What Architects See in Their Sketches: Implications for Design Tools

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ABSTRACT
Freehand sketches are essential for crystallizing ideas in the early stages of design. Through the act of putting ideas down on paper and inspecting them, designers see new relations and features that suggest ways to refine and revise their ideas. We claim that seeing different types of information in sketches is the driving force in revising design ideas. Our retrospective protocol analysis revealed that sketches make apparent to designers not only perceptual features but also inherently non-visual functional relations, allowing them to extract function from perception in sketches. This has implications for ways that future sketching tools can stimulate designers to come up with creative ideas.

KEYWORD: design sketch, sketching tools, architectural design, protocol analysis, creativity

INTRODUCTION
A designer usually begins with freehand sketches in order to come up with promising ideas/concepts/themes, and later turns to using drafting/CAD modelling tools and/or to building mockups in order to visualize, compare, and implement them [3]. Most computational tools available facilitate the latter process. Few tools are available to aid designers in the former process so that freehand sketches remain a kind of art that only skilled and prolific designers have. Our ultimate goal is to implement easy-to-use and enlightening sketching tools, especially for novice designers.

With this goal in mind, we have been observing how professional architects and advanced students use freehand sketches in the early design process. Goel [1] has argued that the properties of "density" and "ambiguity" that distinguish early freehand sketches from drafting-type diagrams are critical for crystallizing design ideas. Schon et. al revealed that inspecting their own sketches allows designers to make unintended discoveries [5]. Architects put ideas down on paper and inspect them. As they view their own sketches, they see new relations and features that suggest ways to refine and revise their ideas. This cycle --sketch, inspect, revise--is like having a conversation with one's self [5]. Why and how do architects get new ideas from their own drawings? Our research suggests that seeing different types of information in their sketches is the major driving force. This paper explores that process in addressing two questions. What types of information do architects extract from their sketches? How do practicing architects differ from students? We brought these phenomena into the laboratory in a retrospective protocol analysis study.

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EXPERIMENT
Experimental Design
Each subject, a practicing architect or advanced student, worked on designing an art museum with certain specifications through successive sketches for about 45 minutes, while videotaped. Later, while watching the videotape, each subject was asked to report what he/she was thinking as he/she drew each portion of each sketch. This session took about an hour. Two architects and seven students participated in this experiment.

Method of Analysis
We classified all the information in the protocols into four information categories: emergent properties, spatial relations, functional relations, and conceptual knowledge. These were further divided into subclasses. Table 1 shows the four categories and their subclasses.

Table 1: Information categories and their subclasses

Information Category	Subclasses
Emergent Properties	<spaces>, <things/items>, <shapes/angles>, <sizes>
Spatial Relations	<local relation>, <global relation>
Functional Relations	<views>, <lights>, <circulation of people/cars>, <other functional rel.>
Conceptual Knowledge	no subclasses

For each subject, we first encoded all the information in the protocol into the subclasses of information categories. Then we divided the protocol into segments that concerned the same item/space/topic. A segment usually included a couple of information categories. An entire protocol typically consisted of hundreds of segments. When several contiguous segments were conceptually related, they were grouped into "dependency chunks." A shift of focus signalled the beginning of a new dependency chunk. We call the first segment of each dependency chunk a "focus shift" segment, and the subsequent segments within each chunk "continuing" segments. There were typically about twenty to fifty dependency chunks per protocol.

Results

Table 2 displays the percentages of each type of information for focus shift and continuing segments for architects and students. There were striking similarities and differences between architects and students in their interpretations of their sketches. For both, the predominant information in focus shift segments was spaces, whereas the predominant information in continuing segments was local spatial relations. This means that finding spaces was the major impetus for shifting focus to a new part of a sketch whereas examination of local spatial relations was the stimulus for continued consideration of related topics. As for differences, architects had both more and longer dependency chunks than students. This means that once architects shifted their focus of attention, they thought more deeply about the topic. We believe this occurs because architects are able to "see" more abstract information in their sketches.

A more detailed analysis of the data in Table 2 supported this claim. The highlighted portions of the table indicate significant differences between architects and students. In focus shift segments, architects considered information about shapes/angle, sizes, circulation and other functional relations more than students. This means that architects, in contrast to students, began thinking about more complex visual relations and some functional relations as soon as they shifted attention to a new part of a sketch.

Table 2: Distribution of Information Categories in Protocols of Students and Architects by Segment Type

Subclasses of information category	Focus shift segments			Continuing segments		
	students aver.±std.	archi-tect1	archi-tect2	students aver.±std.	archi-tect1	archi-tect2
spaces	36.5±5.4	32.4	22.3	19.8±4.1	19.6	15.8
things/items	9.2±5.4	2.4	6.3	4.1±2.5	4.5	3.6
shapes/angle	5.8±2.8	12.2	14.3	8.4±2.9	5.3	4.8
sizes	2.4±2.2	9.8	11.2	3.3±2.0	1.9	4.2
global sp.rel.	9.6±6.3	6.5	7.9	6.3±2.5	4.8	5.5
local sp.rel.	8.1±5.0	5.7	9.5	20.2±3.2	19.1	18.8
views	5.2±2.6	2.4	3.2	5.4±2.3	9.3	6.7
lights	2.1±1.7	3.3	3.2	1.0±1.1	4.3	0.6
circulation	8.1±2.8	11.4	7.9	8.1±1.8	13.8	9.1
other func.	4.8±1.9	4.1	7.9	13.3±3.3	12.4	16.8
knowledge	8.2±4.7	9.8	6.3	10.1±2.2	5.0	14.1
total	100	100	100	100	100	100

Note: Categories in which architects had a significantly higher percentage of responses than students are highlighted.

In contrast, in continuing segments, architects differed from students only in the consideration of more functional relations. This means that architects continued to interpret functional relations, such as views, lighting, circulation, and so on, more frequently than students as their thinking progressed within a dependency chunk. Because they were able to think about both perceptual and functional features and relations at the same time, they could pursue design thoughts more deeply than students, who seemed to shift focus aimlessly.

This analysis has revealed that sketches make apparent not only perceptual relations but also inherently non-visual functional relations to both advanced design students and practicing architects. Practicing architects are even more adept at extracting function from perception in sketches.

CONCLUSIONS

The previous studies of the early stages of design were limited to macroscopic characterizations of the interactions between designers and their sketches [1, 5]. We have characterized in a microscopic way the types of information that designers "see" in different phases of the design process. We have shown that sketches make apparent not only perceptual relations but also inherently non-visual functional relations to both advanced design students and to practicing architects. Practicing architects are even more skilled at extracting function from perception in sketches.

IMPLICATIONS FOR DESIGN TOOLS

Two projects on pen-based sketching tools have also examined how designers use freehand sketches with the goal of specifying features useful to implement in design aids. Kramer [4] pointed to the dynamic and fluid associations between sketched marks and their interpretations, and Gross [2] observed the necessity of retrieving past inventories of sketches from current ones. The intent of these projects is to create an environment in which the designer's initial acts of formulating ideas are encouraged rather than hampered. This may be the first step in developing new sketching tools.

What is the next step? We propose pursuing a tool that can influence and stimulate what designers "see" their own sketches. Our vision is of a tool that will, in response to sketches drawn on an electronic pad, superimpose other stimuli on the sketches and provide a menu of functions that enable manipulations of sketched objects or lines. The present results have demonstrated the importance of thinking of functional relations from the perception of visual features in sketches. What aspects of sketches suggest the different functional relations? This line of research is expected to reveal the kind of superimpositions and manipulations on early sketches that effectively cue designers not only with purely perceptual features, but with functional relations as well.

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