and analyze data.

- Months 11-12 - present results in a Stanford workshop and develop papers for presentation.

- If project results are promising in the first year, then years 2 and 3 will be proposed.
10 Budget

Computer Science staff
1 PhD RA student
20% Staff Engineer - Petrie
5% PI - Genesereth

Mechanical Engineering staff
2 PhD RA students
10% Tech Support staff
5% PI - Cutkosky

Non-Staff Costs
4 Apple iPhones - $1000.00
iPhone maintenance - $3,600.00
Travel - $3000.00 for two trips to Potsdam
Supplies - $1,200

Total Annual Cost Requested
$216,606.00 per year (detailed spreadsheet available)
Project is requested to run for 3 years, subject to review each year.