Design ReExplorer: Interactive Design Narratives for Feedback, Analysis and Exploration

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Designers keep a constant record of the design process through their sketches and notes. In parametric CAD, the record of design moves is implicit and can be found in the elements upon which the parametric model is built. Current systems provide designers with limited tools for recording, viewing or analyzing the design process. We propose a system's approach to capture the design narrative as an artefact for design. The Design ReExplorer was developed to test ideas on using these narratives in gaining insights towards how models are built, exploring alternatives and supporting backtracking and deferral strategies in design exploration. We evaluate its insertion and viability in real-world scenarios through an expert panel study. The results of the study are favourable with positive feedback and multiple suggestions for future work.

Keywords: *Parametric computer aided design, design history, design cognition, design process*

INTRODUCTION AND MOTIVATION

Hidden within the design process are a myriad of alternatives; some good, some better and more importantly, some that have not been explored and are waiting to be uncovered and set free. One of the best methods to understand these alternatives, in particular those developed using parametric computer-aided design (pCAD) tools, is through unravelling the *design narrative* that enabled (propelled, allowed, permitted, laid out) their creation. Design narratives tell the story of the work: how individual actions and alternatives build upon each other and how different solutions come into being. They also tell the story of the alternate paths that were never considered and the paths, which when reconsidered, become the correct path towards finding satisficing solutions (Erhan et al., 2012).

We developed the Design ReExplorer (DReX) prototype to test these ideas and to evaluate its insertion and viability in real-world design task environments. DReX is a creativity-support tool envisioned to extend the capabilities of pCAD systems for exploring design alternatives in past actions. Its goal is to enable designers to capture an editable visual history of design alternatives, and to provide visual feedback on the design process and interactive controls of the parametric model through directly connecting with the pCAD systems working models. We aim to seamlessly integrate exploration of possible alternative solutions within design modelling tasks.

The prototype is built on previous work on *design narratives* (Erhan et al. 2012) and on the Design Analytics framework (Sánchez, 2014). The approach has three tenets: (a) Provide feedback through *de-*

sign narratives; a model of the design process built through the actions and alternatives designers make and develop in terms of what, how and when; (b) facilitate a local and global analysis of the design actions and alternatives across the narrative; and (c) enable the execution of design decisions within the DReX interface based on the preceding analysis. We present a summary of the initial results from the expert evaluation study we recently completed to understand the plausibility of integrating our approach into design task workflows. The results highlight some challenges as well as future directions for our research.

BACKGROUND

Designers keep a record of their designs in the form of sketches, save-as files and notes as part of a need to collect precedents that will later be revisited (Menezes and Lawson 2006). Experienced designers are more likely to save and revisit their sketches than novices (Lawson, 2006; Goldschmidt 2003). As these records accumulate they become an unstructured history of their design process (Makkuni 1987). This is particularly useful when the design process is as important, if not more, than the solution itself. There is also an opportunity for uncovering the relationships between the design process and possible design solutions (Dorst and Cross 2001). Similarly there is great interest in managing the plethora of alternatives that are now at our disposal through the use of pCAD tools (Woodbury, 2010). However, we have yet to see a clear understanding of how these tools may look like and function in practice.

Almost all current pCAD systems (e.g. SolidWorks, Revit, GenerativeComponents, and Grasshopper) have mechanisms to traverse the action history to make changes in the current design state. However, they still work on a single state model providing designers access to only a single design solution at any given time. Systems provide features to circumvent this problem or allow designers to implement ad-hoc solutions but don't provide integrated solutions to use the implicit information within the system (Woodbury and Burrow 2006). History mechanisms in pCAD systems and research prototypes are one of the tools designers have at their disposal to understand and make sense of the design process. The majority of these history tools are command logs taken from the command (undo-redo) stack. Their capacity is usually limited by linear records and don't allow designers to backtrack without losing subsequent work. These mechanisms are not intended to explicitly capture a design process.

On the other hand, the augmented history tools-mostly confined to research prototypes as in Chimera (Kurlander and Feiner 1990)-demonstrated potential for providing graphical histories on design process. The main features found in these tools include the ability to backtrack and edit previous states, and delegate repetitive tasks to the computer using history as a guide. To generate the relationship structures between design states and parametric values, the prototypes with augmented history capabilities rely on the parametric engines that run in the background (Nakamura and Igarashi 2008; Bueno et al. 2011; Edwards and Igarashi 2000; Heer et al. 2008). These capabilities which are made ad-hoc for the prototypes are inherent to pCAD systems. This allows pCAD users to build parametric models and then edit them having changes subsequently propagate downstream updating the current design state. As the individual actions that build the parametric model are executed their properties expose a design process. The history mechanisms can reveal much more about the designers, their design process, and in doing so create a tacit narrative for each design state and final design solution (Erhan et al. 2012).

Although, there are some sub-systems indirectly enabling working with multiple alternatives, e.g. configuration management (Krish, 2011), most explicit solutions capturing design histories are proposed as prototypes for demonstration purposes. These can fall under three categories based on where they propose supporting exploration: on the model through side-by-side editing (Hartmann et al. 2008; Lunzer and Hornbaek, 2008); as records in a history of action and states (Heer et al., 2008; Jankun, Ma, and Gertz, 2007; Kurlander and Feiner, 1991); and on a set of alternatives created by generative methods (Marks et al. 1997; Terry et al., 2004). We have yet to know how these prototypes translate into functional systems or the combined effect of the three categories. Although all these categories are important, in this research we address the second category based on our experimental findings and on our observations that potentials of augmented process-centric tools have yet to be explored. Below we describe the prototype we aim to use as a probe to further understand alternatives in the design process and in developing functional tools to support working with them.

THE DESIGN REEXPLORER PROTOTYPE

DReX uses the parametric modelling capabilities of pCAD systems to generate a *design narrative* graph in the background as an integral part of the task flow (Erhan et al. 2012). Our goal is to allow designers to break down the sequential nature of design by making it an atemporal process, setting designers free to explore new alternatives unconstrained by time as exemplified by other prototypes (Edwards and Mynatt 1997; Rekimoto 1999). The DReX prototype experiments with ideas on how designers can traverse the history of their actions to re-explore, understand, describe, and analyze the design process and design alternatives in relation to their design moves. As a creativity support tool it aims to augment the designers' creative search through visualizing, exploring and reviewing of design actions and states (Shneiderman 2002).

The information structure used by DReX is the same as that proposed to develop *design narratives* (Erhan et al. 2012). In both cases information is gathered directly from the actions performed by the designers on the pCAD system. In DReX the design moves are captured synchronously to the actions performed by the designer, and DReX presents feedback immediately in the form of a design narrative graph. The actual speed of the feedback depends on computational capacity and complexity of the parametric model.

DESIGN NARRATIVES - VISUAL FEEDBACK

DReX allows designers to look at their design process as an artefact in itself as suggested by (Makkuni 1987), which designers now can backup, replay and recall (Woodbury and Burrow 2006). The interface is divided by a timeline that separates the two feedback types. Top section contains salient parameters shown as parameter blocks; these contain parameter controls, thumbnails of previously visited states/alternatives, and a view of the 3D model for a given combination of values. The bottom contains the *design narratives* graph with backtracking edges, these connect with other blocks as a sign of backtracking (Fig.1) (Akers et al. 2009). Parameter blocks are mapped sequentially over time (left to right) to the actions taken by the user on the base pCAD system (Erhan et al. 2012). Parameter blocks are preset in the DReX prototype.

ANALYSIS AND RE-EXPLORATION

In DReX, the designers can navigate the timeline, complete a basic analysis and edit the parametric model. Analysis is attainable at two levels: (1) globally by identifying patterns in the distribution of parameters, backtracking edges and deferral; and (2) locally by identifying patterns in the local collection of alternatives. Re-exploration in response to the analysis or otherwise is achieved through controls on each parameter block. Local collections contain a thumbnail for each alternate CAD model. These design states are created by editing the parameter's value. Future implementations would allow edits in both base system and DReX.

SYSTEMS DESIGN

The prototype is based on the Design Analytics principles: feedback, analysis and re-exploration (for details see Sánchez, 2014). As such, the prototype tries to approximate real-world scenarios and situations whenever possible while not trying to be comprehensive in terms of the design process. Our objective

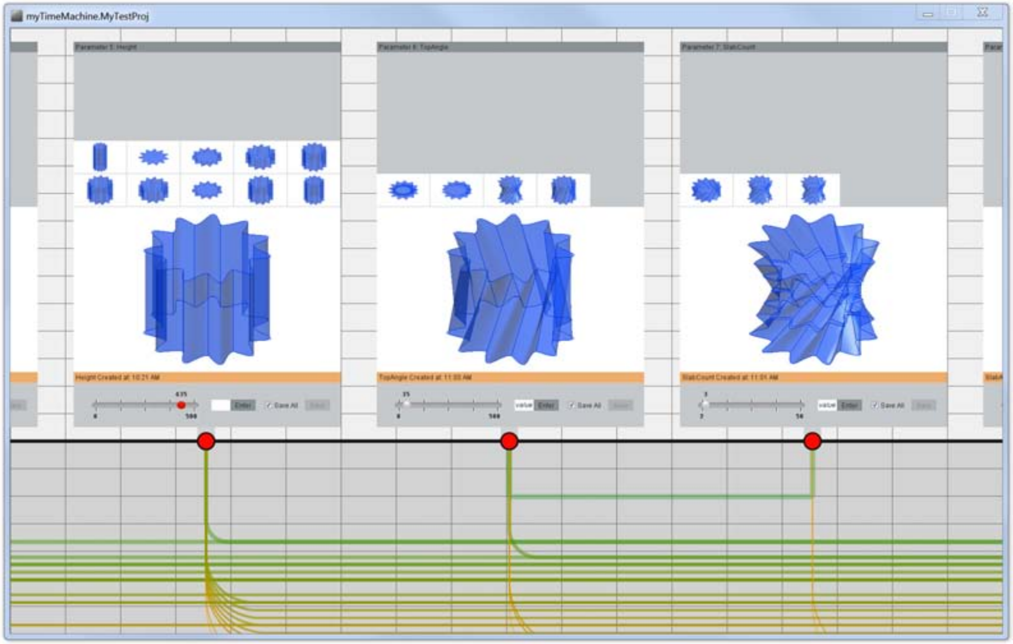

Figure 1
The Design ReExplorer UI with 3 parameter blocks, each with a collection of alternatives and slider and text box for model editing. The edges below signal backtracking from one node to another.

was to be able to maintain the level of complexity of the models we used at a par with the complexity of real-world projects.

An initial design decisions was to decouple the prototype from existing pCAD systems; only providing interaction indirectly through parametric changes done outside the prototype. Our belief was that this would help developers and participants of any future evaluation to interface with DReX independently.

The prototype system consists of three components: the pCAD system; DReX to interact with past design moves and multiple design alternatives, and the conjunctive adapter (Microsoft Excel, RhinoScript and the JavOnet API) that interconnects the system (Fig. 4). The current implementation of the conjunctive adapter is tailored for Rhino Grasshopper (Fig. 5) but it is relatively simple to create such adaptors for other pCAD systems (GenerativeComponents, SolidWorks or CATIA) or other deterministic systems.

CAPABILITIES AND FEATURES OF THE PROTOTYPE

Through an incremental development process initially the most essential features have been implemented in the prototype. They allow designers to view a design process by navigating the timeline to identify blocks or areas that are relatively more active or inactive based on the density and location of backtracking edges. This allows designers to identify different stages of the design process, for example detailing, deferral of work or decisions, and slips, errors or mistakes (Fig. 2) (Erhan et al. 2012). Additionally, the designers can view a block's local collection of alternatives and identify past alternatives for reuse or values that represent untested parameter values

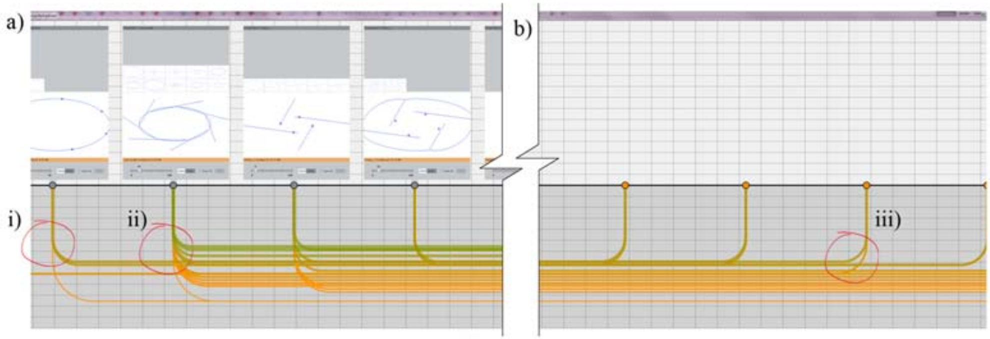

Figure 2
DReX timeline showing backtracking edges that link parameter blocks and nodes set in the present (i) and (iii). Differences in backtracking clustering i) and ii) allow us to identify deferral strategies (Erhan et al. 2012).

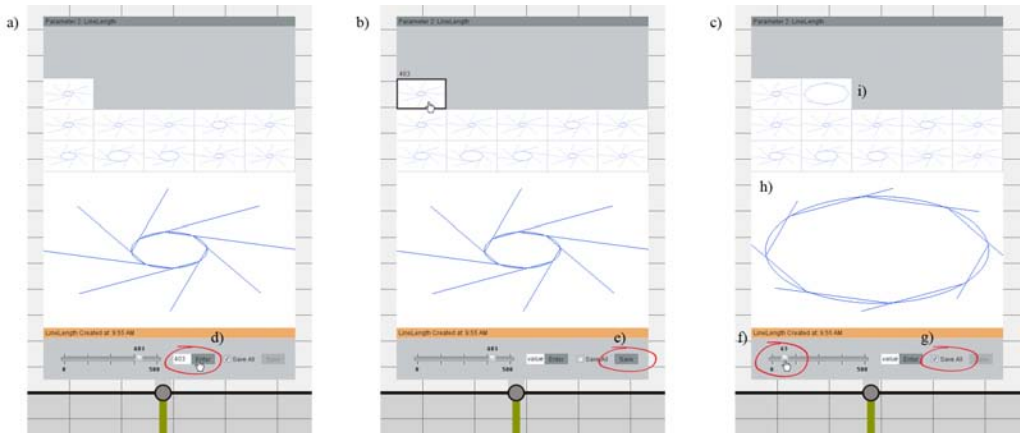

Figure 3
Parameter blocks contain local collections of alternatives (i) with sliders (f) and text boxes (d) to explore the design space and a larger image of the local geometry (h). A new value can be explored in a) using the text box (d). In b) a thumbnail of the new geometry is shown and the SaveAll toggle (g) is unchecked. The Save button (e) can be used to save. In c) a new alternative is generated using the slider adding to the local collection of alternatives (i).

within the collection (Fig. 3). The user can alternately try different combinations of previously tested alternatives using controls in each block by matching values across the prototype.

EVALUATION: SUMMARY OF THE EXPERT PANEL REVIEW

We have recently completed an expert panel review of the DReX prototype and the ideas behind it. The goal was to assess the validity and viability of a future, more refined and robust, system and to evaluate how the core ideas presented here are met by domain members, both novice and expert. The qualitative study was completed over a period of two weeks and was comprised of 7 participants and 2 pilot. Audio recordings of the participants' answers, questions and general feedback was made as participants were shown a presentation, a demo of the prototype and finally answered a set of open ended questions. These recording have been analyzed and the results are presented below.

The study was divided into four parts: (1) Participants filled out a questionnaire and signed a consent form; (2) Participants were shown a PowerPoint presentation to introduce the main ideas and the prototype. Slides provided an introduction to the do-

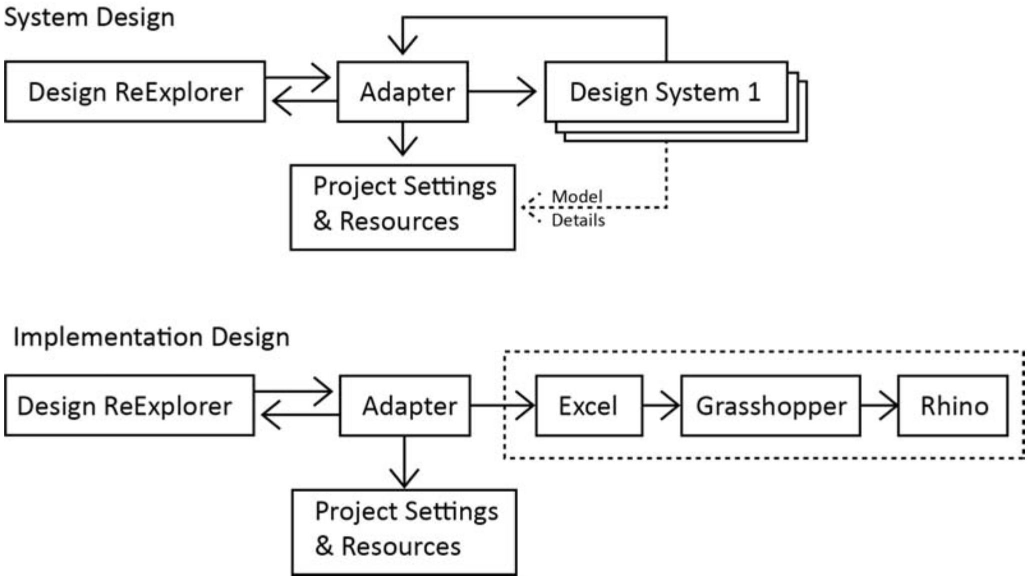

Figure 4
System and implementation design for DReX.

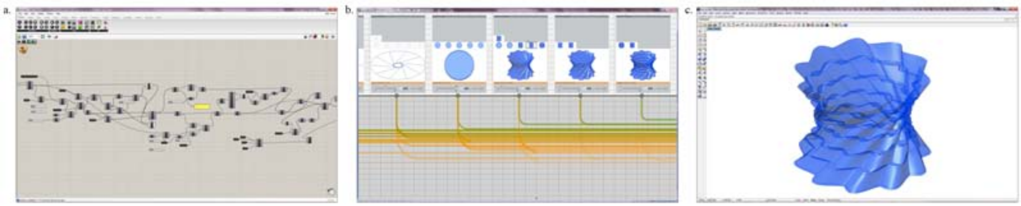

Figure 5
From left to right: Grasshopper with Tower definition, Design ReExplorer interface and Rhino showing current state of the design. The Grasshopper definition and Rhino model are set in the present moment while DReX shows the different paths the design has taken before completion.

main, preliminary studies, the core ideas behind Design Analytics (Sánchez 2014) and an introduction to the prototype's user interface; (3) Participants were shown a demonstration of the prototype using scenarios and use cases. Participants were then encouraged to try the prototype for themselves; and (4) Participants were finally asked a set of open ended questions. During the course of the study participants were encouraged to ask questions regarding the questionnaire, the presentation and the prototype. Open-ended questions were pre-defined but frequently follow-up questions were used to further understand the participants' response and complement their feedback.

STUDY SETUP

The presentation and interview process was carried out in person using a laptop with half of the participants viewing the presentation and prototype on an additional 23" monitor. The two screens provided a better viewing experience; other participants viewed the prototype by switching between applications or side by side. A standalone digital audio recorder was used to record participant's comments during the study.

The prototype used a basic parametric model of a tower developed in Grasshopper. The tower model is a basic pCAD model to demonstrate possible uses cases and scenarios that could be completed using the prototype. The tower example follows a simple design pattern of transforming basic 2D geometry into 3D objects though an amassing of features and operations Fig. 5c. A more complex model would impose greater computational challenges and was beyond the scope of this study. The tower model was created for demonstration purposes only, editing was limited to editing values attached to Grasshopper nodes, and structural changes of the pCAD model were not implemented.

PARTICIPANTS

Participants were identified within the CAD, computational design and AEC domain. We identified individuals with experience in real-world scenarios that dealt with complex design problems and had experience managing and teaching other designers. Additionally we wanted feedback from computational designers and developers and the fresh eyes of pCAD novices. Their academic backgrounds ranged from engineers and architects to computer scientist. Participants were selected based on characteristics that lay across multiple axes: novice and expert designer, graduate student/researcher and design studio professional, management and non-management and their knowledge and knowhow of pCAD.

INITIAL RESULTS

The open-ended questions gave us disorganized answers that were spread across multiple questions. In analyzing the interviews we have grouped together answers that relate to the same theme. As with any proof of concept prototype many comments focused on issues that can be easily solved and provide no new insight into the future of the tool and have therefore been omitted. As expected participants answers were consistent with the occasional outlier and with personality, background and experience shifting answers one way or the other.

Initial results are very promising. Participants were enthusiastic about the prototype and the ideas behind it. When asked about integrating a future prototype (FP) into their workflows answers were positive. There were several reasons for this. The first is that the prototype transformed the design process from a unknown black box into an open artefact that could be visualized onscreen. The second is that it allowed them to see a true visual history of the design by seeing all the thumbnails that are automatically saved when changes are made. Some participants mentioned that the FP would both encourage you to review your design process and be more introspective; while other described only specific scenarios for its use. Participants were also wary of its implications within the workplace in terms of competition, being too self-aware of the processes and overreaching managers. Procrastination was also mentioned.

Participants were asked to assess their willingness to accept automatically generated feedback based on their design process. This was asked with the current prototype in mind and a FP in which AI and pattern recognition would be included. Participants were both open to having a computer provide feedback but always with some hesitation. The main concern was intrusive feedback so user control was a common request. Participants were enthusiastic about the possibility of having higher level feedback than lower level in particular when related to AI or pattern recognition.

Regarding the *design narratives* (backtracking edges between nodes) opinions were less favourable. The main concern was the visual aspect, scale and overall usefulness of the *design narratives* feedback; even so they all saw its importance when shown better examples at different scales using the presentation slides. Relative to this issue participants suggested several solutions: conventional zoom, semantic zoom and hierarchical structures or simply turning them off when not in use.

Higher-level usability issues did arise. Propagation control was the main issue expressed by participants. The current version of the prototype only updates the thumbnail of the parameter that is being edited. Running in the background Grasshopper update all parameters but these are not loaded by DReX. This caused a lot of confusion but was done to lessen the computational load. The solution, shared and liked by participants, was to include propagation and update controls that would allow designers to have more control over the impact a parametric change would have in DReX. The other issue was complexity and the computational load real-world projects would impose on a FP. To mitigate these issues hierarchical structures would be added to increase the abstraction gradient and cede control of computationally heavy tasks to users. Another issue that required deeper analysis is how to manage semantically complex design moves than those currently implemented e.g. copy/paste or merge files. The prototype currently is unable to include structural changes to the parametric model.

There were several interesting UI and interaction suggestions: adding a secondary notation to annotate blocks, alternatives and edges; adding split screen capabilities, responsive design for the timeline and local collections, have alternatives generated automatically by setting up minimum and maximum ranges and multiple graphs for collaboration.

CONCLUSIONS

From this prototype we have identified several key issues that need to be resolved for this tool to be effective. We have also been reassured that research in this area is both promising and relevant to practitioners and researchers alike. Our future work is well delineated by the prototype's shortcomings and strong points and empowered by the confirmation that designers, in particular experts, hold the design process and the search for alternatives paramount; and that these experts need tools to support them.

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