A DERIVATION GRAPH OF COMPUTER MODELS FOR THE DESIGN PROCESS ON THE WEB

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Abstract. To propose a derivation graph by utilizing Computer modeling to represent the thinking processes in the design of Akkach House that will be demonstrated on the web.

1. Introduction

The thinking process for creating something that does not yet exist comprises a range of mental activities, from defining the purpose, creating the form and defining the meanings as well as the practicality of form, to adapting an appropriate technique for producing the objects. This mental process is termed Design.

Design is not often a linear process; options are explored and paths of potential solutions are generated and assessed. It is a learning experience in which the interdependencies of problems and solutions, the new and the old, are explored (Jones, 1979). When the potential solution is rejected as unsatisfactory, the designer often returns to an earlier stage and a new design path is then generated.

The design process relies on the memory of early design explorations, experiences and prototypes. One of the records architects or other designers have of their design process are the series of sketches drawn at various stages of the design (Akin, 1978). Each individual sketch provides a ‘snapshot’ of the particular stage of the design process. However, the thought process from one stage of the design to the next is rarely recorded.
The focus of this paper is representing the design process through the use of computer models to externalize the 'memory' of the architect/designer of a project. Each computer model is not only a representation of an abstract idea but also a snapshot of the particular design stage. Clustering the computer models in terms of interrelationships allows the creation of a visual record for stages of the design process. Most importantly, a record of the thinking process is created and this process becomes transparent so that it can be better understood. Professionals, researchers and students can use this record.

The representation of computer models presented here is derived from investigating related research works on generative design systems and knowledge-based design systems but differs in significant ways. These differences will become evident as the models are applied to the chosen case study of Akkach House and a representation called a derivation sequence graph derived. One particular design process of the architect Samer Akkach will then be demonstrated as a web site.

"A design process is about the sequence of events. It can be defined as the sequence of design order. It starts with two design-oriented events. Between the two is a period of time. A period of time in which stages and sketches are involved." (See “Interviews with Akkach” on the web)

2. A Derivation Graph

The paper commences by defining three key components of the derivation graph: direct links, an alternative graph and a partially completed sequence. The resulting derivation graph is shown on the web. Each node of this proposed tree-like derivation graph is a partially completed geometric computer model of one particular stage in the design process. The computer models are made from the first-hand sketches shown on Figure 1 provided by Akkach. To explore whether this derivation graph could be mappable to the internal memory of Akkach, we then go on to define components of the derivation graph in relation to the design process and use them to describe the mode of thinking in design. This derivation graph only represents partial information of the design process of Akkach House. It also attempts to demonstrate the influence of the architects' dual-cultural background on some of his design decision-making.
The nature of design has the attributes of the structure of a tree, especially the branches. A branch always grows out from one node and branches out again. All derivation graphs are composed of three basic components: a direct link graph, an alteration graph and a partial derivation sequence. They will be defined based upon their structure in relation to the design process.

2.1. A DIRECT-LINK GRAPH

A direct-link graph which is shown on Figure 2 displays a direct transformation and makes a connection between two design ideas. It shows a one-to-one relationship. The computer model above the arrow represents the initial idea and the one below the arrow is derived after a concept is introduced.

![Figure 2. Direct-link graphs from early stage to later stage](image)

The relationship of a direct link graph is based on a one-to-one partially completed design order. Any direct link gives the opportunity of either tracing directly back to the previous design stage and generating another new idea, or going directly down to the next development stage.

It is often difficult to imagine the link between two design ideas and, therefore, it is also difficult to understand the relationship between them. This is because this link is often very abstract. As the basic component of the derivation graph, a direct link graph enables the link between design ideas to be concretely depicted.

Every computer model for a direct link graph represents a partially completed design idea at one moment in time. The actual line of direct link is also the metaphor for a period of time elapsing between two related partially completed designs. Utilizing the line to connect two partially completed design ideas is to
make a clear record of a design sequence and indicates the interrelationship between two designs.

The aim of formalizing and deriving direct link graphs from the sketches is to segregate and show possible design ideas at one particular time of the design process. In the design of the Akkach House, the sketches clearly reveal a strong notion of interplaying forms and relative positions. The direct link graphs make it easier to understand which design features are common between design ideas and the differences between design ideas. The following paragraphs are the exploration of the chosen direct link graphs with cross references to interviews and sketches. These graphs appear according to my own interpretation of the order in which design ideas took place.

2.1.1 Architect's Intention: Volumes
The sense of enclosed spaces in Akkach House is important. It affects the desired spatial experiences and conduct in the house. From observation and interviews with Akkach, the volumes are designed according to the specific functions of the spaces. Consciously, Akkach had clear images for certain qualities of spaces and the relationships between each space.

The purpose for Akkach here is to explore with volumes shown on Figure 3. The volume of one space is fixed and the volume of the second changed. The aim of exploring the change in geometric shape, and therefore volume, is to find the relationship between the two spaces and the spatial experience. For instance, the relationship between the courtyard and the kitchen, the lounge room and the entrance are explored. One geometric space of each graph is fixed in turn, and the other one altered until the most harmonious proportions are achieved.

"spatial experience of moving around the side, with approaching the house and with moving inside the house.....".(See “Interviews with Akkach” on the web)

Interpretation of Intention with Direct Link Graph: The idea of two independent spaces is kept in mind. This direct link graph reveals the design thinking of reducing the size of one geometric form while the other one remains fixed.
In this graph, the relationships between the courtyard and the kitchen, the lounge room and entrance are dramatically changed. The space of the courtyard is decreased but this is offset by the change in the relationship between the courtyard and the kitchen. The spaces become closer and more related. The sense of cultural belonging and longing described by Akkach is retained. From an aesthetic point of view, the adjusted proportions for these two forms show more elaborate thinking about the relative architectural experience.

When two or more ideas are derived from a single original, the one-to-one relationship is changed to a one-to-two or more relationship. If more than one idea is derived, the direct link graph is no longer an appropriate term to describe the complex relationship. Instead, the term of an alternatives graph is used.

2.2. AN ALTERNATIVES GRAPH

An alternatives graph represents clusters of potential design solutions and demonstrates their interrelationships with their prototype. It is a one-to-many relationship. It is a multiple-step for one design concept and it is looked at from top to bottom. Each computer model below the arrow represents one particular idea/solution derived from the one above the arrow.

An alternatives graph shown on Figure 4 composed of at least two direct link graphs between one origin and at least two potential later design forms. This concept is based on concepts of search and exploration the design process, known as design space exploration (Woodbury 1987, Chang 1998). Design space exploration is physically expressed through this derivation graph.

Design is often described as a decision-making activity. This implies that choices do exist within the domain of the design process, and an alternatives graph is simply a structural exploration of design behaviour in terms of decisions about design options. It is a representation of the relationships between an existing design state and modified or new design states in the design process.

Each alternatives graph represents two design stages in time but does not describe how much time passed during the two stages in the design process. Due to the lack of dated records of the design of the Akkach House, the sequence in which the sketches were drawn is uncertain, and therefore this alternatives graph may not display the potential design stages in correct order. This is key
information about the design process which the alternatives graphs cannot provide when created in retrospect. However, the interrelationships between new design state spaces are still clearly demonstrated.

The significance of cultural diversities and professional experiences is demonstrated through the design process of Akkach House. The alternatives graph represents the abstract design state spaces of Akkach House.

2.2.1 Architect's Intention: Composition of Forms, Volumes and Circulations between Spaces

Akkach's intention at this specific design stage was to explore potential solutions for geometric forms which enhanced the views and the nature of landscape and framed the spatial experience. In this particular case, three design ideas were generated, based on the initial design state space of one rectangle and one triangle. Akkach's consideration of alternative forms, volumes, relative positions and transition between spaces are clearly shown by the alternatives graph shown on Figure 5, which represents his own early sketches.

Figure 5. Intention for Forms volumes, relative positions and circulation

"continuous interaction with the views and the nature of the landscape, and the ways in which the created spaces were going to enhance or frame the spatial experience in one way or another............" (See “Interviews with Akkach” on the web.)

An interesting discovery from an alternative graph: In the alternatives graph above, unlike the previous chosen graphs shows the two design state spaces below the arrows take place in different design stages. This particular graph shown on Figure 6 makes a significant contribution to the understanding of the structure and the design behaviour.
Lower ground space is changed due to the construction reasons on the hill side.

Figure 6. The alternatives graph with different design stages.

Discovery: One feature of this alternatives graph, which is distinct from previous graphs, is that it shows the interrelationships between two derived graphs. Because the intentions are taking place at different stages in the design process, the meaning of the link on the right is interpreted slightly differently. It is no longer a direct transformation from one design state space to another. Instead, it is a link that represents a design route.

2.3. A PARTIAL DERIVATION SEQUENCE GRAPH

A partial derivation sequence graph shows a completed sequence of one specific design result. It displays multiple successful pathways of design development for the design process. For the Akkach House, the intention of a partial derivation sequence graph is to demonstrate the evolution of design thinking and trace the design pattern, if there is any.

A partially completed derivation sequence is generally a representation of the journey of exploring each design state space of different stages. It displays one specific pathway from the initial design stage, through the chosen one of the potential developments for different design stages, to the final design stage. Therefore, the partially completed sequence also can be described as the "design route" of the design process.

An unexpected partially completed sequence: One potential of showing this sequence is to demonstrate a possible 'short-cut' within the design process shown on Figure 7. Referring to this sequence, it also provides the chance for the architect to see the design route for the Akkach House.
The derivation graphs of Akkach House clearly demonstrate the possible potential solutions to a particular design problem and illustrate the existence of 'short-cut' design routes.

3. The Derivation Graph on the Web

After the decision to represent the graph on the web, various questions remain to be answered. How is the derivation graph to be viewed on web? What kind of exploration behaviour will the derivation graph allow? Will the derivation graph be interactive with the viewers?

In order to keep the consistency of the representation throughout the derivation graph on web, 3D computing models are used for the purpose of better spatial visualization. Since the computing models of the derivation graph are transformed from the first-hand sketches provided by the architect, the correctness of the interpretations made by the CAD model-builder from the 2D drawings to 3D CAD models is vital. Interviews with the architect are inevitable and crucial in this process.

The derivation graph will be programmed to display on web as a whole. As the cursor moves on top of one particular model, a larger scale image of that model will be displayed. When the viewer clicks on that particular computing model, a new window of that design model along with previous and next design stage models will be shown. Viewers will always keep in mind the transformation between design spaces and furthermore, they can understand the notion of design space exploration.
4. Conclusion

Finding a representation for the sequences in a design process is not easy. Drawings, models or photographs are the most common media used. However, these media only provide a snapshot at one specific stage of the design process and they also fail to demonstrate the links between stages. Therefore, the thinking process in the design which lies within the architect or designer remains a mystery. The use of derivation graphs is an attempt to externalize this thinking process, documenting the sequence of the design process more accurately and in a form which is more easily, visually comprehensively. The derivation graph then unfolds the mystery of the design thinking process.

The use of derivation graphs is an attempt to externalize the thinking process, documenting the sequence of the design process more accurately and in a form which is more easily, visually understandable. The derivation graph not only unfolds the mystery of the design thinking process but also demonstrates the possible potential solutions to a particular design problem. Most importantly, it could illustrate the existence of ‘short-cut’ design routes. Placing such derivation graphs on the web gives designers and students from every corner of the world a chance to better understand design behaviour and provide a focus for its discussion.

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References

1 “Interviews with Akkach” is shown on the web page at
2 This proposed derivation graph for the design process is also on the web at