THEME III. INTELLIGENCE

DESIGN INTELLIGENCE (4A)

EXPLORING INTENDED IMPLICATE SOLUTION

from searching through discrete continuous design graph

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Abstract. Design is an iterative exploration process that will invoke many fragmented information with continuous iteration. While fragmented, implicit information lay among these fragmented pieces has shown more potential to achieve some goals that we might skip during the decision-making. These potential design goals named *implicit intended solution* are the problem spaces we want to explore in this research. Therefore, the continuous thinking/operation process cross these fragmented design decision might show some insights for discovering implicit intended solutions. This is a two-fold problem, without exploration and its continuous iteration characteristics, these solutions might not even be found or possible found. Therefore, in this paper we have conducted a research based on visualizing these implicit intended solutions as well the exploration process for finding them.

Keywords. Design diagrams; time-based media; visualization.

1. Background

Design process is an iterative exploration process that will invoke many fragmented information with continuous operations. While fragmented, implicit

information lay among these fragmented pieces might have more potential to be our primary solution than the ones already chosen. Additionally, a complete solution graph with its infinite nature is not feasible for practical reasons. This paper is presenting an alternative representation tackle this problem. Based on the derivation graph (example shown in Figure 1), we name these implicit but intended solutions within the fragmented search process over design graph *implicit intended solutions.* For testifying this approach, we use *design diagrams* and *continuous operation* for the purpose of defining our visualization representation—time-based graph. Each will be elaborated in the following sessions.

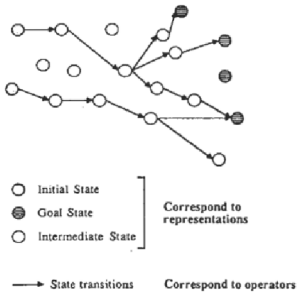

Figure 1: A state-based view over design process (Woodbury, 1991)

1.1 DESIGN DIAGRAMS

Design diagrams are often used for analysis or representing partial information within a complex design context (Chang, 2008). Among many types of design diagrams, design process diagrams are the one we are aiming at. They can represent the transition among design decision as well as the visualization of process itself. Moreover, the logic for design transition is also shown in the diagrams while organized them into the state space.

Three main characteristics of design process diagrams above: 1) strong design knowledge relation: the diagrams while representing the design have strong connection with the design knowledge as well as the solution from the knowledge; 2) structured description with visual: the syntax as well as semantic can be adopt with ease since the organization of diagrams is structured with sequential reasoning capability; 3) direct visualization with design: since the diagrams often are from the sketches draw by the designers, the visualization is direct and strongly related to the outcome of design.

Furthermore, while the processes among these diagrams are continuous, the visualization of these diagrams is discrete because of the nature of static diagrams. Therefore, a dynamic and continuous representation over these

diagrams or so called discrete continuous design diagrams is desired for the purposes of exploring implicit intended solutions.

1.2. CONTINUOUS EXPLORAITON

Diagrams described above contain the discrete operations. We need to find some continuous operations across the design process diagrams in order to provide essential operations. In architectural or similar design domain, the folding (Lynn, 1999) operation is often used to investigate continuous form and their consequences can be adapted for the purpose of continuous operation cross discrete design diagrams.

Via the diagrams shown by Peter Eisenman and other architects, this folding can also be represented by modelling operations with sequential diagrams (Eisenman, 1999) (shown in Figure 2). Also, the comprehensive diagrams published by Eisenman (Eisenman, 1999) with folding operations provide essential first-hand design information for this research.

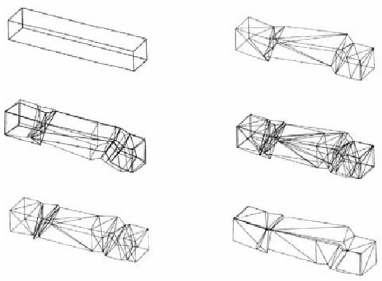

Figure 2: Diagram of Emory Arts Center.

Furthermore, the folding inspired by Computational Origami (Andersen, 2002) provides the mathematical foundation for 3D diagrams representation as well as the continuous media—time-based media that is used for our conceptual metaphor of our design graph.

1.3. WHY WE WANT TO VISUALIZE CONTINUOUS DESIGN PROCESS

While the implicit intended solutions are implicit and difficult to represent, the visualization of these solutions might be the way to understand the solutions themselves. On the other hand, the relations between two design solutions (often represented visually with pictures or drawing) are represented by diagrams. Further with the continuous operation, a case study and a visualization tool is developed according to our research intention—finding the implicit intended solutions among fragmented design decisions. The following sessions

show the often used design diagrams as the possible visualization of our design process and the continuous exploration over these diagrams.

2. Research Steps

With the design information—design diagrams in place, continuous operation cross these diagrams need to be visualized in order to understand the exploration process itself. Therefore, the design problem in this paper is divided into two parts: 1) how to represent continuous (time-based) design exploration process with suitable representation; 2) what are the characteristics of time-based media that can be adopted into selected representation. Finally, how to elaborate the design graph according to the lessons learned from the visualization of design process.

Four steps are described as follow. First are the literature reviews that are comprised of models of design and time-based media reviews. We need to discover a way to integrate the continuous characteristics of continuity. Time-based media is the domain in our focus because of its time factors and visual feedbacks. The review criteria are based on how we can integrate the mechanism into derivation-like graph and with the design diagrams available. Second is leaning from diagrams using folding as the continuous form transformation operation. By simulation and observation, exploration process is argued and discussed for finding possible characteristics of continuous exploration process. Thirdly, the exploration criteria are elaborated and simulated in finding implicit intended solutions in the design graph. The features of time-based design graph are unleashed and a possible conceptual model for design process is thus generated. This we name a *time-based design graph*.

3. Literature Reviews

3.1 MODELS OF DESIGN

Many models of design such as analysis-synthesis-evaluation (ASE), Case-based, cognitive approach, algorithmic design and artificial intelligence (Braha & Maimon, 1998) are presenting different views over design process. Further, each vertex in this state space represents a design and the edge of two vertices is the operation that transfers the design from one vertex to another. We are favouring derivation-like design graph because of its step-wise nature and graph-representation that will easily be adapted for the exploration process of design.

3.2 TIME-BASED MEDIA REVIEWS

Time-based media, in general, describes the information with extra factor—time, and the continuous transformation over time. With the continuous operations over design diagrams, time-based visualization for the diagrams and the continuous operations (folding in this case) provides the continuous visualization over form transformation. Time-based media provides the fourth dimension view on the 3D diagrams above.

The animation is the key to provide the needed transformation visualization. The connected path among these diagrams can then be visualized as the timeline or the animation for the form transformation path. Further among these representation cases, two are mostly relevant; one is the comparison of transformation within single model. Differences and comparison of multiple information is captured in a single model (Dionisio & Cárdenas, 1998). Another uses stages to divide the timeline into several timelines. Multiple stages contain multiple timelines (Girgensohn, Shipman, Dunnigan, Turner, & Wilcox, 2006).

4. Learning from Diagrams—Defining Design Graph Representation

Based on the reviews above, we organise the continuous form transformation as it appeared in the diagrams into the derivation like design graph representation. Starting from observation, graph structure analysis, each is described as followed.

4.1 OBSERVATION AND GRAPH STRUCTURE ANALYSIS

Design diagrams used in this research is derived from the Project Emory Arts Center (Eisenman, 1999) (sample of diagrams and the model created are shown in Figure 3). With time-based characteristics described above, each derivation path is conducted as an animation series and represented as a sequence of derivation vertices in the derivation-like graph.

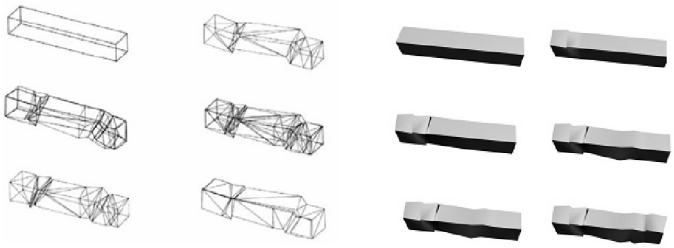

Figure 3: Diagram and model of Emory Arts Centre

When most of diagrams are connected as a continuous animation, the possibility for finding implicit intended solutions are explored in three direction graphically 1) possible alternatives of each vertex provide horizontal dimensional exploration; 2) one vertex to next vertex provides vertical exploration; 3) the path from one vertex to another vertex in the graph provides a sequential representation and recording mechanism on the form transformation process. For analysis purpose, we lay the form transformation diagrams from Eisenman in the middle of graph, then, expand the graph vertically and horizontally. Starting by discrete decision such as the degree of folding, each decision making as the simulation of designing is recorded and generated. An example is shown in Figure 4.

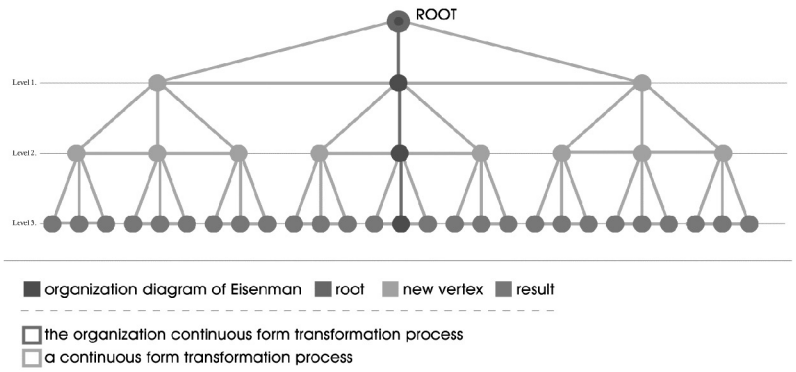

Figure 4: continuous form transformation realized in a state-space like graph

Based on observation, such representation has cycles that will increase the complexity for exploring intended implicit solutions among these cycles. Based on the derivation-like design behaviours observation, the graph is refined as directed acyclic graph (DAG). Each edge is the operation (folding) applied to a set of geometry that is represented as the vertices. (Shown in right-most of Figure 5) Based on this representation, design process over continuous form operation is simulated and illustrated (Figure 7).

For the simulation of the design process, we discover the expanding of the graph is following—checking the continuous form transformation, we create a break-point between two vertices and derive another thread of sequential form transformation. However, while comparing to complete derivation graph, the derivation from Time-based graph can be viewed as a partial graph of the complete derivation (shown in Figure 6). This reveals another advantage of this approach: to realise the partial but goal-oriented derivations without computing the whole derivation.

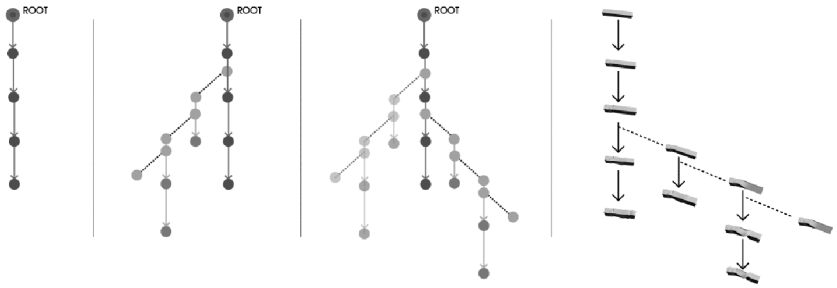

Figure 5: graph inference process

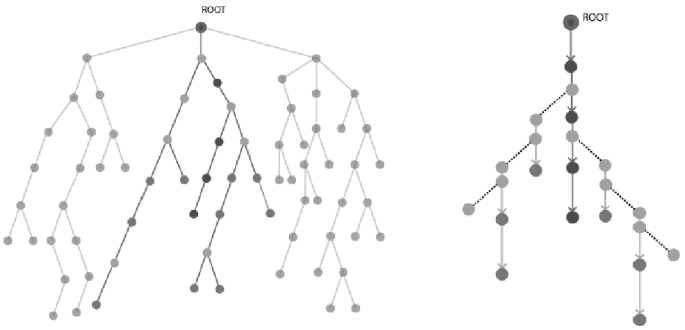

Figure 6: the Time-based graph is partial complete derivation graph

4.2 TIMELINE—A PATH

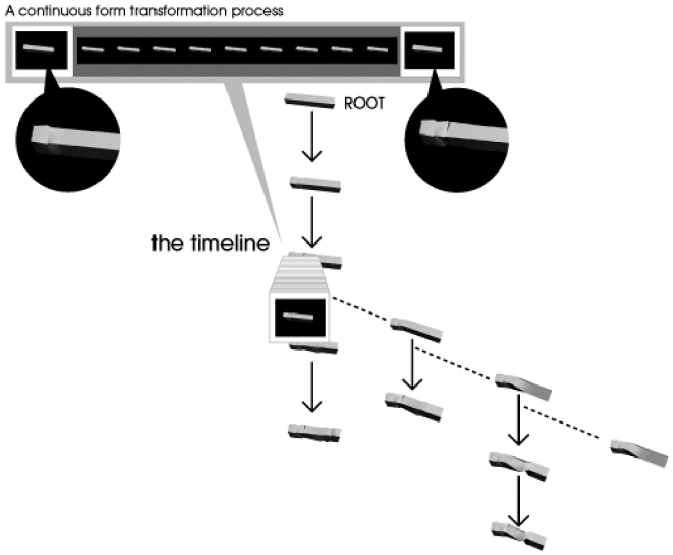

Figure 7. A continuous form transformation process

Base on the time-based media simulation with graph structure analysis over several similar cases, we observed five phenomena: 1) once discrete design decisions are made, the continuous operation can generate detailed different alternatives with fine tune; 2) each solution can be generated via various path while each path might reflect some part of design thinking; different path can provide continuous decision making vertex constantly and effectively; 3) Each vertex represents one operation with parameters defined, therefore, the continue operation and the transition between operations can provide more diverse design solution; 4) due to the nature of derivation, multiple timelines are desirable; 5) comparison between different alternatives and different path can provide better visual feedback, and different timelines are also able to be compared according to the time factor. These five phenomena show some insights for providing a better design graph, especially for the design itself and the way to achieve the design.

5. Time-Based Design Graph

Following the analysis and five phenomena unleashed above, the Time-Based Design Graph should provide 1) design decision making should lay out the discrete derivation graph before the continuous exploration occurs; 2) the edges between vertices provide a memory mechanism for the transition between vertices; 3) generative characteristics can be defined as creating new vertices on the graph; 4) two or more timelines are the key for integrating derivation information with continuous operations; 5) should have the capabilities to visualize and compare different design paths with intuitive interface.

During the exploration process among the graph, two-dimensional timelines should be able to represent the dynamic characteristics. In addition, from the time-based media reviews, we discover, if we want to visualize and compare multiple dynamic solutions, layers are one of key metaphors for two or more continuous processes. Different event in different context can also generate diverse procedural information. An example of the Time-Based Design Graph is shown in Figure 8.

Following the graph shown in Figure 7, vertical and horizontal transitions are two key factors for time-based media, thus we can use these two factors as the exploration operation for finding possible solutions and further the implicit intended solutions. While designers select different vertex in different path can be used to generate different path comparison for different time layers and further provides visual feedback.

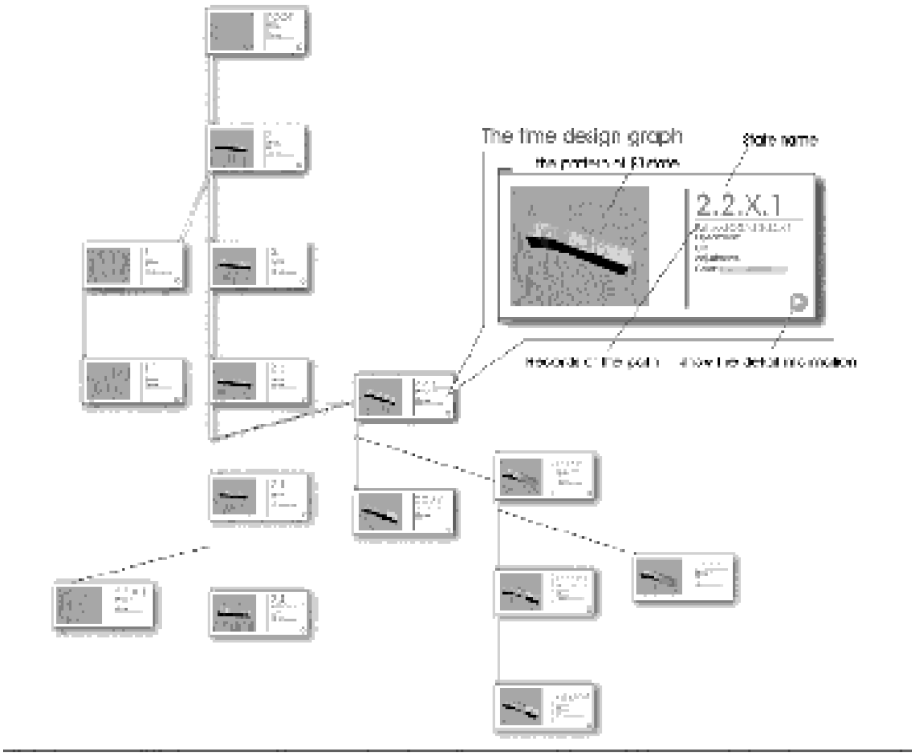

Figure 8: Time-based exploration simulation

6. Discussion and Conclusion

Design iteration is important. Recording the process of design iteration provides further information for discovering the implicit intended solution among discrete design decision making. Time-based media or just time-based factor provides a way to represent the continuous design activities and the thinking process in the derivation. Visual feedback let designers clarify their design concepts and can the focal steps of decision-making becomes easier to find.

The designer may leave out possible solutions when they are in the midst of the design process. Through developing an animation record of the design process, we can know the decision-making require more development, by the continuity of the design process so that we can let designers to explore the design decision-making. Therefore, when the design process adds the factor of which one is continuous, the design process step is: 1) decision-making, 2) and observe, 3) exploration, 4) then proceed to decision-making again. If we can make the different timeline paths be comparable to each other, exploration of the design process will be better.

Single timeline can't to show the design process adequately. Different paths of simultaneous representation are important. We will make the decision first and then observe, when we are in the continuous part of the design process. And the timeline will help us to explore possible alternative solutions. In the future, we will use computers to record the design process and develop the Multi-timeline system to better support designers to explore alternative possible design solutions.

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