ParaXplore Interfaces: Parametric Interfaces for Parallel Exploration in Design

Naghmi Shireen
School of Interactive Arts and Technology
Simon Fraser University
nshireen@sfu.ca

Abstract
Computer Aided Design (CAD) tools provide little direct support for working with multiple parallel designs. This lack of version-control has lead designers to adopt ad-hoc techniques, such as opening two files side-by-side; layering designs for comparison; copy-pasting partial solutions to merge; saving versions manually, etc. These techniques for one are rudimentary, and have limited benefits for designers when it comes to common operations on multiple designs.

On one hand, design literature motivates designers to explore multiple designs in parallel for better comparison and decision-making; on the other hand, existing computational support limits such activities. Furthermore, the implications for a system capable of working with multiple parallel designs have yet to be explored. In this dissertation, I aim to identify, propose and develop *parallel exploration interfaces* to answer how designers can work with multiple design variations in parallel? A series of experimental studies are proposed with cyclic prototype-evaluate-feedback phases. Each phase informs the prototype development for the next phase, along with a new set of research questions.

Author Keywords
Design space exploration; parametric CAD system; exploratory research methods; parallel design exploration; user-centered design research

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Introduction

Designers explore variations from inception through conclusion. As important as it is to develop these variations, it is equally important to keep them available and accessible on suitably large displays for further interaction, sense-making, exploration and reflection-on-action. In fact, most *Aha!* moments happen while reflecting on previously explored (partial or complete) designs, when experts decide to backtrack and choose to branch out, deviate, or mix-and-match various pieces of design, towards an improved design variation. While this behavior of working through design variations in parallel on office walls, is prevalent in expert designers [1, 2], current computational design tools fall short of meeting their needs. Not only that these tools are designed for desktop computing, they also only support working on a single model at any given time [8].

With the advent of generative design tools, it has now become possible to manually *explore* – and in some cases algorithmically *generate* – huge number of design variations instantaneously (based on the Cartesian product of input parameters, for instance). However, even these generative tools are not equipped to help store and navigate through the generated design space on desktops, rest alone large displays. Except few, most are not even able to display these variations side by side – a very basic strategy for quick comparison that promotes fundamental design behaviors such as reflection, sense-making and exploration. Our research goal is to instigate innovation in this regards, by bridging the gap between existing design literature and the computational support required for design exploration.

The premise of this research is that *if* designers can access and work directly with design variations in a design task environment with new representations and tools as part of the design workflow, we expect new patterns and strategies to emerge and change design process. Working with multiple designs encourage novel interaction methods and techniques. However, what would be the new interfaces and interaction modalities in the new tools that would enable working with design variations? I propose a research recourse to answer this (and similar) questions through a series of iterative experimental studies. I expect that each iteration in studying parallel exploration behavior will reveal different aspects of the new task environment. I will use the results from these experiments to develop and refine exploratory interfaces. These interfaces would then become experimental devices to contribute in describing how designers can work with multiple parallel design collections using large displays. The outcome will primarily address CAD industry and inspire future development of interfaces to enable design task environments to edit and visualize collections simultaneously. In addition, the results may be useful for interface design in other domains where working with interactive surfaces is imperative, such as natural user interfaces, table-top interactions, interactive board games etc. We expect that the research will initiate a new set of methods to enhance the interface design practice.

Background and Motivation

The main motivation for this research comes from previous academic studies based on observing designers working through goal oriented tasks. Although, it is not a new research domain; it is just recent that the literature regarding parallel exploration

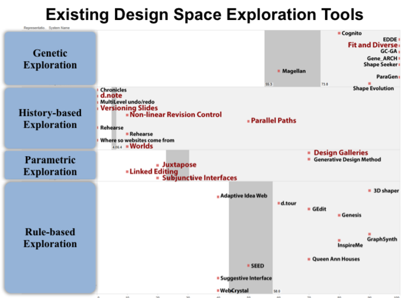


Figure 1 – A classification of design space exploration interfaces and techniques

of design variations has emerged in this field. As part of the background research for my dissertation, I performed an extensive research on design space exploration, its techniques and interfaces. A complete list of those techniques and interfaces (~43) is beyond the scope of this paper. To simplify, I have classified them into four categories based on their underlying representation used for exploration and the degree of automation in performing exploratory tasks. The four categories are Genetic Exploration, History-based Exploration, Parametric Exploration, and Rule-based Exploration (definition and examples will be part of the full dissertation).

Out of the collected literature repository of exploration techniques, few focus entirely on parallel exploration (highlighted in red in Figure 01); consequently, I find it important to briefly report them in the next few paragraphs.

Parallel Path [8] concept is based upon the argument that there is a potential design variation, before, during or after a command is evoked. Authors introduce the concept of *skating through time*; which essentially allow users to backtrack in the history and make changes to the design states. On similar lines, [3] presents an interface that helps comparing and managing parallel presentation slide versions.

[9] presents *Linked Editing* technique as a novel way to support parallel editing of duplicated code. *Juxtapose* [4] is built on top of this technique by turning design into lines of code that is executed in parallel. When designs are linked, new addition of code is shared among linked variations. In case of unlinked insertion, an empty block appears in the rest of variations. Same concept is applied for deletion. A colored background inside the code editor is used to highlight differences among alternatives.

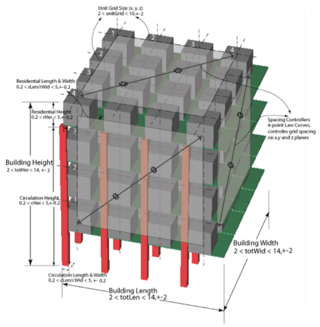
Subjunctive Interface [6] is a parameter-based exploration interface with sliders for each parameter with multiple handles representing a different input value, resulting into multiple scenarios. One thing that is common between *Subjunctive Interface* and *Design Galleries* is the play of parameter settings. However, *Design Gallery* [7] presents a computer-assisted parameter setting mechanism compared to human-assisted parameter setting of *Subjunctive Interface*. In *Design Galleries*, once the user provides the input parameters and defines the output vector, the system runs a dispersion method.

The highlighted literature presents valuable techniques for working with multiple parallel designs. Sadly, most techniques focus on performance and the ease with which the design variations can be generated. There are two important things still unknown in this domain: 1) the parallel design process itself, i.e., how the change in task environment of working with multiple parallel designs has affected the traditional design process, and 2) what is the potential cognitive cost of working with such task environment on designers. My research is an attempt towards answering these first, then proposing an interface solution and interaction techniques.

Research Design and Current Status

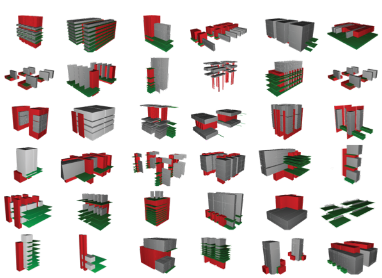
As already mentioned the research will be conducted through an incremental and iterative process of prototype-evaluate-feedback phases. At each phase a parallel exploration prototype will be adapted or developed, and analyzed based on a set of predefined research questions. We expect each cycle to reveal

Design Variation Generator



Design: A hypothetical design scenario was brainstormed that is capable of generating a *large* set of parametric variations. it should be appropriately abstract, i.e., should have sketch-like characteristics (Buxton 2007).

Generation: Parametric combinations were generated and filtered into 1000 design variations based on a dissimilarity matrix.



further questions related to parallel exploration process, human-cognition, parallel exploration modalities and interactions. The analysis at each phase will feed new information and new set of questions back to the next cycle--along with possibly better understood parallel exploration interfaces for refinement.

To achieve my research objectives, I have conducted a series of preliminary studies, below I present the current status for two of them.

Study#1: ParaXplore Gallery Interface

Introduction and Motivation

In Cognitive Science literature, studies on observing human behavior suggest that in situations where experts are to work with multiple objects, they resort to workspace management by intelligently laying out cognitive cues for themselves within the task environment they are working in [5]. However, it is still a black box when it comes to observing designers working with multiple designs. Therefore, it is crucial to understand how designers can use their work environment as a cognitive ally, by intelligently structuring their design workflow, before suggesting potential interface solutions for such design activity.

In this study, we investigate how designers can effectively and intelligently, use their work environment including surfaces and work materials, in order to make design decisions when overloaded with large number of design options. Following distributed cognition theory we believe an important first step in this endeavor is to identify basic interactions between a designer and his familiar tools in an organic setting and then develop a simplified framework with which these interactions, can be interpreted and visualized in a different display format for future design interfaces.

In order to study designers in their native environments, we chose to carry out a mixed-method observational study using a protocol analysis method. Through this study, we aim to address four broad highly interrelated research questions (RQs), which are:

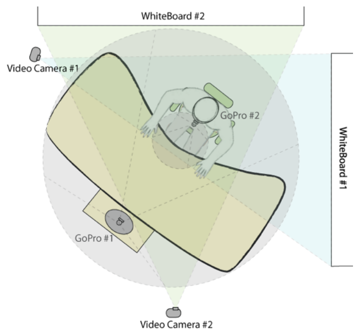
1. What are the higher-level design tasks associated with exploring a large number of computer generated design outcomes and finding a set of satisfactory design solutions?
2. How do designers define and structure their work environment during each of these design tasks?
3. How does this structure of the work environment affects design cognition, hence the cognitive cost of over-loaded design spaces?
4. What are the observable spatial interactions that can be abstracted, to a new digital display format for future user interface design?

Experiment Procedure

Experiment began by bringing the participant into the experiment room, exposing them to the high-level structuring of the design space. They were then briefed about the study, its (potential) risks and were asked to sign a consent form to release video and audio rights to the researchers and the confidentiality of their identities. Participants were specifically requested to vocalize their thoughts while performing the task to emulate and capture the design through processes.

The participants were first asked to fill in a pre-experiment questionnaire. The questionnaire was intended to collect demographic and experience related data. In addition, they were asked to rate their experience in various CAD tools on a 5-level Likert scale, where 1 represented ‘Novice’ and 5 represented

Experiment Design



Setup: The entire experiment was videotaped using two GoPro® and two normal. One GoPro® camera was head-strapped, the other was used to capture the aerial view. The two video cameras were set up to capture the two whiteboards and other areas.

Materials: The set of 1000 printed designs, a table, the whiteboards, board markers, sticky notes, pen, pencils, extra whitepapers, erasers, board magnets, and masking tapes are the basic material.

'Expert'. This information was used to interpret the spread of expertise and to reason out any anomaly in the collected data.

The participants were then introduced with the design task and design scenario. They were asked to voice any questions or clarifications. Once the participant was clear about the task, he was given a single stack of randomly ordered 1000 index cards; followed by the participant performing the actual design task. Once completed, the researchers confirmed the participant's final decision on the design solutions and performed a formal follow up post-experiment interview.

Data Collection and Analysis

The video and audio data was transcribed and coded in an excel sheet. Close attention was given to events that resulted into a *change* in the workspace environment in any way possible. Through this researcher were able to divide the entire design process for each participant, into chunks of observable change-events. A spatial snapshot of these events was logged from all four cameras with a time stamp.

Later for each change-event, participant's observable *actions* were identified and recorded, in order to identify the design *activities*. These design activities were then used to identify *design tasks* to understand the design patterns in the overall process of going through the huge number of design solutions. Researchers adapted a bottom up approach to develop these codes, hence the process was cyclic and ran multiple times, until an exhaustive list of codes were observed repetitively. The coded data was transformed into a customized interactive visualization, made in Java using Google API. The visualization is a timeline of the design process, such that it incorporates the action, activity and task durations, along with the spatial snapshot from all four cameras. See Figure 02.

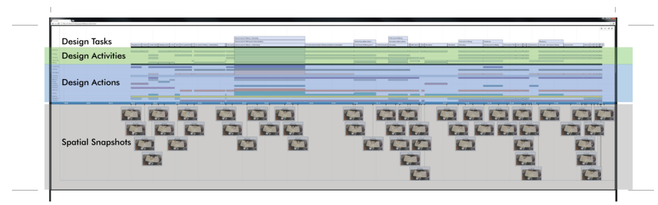


Figure 2 - An interactive visualization for data analysis

This interactive visualization became the major tool of analysis for researchers. Two researchers carefully analyzed these timeline visualizations for each participant initially one by one and then together on a 3 x 2 large display system (Figure 03). The analysis sessions ran for couple of weeks, for around 4 to 5 hours each day.

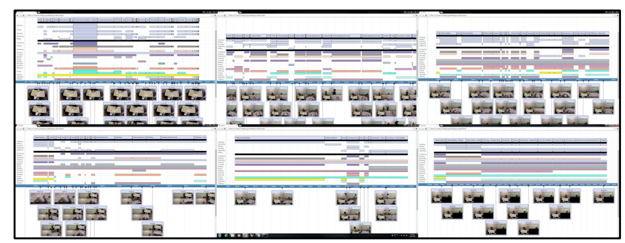


Figure 3 - Six monitor system used for analysis

Results

We are still in the process of analyzing the results of this study.

Study#2: ParaXplore Editing Interface

Introduction and Motivation

Through study#1, we have established that during the evaluation and selection of a possible design solution, designers organize multiple generated solutions to

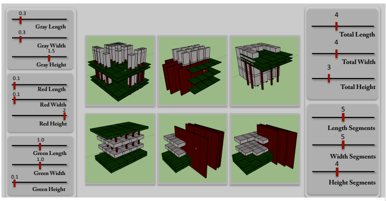


Figure 4 – An interface sketch proposed for ParaXplore Editing Interface

compare their features against a set of design criteria and with each other. For study#2, I propose to investigate if and how these activities can expand to include editing of the design variations in parallel, so that designers not only work on static representations for evaluation, but also changeable models for seamless design creation. Parallel exploration implies that design models are parametric such that common design features respond to changes simultaneously; designers decide which variations to be under-edit; transferring features from one solution to the others is possible; and a group of selected variations can be viewed together.

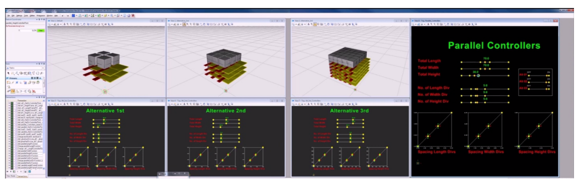


Figure 5 - ParaXplore Editing Interface

Material for this study includes prototype interface that I have developed on an existing CAD system, *Generative Components by Bentley*® (Figure 04 & 05).

Current Status and Future works

In this mixed-method study, we applied concurrent triangulation of data. Our goal was to learn more about the observable design moves and actions when working with multiple generated solutions simultaneously versus sequentially. In the next stage, we will translate our findings to system features on prototype systems and continue conducting their evaluations.

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References

[1] Akin, O. Variants in design cognition. *Design Knowing and Learning: Cognition in Design Education*, (2001), 1–17.

[2] Cross, N. Design cognition: Results from protocol and other empirical studies of design activity. *Design Knowing and Learning: Cognition in Design Education*. (2001). Elsevier Science, 79-103.

[3] Drucker. S., Petschnigg, G., and Agrawala. M. Comparing and managing multiple versions of slide presentations. In *Proc UIST'06*. ACM Press (2006).

[4] Hartmann, B., Yu, L., Allison, A., Yang, Y. and Klemmer, S. Design as exploration: creating interface alternatives through parallel authoring and runtime tuning. In *Proc. Of UIST '08*. ACM Press (2008) 91-100.

[5] Kirsh, D. 1995. The intelligent use of space. *Artif. Intell.* 73, 1-2 (Feb. 1995), 31–68.

[6] Lunzer, A., & Hornbæk, K. Subjunctive interfaces: Extending Applications to Support Parallel Setup, Viewing and Control of Alternative Scenarios. In *Proc. Of CHI'14.* ACM Press (2008): 1–44.

[7] Marks, J., Andalman, B., Beardsley, P., Freeman, W., Gibson, S., Hodgins, J., Kang, T., Mirtich, B., Pfister, H., Ruml, W., Ryall, K., Seims, J. and Shieber, S. Design galleries: a general approach to setting parameters for computer graphics and animation. In *Proc. of SIGGRAPH '97*. ACM Press(1997) 389-400.

[8] Terry, M., Mynatt, E., Nakakoji, K. and Yamamoto, Y. Variation in element and action: supporting simultaneous development of alternative solutions. In *Proc. of CHI '04*. ACM Press (2004): 711-718.

Toomim, M., Begel, A. and Graham, S. Managing Duplicated Code with Linked Editing. In *Proc. Of VLHCC '04*. IEEE Computer Society (2004): 173-180.