DESIGN THINKING VISUALIZATION

Case Studies on Form Generation and Design Evaluation

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Abstract. In this paper we advocate design thinking visualization and present two visualization case studies for design thinking. The objective of the research is to visualize design thinking process for the study of this process, which is generally fairly complex. The significance of the work lies in that the research can advance the current design visualization from design product visualization and design data visualization to design thinking visualization, which can be applied to education and practice of design.

1. Introduction

Visualization is of great interests to architectural designers because it can assist in presenting complex patterns and relationships in design form and data to users for them to understand design and to designers themselves to aid cognition and reasoning. Design visualization includes design product visualization, design data visualization, and design thinking visualization. Design product visualization consists of 3D modeling, rendering, and animation about a building. Design data visualization can be used for analysis of collected design data, e.g. transportation patterns, energy consumption, etc.

Design thinking visualization is the interactive and dynamic visualization of abstract and nonlinear design thinking process. Design thinking visualization can convey important design information and strategies effectively to designers and design students therefore its use in education and practice can be phenomenal. So far, however, more attention of research has been given to design product visualization and design data visualization (e.g. Greenberg, 1986; Koutamanis, 2000; Göttig et al., 2004; and Ong, 2004) and little to design thinking visualization. Speaking of design thinking process, “we are still slowly moving from the notion of Christopher Alexander's of a partially unself-conscious design to self-conscious and explicit design processes” (Eastman, 1999). We believe design thinking - a major phase in design process - can be made self-conscious and explicit through creative visualization.

It is more challenging to visualizing design thinking than design products and data because the thinking process is very complex, which involves a large amount of abstract data and parallel brain cognitive processes. There
can be too large amount of data (design variables or parameters) to draw on the computer screens (and in human brains as well) for visualization at one time, we therefore view the visualization as a process of mapping a high dynamic range of data to a low dynamic range data display device. For this reason, we need to display only those essential details, e.g. points of inflection, where the significant changes occur. To visualize these changes, it is important that animated or dynamic visualization be used. By the nature of design visualization where form generation is a common task, 3D visualization environment is normally useful because it can seamlessly integrate the 3D forms with visualization of the generation process. Furthermore, 3D environments can suggest 3D interaction metaphors (Wann, et al., 1996), for example, fly-around or walkthrough. 3D visualization can also be used beyond form generation, e.g. to visualization of evaluation process, which is also an important process of design thinking. Finally, interactivity gives control of the visualization process and create the feeling of “being there” (Heeter, 1992), therefore it is also an important feature of design thinking visualization.

We have developed two prototypes of design thinking visualization systems and used two case studies to demonstrate them. 1) Alvar Aalto’s Town Hall Säynätsalo – visualization of the form generation process. With the visualization system users can control and play the building’s morphing in twenty steps from a simple box to a complex architectural form interactively. 2) Visualization for lighting design evaluation. This project analyzes lighting design in four offices and visualizes the results of the evaluation in an interactive 3D chart. Technical effect, aesthetic effect, and economic effect are evaluated and visualized for each design. A real time animation makes it easy to compare the final grades of the four design cases by showing the process of combined grade change from one case into another.

2. Case Studies and Methodologies

We use two case studies to demonstrate the visualization systems for design thinking.

2.1. CASE STUDY 1: VISUALIZATION OF A FORM GENERATION PROCESS

Different from other form generation and shape grammar research projects (e.g. Knight, 2000), this project focuses on the visualization aspect of the process, and uses an Alvar Aalto’s building to demonstrate the necessity and effectiveness of visualization (Figure 1, 2, and 3). Aalto’s Town Hall Säynätsalo in Finland aroused interest in form generation studies. Examples are Eisenman’s dissertation on architectural forms (Eisenman, 1963) and Baker’s book on design strategies (Baker, 1989). Based on these studies, we developed a program to interactively visualize the form generation process. The basic goals of the study are: to understand the formal characteristics of the building; to find the appropriate graphic language to represent the fundamental qualities of the building; to devise a critical vocabulary derived from the analysis of the building; and finally to visualize the design thinking process. The project “Town Hall Säynätsalo:
Form Generation” shows a logical generation process of the building’s geometric form. It is an interactive VRML program with graphical user interface. Users can control and watch the building’s morphing from a simple box to a complex building form interactively: starting from a box, a courtyard is formed in step 1; two major volumes are separated in step 2; the shapes are refined horizontally from step 3 to 10; then raised vertically from step 11 to 16; roof slopes are formed and the complex building form is generated from step 17 to 20. This process can be replayed in a continuous mode to examine the smooth transition from beginning to the end.

In this study, there are too large amount of geometry data (3D coordinates in all the steps and interpolations between them) to store in the computers for visualizing the whole process, therefore we stored only those essential 20 steps, where the significant changes occur, and all the interpolations are computed in real time automatically. We used 3D modeling software to create all the models in the 20 steps in order to retrieve their coordinates, with a reversed order starting from the complete model at step 20 and morphed the model manually back to step 19, 18, …, 2, 1, and recorded their coordinates for use in the interactive or automatic forward morphing.

Though the form generation process in this study indicates just one of many possible design strategies and may not be the actual thinking process employed by Aalto (and very likely not the actual one), it does explicitly and visually describes a process that can be used in teaching design thinking. Alternative thinking processes can be studied, visualized, and compared for helping design students develop their own design strategies. Compared to traditional illustrations (on paper) about the thinking process (e.g. Baker, 1989), interactive 3D animation can greatly improve the visualization effectiveness, including a better understanding of the thinking process.

![Figure 1. Town Hall Säynätsalo. Left: Southeast; Right: Northeast (source: Weston, 1993)](image1.png)

*Figure 1.* Town Hall Säynätsalo. Left: Southeast; Right: Northeast (source: Weston, 1993)

*Figure 2.8* out of total 20 steps of the form generation process. In each step, a wireframe model of the final building form is shown for reference.
Evaluation of design is another important aspect of design process (Kalay, 1992), and it is also an extensive thinking process. There are many criteria that consist of the final result of the evaluation. Some of the criteria are objective but many are subjective, which distinguishes it from data visualization greatly and makes design evaluation a quite complex issue. Visualization can be expected to have a big impact in assisting the evaluation and decision making process.

Below we describe a project that visualizes the evaluation of four lighting designs described in *Lighting the Electronic Office* (Steffy, 1995). The results of the evaluation are visualized as an interactive 3D chart with hierarchical criteria structure (Figure 4 and 5).

In the chart, the transparent volume represents the full scale of satisfaction. Within that volume, different colors represent different criteria, for example, red color volume represents the Technical Issues, green color volume the Aesthetic Issues, and blue the Economic Issues. In the hierarchical criteria structure, there is a root group consisting of these three issue categories, and subgroups addressing the issues within each category, e.g. Luminance, Reflectance, and Light Control in Technical Issues, Light Position, Lighting Variation, Color Quality, and Personal Preferences in Aesthetic Issues, and Initial Cost, Power Budget, and Maintenance in
Economic Issues. Furthermore, there are third-level subgroups under many of the second-level issues.

The height of a volume represents the degree of satisfaction for a criterion, and in our case study this value is assumed to be a constant as it can be obtained through measurements and surveys. The area (or angle) of a volume represents the weight of this criterion. Since the weights depend very much on individuals, they are variables in the evaluation process. Users can interactively select a group or a subgroup of the criteria and adjust the weights based on their preferences, then the grades of the evaluation criteria of the selected group or the subgroup and the final grade of a design will change accordingly and be displayed visually in the 3D chart window. The final grade of a design is the weighted sum of the grades of all criteria. The program can show the final grades of evaluation criteria in the four design cases. To compare the final grades of the four cases, a real time animation is used to show the process of grade change from one case to another.

The implementation of this project was done with VRML and Java programming language. Through visualization, the complex and abstract evaluation process is made easy to understand. Again, compared to traditional illustrations about the evaluation process, which may be static charts or tables on paper, interactive 3D animation can greatly improve the visualization effectiveness.

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\text{Final Grade} = \sum_{i=1}^{n} \text{Criterion Grade}_i \times \text{Weight}_i
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*Figure 4.* User interface of the visualization of lighting design evaluation. Upper left: 3D chart displaying the selected group or subgroup of the evaluation criteria. Lower left: four lighting designs. Right: evaluation criteria. Users can select a group of the criteria and change the weights of each criterion by adjusting its volume’s angle. Final grade of a design is the weighted sum of the grades of all criteria.
Figure 5. Visualization of lighting design evaluation – hierarchical criteria and a possible set of user’s predefined weights for the criteria.
3. Conclusions and Future Work

While design product visualization and design data visualization can provide visual communication about what the design is, design thinking visualization can provide visual communication about how to design. Design thinking is a complex issue. Therefore it normally requires customized user interfaces and the interfaces are normally more complex than those of product and data visualization. We expect that with creative design thinking visualization, the thinking process can be better taught and understood.

We have demonstrated some experimental prototypes and results in this paper. Our future work will include exploring a more systematic approach to design architectural specific mechanisms for visualizing design thinking. We will also conduct evaluation of the visualization systems in design education.

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References