The Intelligent Sketch: Developing a Conceptual Model for a Digital Design Assistant

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Abstract

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The computer is a relatively new tool in the practice of Architecture. Since its introduction, there has been a desire amongst designers to use this new tool quite early in the design process. However, contrary to this desire, most Architects today use pen and paper in the very early stages of design to sketch.

Architects solve problems by thinking visually. One of the most important tools that the Architect has at his disposal in the design process is the hand sketch. This iterative way of testing ideas and informing the design process with images fundamentally directs and aids the architect's decision making.

It has been said (Schön and Wiggins 1992) that sketching is about the reflective conversation designers have with images and ideas conveyed by the act of drawing. It is highly dependent on feedback. This "conversation" is an area worthy of investigation. Understanding this "conversation" is significant to understanding how we might apply the computer to enhance the designer's ability to capture, manipulate and reflect on ideas during conceptual design.

This paper discusses sketching and its relation to design thinking. It explores the conversations that designers engage in with the media they use. This is done through the explanation of a protocol analysis method. Protocol analysis used in the field of psychology, has been used extensively by Eastman et al (starting in the early 70s) as a method to elicit information about design thinking. In the pilot experiment described in this paper, two persons are used. One plays the role of the "hand" while the other is the "mind"- the two elements that are involved in the design "conversation". This variation on classical protocol analysis sets out to discover how "intelligent" the hand should be to enhance *design by reflection*. The paper describes the procedures entailed in the pilot experiment and the resulting data. The paper then concludes by discussing future intentions for research and the far reaching possibilities for use of the computer in architectural studio teaching (as teaching aids) as well as a digital design assistant in conceptual design.

1 Introduction

Architecture as a profession has always relied on tools to get the job done. The computer, the latest of such tools used in practice, is so recent that most senior practitioners have little or no experience using it. Today, its use has been mainly in the realm of drafting and production. Notwithstanding this, there has been a desire amongst designers to use this new tool quite early in the design process. Practical reasons such as the need to get information digital as early as possible and the computers potential to generate several options have added some credibility to this desire.

Despite this willingness, most Architects, even today, still use pen and paper in the very early stages of design to sketch. (Novitski 1991; Haapasalo 1997). Based on this observation, it would seem that computers are unsuitable for the early stages of conceptual design. At present, it is widely admitted that characteristics of the computer make it inept when used with "traditional" methods of design thinking, *especially* in the earlier stages of design. (Soufi and Edmonds 1996; Haapasalo 1997;

Novitski 1991). The fact is; Architects still prefer the simple interface and tactile feedback of sketching to using computers (Palmer 1998). This places an importance on comprehending the role the sketch plays in the activity of conceptual design.

This paper discusses sketching and its relation to design thinking by exploring the *conversations* that designers engage in with the media they use. It suggests two essential players (the mind and the hand) in these conversations. The paper introduces a pilot experiment derived from protocol analysis with a view to examining the activity of sketching. This unique analysis is designed to determine the nature of the interaction between hand and mind, specifically how intelligent the hand has to be in order to enhance the design process. Descriptions of the procedures entailed in the pilot experiment and the resulting data is given. It then concludes by discussing future intentions for research and the far reaching possibilities for use of the computer in architectural studio teaching (as teaching aids) as well as realising the computer as a digital design assistant in conceptual design.

2 Sketching and the Design Process

Design process is seen largely as the activity of organising ideas in order to produce a desired result. It involves synthesising or analysing various parts of the "problem" in order to understand or reveal the overall "essence" or solution.

Architects design by thinking visually. This visual activity makes extensive use of images. The designer understands an idea by putting it down on paper "to see if it works". The process by which images are used as fundamental objects for design decision making can be called graphical thinking (Laseau 1989), or design drawing (Lockard 1982), or simply sketching. This iterative way of testing ideas and informing the design process using images fundamentally directs and aids the architect's decision making. Therefore, one of the most important tools that the Architect has at his disposal in the design process is the hand sketch.

2.1 Conversations in Design

One school of thought sees the early stages of design as conversations being held with the materials of a design situation (Schon and Wiggins 1992). Sketching, therefore can be referred to as the reflective conversation with images and ideas conveyed by the act of drawing (Schon and Wiggins 1992). In his book "Graphic Thinking for Architects and Designers", Paul Laseau agrees with this premise by claiming that the process of graphic thinking can be seen as conversations with ourselves in which we communicate with the use of sketches (Laseau 1989).

Using Schon's argument we can infer that a reflective conversation is about the designer seeing what is there, drawing in relation to it, seeing what is drawn and so further informing the design. To put it simply, The Architect makes a mark, criticises it and makes a decision based on this criticism (with a desired result in mind). New ideas are really new ways at looking at and combining old ideas with the use of the eye, brain, hand and sketch (Laseau 1989). The activity of sketching is therefore interactive and highly dependent on feedback. This interactivity involves chiefly two thought processes - the coming up with ideas and the interpretations of those ideas in order to represent them in a physical sense and spatial sense. The brain through the eye reacts to the sketch the hand has drawn. This can be translated into two players – the mind and the hand. The question is - What is it the "hand" should know to better inform the "mind"?

2.2 Drawbacks with sketching

Despite being a premium tool for design there are some limitations in the activity of sketching. The sketch is a passive medium and relies on initiative from the designer. The designer has to be experienced in order to identify and react effectively to some of the multiple design issues embedded in a sketch. The fact that the sketch isn't digital (or compatible with CAD information) is another limitation. The reality that all information in the industry is digital puts the sketch at a disadvantage and poses the problem of transferring information into digital format that can be handled by the design team. The sketch is also labour intensive. Ideas usually require lots of reworking or redrawing resulting in information loss (Herbert 1993). Any attempt to bring the sketch into the digital realm would be welcomed by designers

3 Research

Research attempts to investigate and address the problem have ranged from examining emergent shapes (Soufi and Edmonds 1996) to applications that recognise sketch diagrams made on screen (Gross 1996). Most of the concentration in research however has been in making the *content* of sketching digital rather than considering its interactivity as an aid to thinking and taking advan-

tage of that quality in the digital realm.

Understanding the *act* of sketching is crucial to understanding how we might apply the computer to enhance the designer's ability to capture, manipulate and reflect on ideas during conceptual design. This comprehension would enhance designing by making the computer a partner in the process. The interaction of the designer and the media (in this case the computer) would be through the provision of an environment for decisions to be made. Research energy would be directed towards a design environment where there is sufficient feedback for the designer to be informed. Emulating this "conversation" is an area worthy of pursuance.

One technique of understanding the conversation that characterises sketching is by using a derivative of protocol analysis. This variation on classical protocol analysis sets out to discover how "intelligent" the hand should be to enhance *design by reflection*.

3.1 Protocol Analysis

Protocol analysis used in the field of psychology to study human problem solving and information processing techniques, has been used extensively by Eastman et al (starting in the early 70s) as a method to elicit design thinking (Eastman 1970). A protocol is the recorded behaviour of the problem solver or (in this case) the designer. This usually takes the form of " sketches, notes, video or audio recordings" (Akin 1986).

This research method usually involves sole designers verbalising their thoughts while they sketch and tackle the design problem. Since the 1980s, however, single person study has crossed over into team design activity. Protocol analysis has recently also been used to investigate techniques in computer mediated collaboration (Gabriel and Maher 1999).

3.2 Criticisms of Classical Protocol Analysis

Despite its popularity in eliciting "design thinking" classical protocol analysis has been criticised by some researchers. Critics usually say that:

- The small sample does not produce enough data

That protocol analysis techniques lack sufficient subjects to get a large enough sampling in which to make generalisations. Arguments to the contrary suggest that the dozens of observations found in the protocols of subjects offset the small size of the sample (Akin 1986).

- Concurrent verbalisation alters subjects' behaviour

Critics argue that placed under a "microscope" in this way make designers conscious of their actions and so tend to engage in activity they think the researcher wants to see rather than action they normally engage in. This criticism isn't easily refuted and can only be minimised if special care is taken to avoid this and the observer is as unobtrusive as possible.

- Experiments are not reflective of real design episodes

Supporters of this view point to the fact that there is no negotiation with clients, no discussion of ideas with peers and no opportunity for reflection (away from the task) (Lloyd, Lawson and Scott 1995). This view while being valid doesn't take into consideration that only the period of specific activity is under investigation and not the factors that indirectly *influence* design process.

4 A different approach to protocol analysis

Considering these criticisms and the aim of getting a clearer picture of the designer's expectations of the tools, an unexampled variation of the protocol analysis method has been developed to determine the interaction between hand and mind in design activity. This variation integrates classical analysis with that of collaborative environments. In the pilot experiment described in this paper, two subjects are used. One plays the role of the "hand" while the other is the "mind"- two elements that are involved in the design "conversation". The designer or *mind* tells the *hand* what to do. The *hand* then has the responsibility of coming up with images that would greatly assist the mind to grasp the problem and progress towards the design solution. The goals of this modification is as follows:

1. To determine the importance of *hand* sketching to the designer.
2. To examine the role images/sketches play in design activity.
3. To validate the purpose of a "design partner/assistant" in the design process.
4. To find what it is a computer needs to know to help the designer "sketch".

The protocols are established with the subjects being given a design problem to solve.

4.1 Advantages of this method

Approaching the investigation in this manner has some advantages. By allowing a dialogue between the subjects and looking at the questions the subjects ask each other one can begin to speculate on what sort of dialogue occurs when the designer is alone. Easily identifying the nature of the images and information requested by the designer to inform the process (and enhance his strategy) was thought worthy to investigate rather than solely concentrating on the designer's strategy. In addition, by using this technique it allows one subject the benefit of sketching without the added distraction of verbalisation (except to ask for clarification which itself can indicate importance of elements to represent data). The other subject verbalises without worrying about sketching. The behaviour of the subject is less affected by this arrangement. Data collected would illustrate two different approaches to design instead of one hence providing more data for analysis.
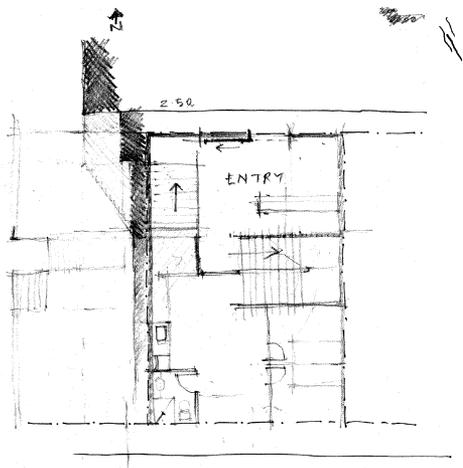

Figure 1. Design session 2 – student/hand, practitioner/mind

5 A pilot experiment

Two subjects - one a practitioner with over 9 years experience and the other a third year architecture student - participated in the experiment (Figure 1). The decision to use a practitioner and a student stemmed from the desire to witness what effect experience has on the activity. The experiment consequently was done in two design sessions.

In the first session the practitioner was given the role of "hand" and the student as the "mind" was given a design program for an architect/artists studio and gallery on an inner-city site (Figure 2). In the second design session the roles were changed and the practitioner as the "mind" was asked to design a 4-bedroom residence on a beach site.

During the experiment, the subjects had to adhere to the following "rules of engagement":

Hand:

1) Follow instructions of the *mind*; only asking questions as they relate to the image (except in 3)

2) Draw or illustrate concepts that you think would enhance the understanding of the *mind. The* hand *has a right to ask what projection/representation to illustrate (plan/elevation/section/3D) and what scale if any.*

3) Advise on the consequences to other design domains that are not being investigated. *The hand has a right to point out potential problems and discrepancies overlooked that has to do with the objective (practical) side of the design.*

Figure 2. Design session 1 – sketch for an architect's studio.

Mind:

1) Design a solution relying on images and information presented by the *hand*

2) Ask specifically for the image/information needed to make decisions. *The* mind *has a right to tell the* hand *exactly what is necessary in the image and what is redundant.*

3) Set out and specify the kinds of questions you want the *hand* to ask

4) Request any "non-visual" information from the *hand* i.e. solar paths, distances, max. room widths, stair configurations etc.

The designer was instructed to go as far as the end of the schematic design stage i.e. when the *mind* considered the scheme was ready for "drawing up" (i.e. ready for technical drawing/entering on the computer).The following *minimum* however, was required:

Floor plans (to some scale)

Site section (to some scale)

Elevation and/or another section (to some scale)

3D sketch (optional)

On average, each session took one hour (this was the time specified by the researcher). On both occasions a video camera was used to record marks on paper (by the "hand") as well as any gestures by the "mind" in directing the sketching operations. The sessions were also recorded on audiotape while the observer took notes of the activity. Prior to and after the experiment the participants were given a short questionnaire and engaged in a discussion with the observer about the activity respectively.

5.1 Subject responses to the experiment

Both participants in the experiment expressed delight in the exercise and thought it was a novel way to look at design. They declared surprise at their ability to verbally communicate design ideas well enough to get the needed feedback for further development of the design.

Persons in the role of "mind" claimed full authorship of their respective schemes despite having no physical connection to it; meanwhile the "hands" felt no stake or connection to the design despite producing the images. Interestingly the persons who sketched asserted that there was no "thinking" involved in their activity.

Subjects saw the experiment as mainly an exercise in planning with no architectural concepts involved. It was mentioned that they usually spend more time doodling (sometimes not "building things") before starting to design at which point codes and ergonomic issues "take over". This was attributed to the time limit imposed on the sessions.

Participants felt their usual process (whether sketching or designing) had to be modified in order for the other person to understand intentions but not to the detriment of the design. The student as "mind" expressed appreciation and benefit from having the answers "spat at me" in that it "made it easier to get your mind around the problem". The claim was made that the design was more "purposeful" when questioned (by the practitioner) as to spatial and physical aspects of elements. On the other hand, the practitioner found it frustrating having to specify precisely what image was needed. Both subjects reported frustration at not using their hands to draw.

5.2 Analysing The Data

The protocols of the subjects were transcribed and examined in conjunction with the video evidence by the researcher.

In order for protocols to be properly scrutinised to determine a suitable model of the activity, it is usual for a coding scheme to be developed. The development of the code is usually dependent on the researcher's view on design methodology. This influences how information derived from the experiment is examined and described.

According to Dorst and Dijkhuis, there are two different paradigms for looking at design methodology (Dorst and Dijkhuis 1995). One paradigm sees design as a rational problem solving process and so is more interested describing the process and examining concepts like acts, goals, contexts etc. The other viewpoint takes a constructionist approach and is influenced by Donald Schön's theories of design as a process of reflection-in-action. This takes a more content oriented approach while maintaining some link to process.

Since we have aligned our theoretical stance with that of Schön our approach to analysing the data, while being interested with the process, was more interested in the interaction between the two subjects and how they interacted with the images and information traded between them.

The observations and results presented below are based on first impressions of the data (as well as other observations used in the design of the pilot). Unfortunately, since we are looking at a preliminary overview of a pilot experiment, we can only at this point speculate on a likely coding scheme. Whether or not this coding scheme will resemble previous schemes or is unique is based in part, on how the results relate to previous analysis (Akin 1986; Gabriel and Maher 1999; Suwa, Gero and Purcell 1998). This researcher acknowledges that further detailed analysis is required to confirm first impressions and elicit other relevant pieces of information from the investigation.

P	Transcription (speaking)	Action	Observations
M	Storage space is going to be under there so entrance is from this side so coming in there at the back of this space we are going to have another staircase which will lead upstairs.		
H	Is it going to be running this way or is it going to be that way.	Gestures	
M	Yeah running this way.	Gestures in direction	Spatial Gesture
H	That way.	Repeats gesture	Clarification
M	Towards us yeah.		
H	Okay so how high do you want your floor to ceiling in the …	H draws stair and calculates treads	Info for stair representation based on height
M	In the reception area um lets call it 3 meters which is the height of the …	Looks around room	Seeks relationship for dimensions
H	How wide do you want this staircase?		Info for stair representation
M	The staircase is going to be 3 meters wide. No… it has got to be in the middle of the….	Points to halfway line on drawing	Corrects hand
H	In the middle of here?		Clarification
M	Yep.		
H	Okay, 3 meters wide.	Starts to draw stair	
H	All in one direction? It's not wrapping around?		Expert Advice
M	How much space does that give us?		Request for information
H	Ahhhh, if you have got to go up 3 meters, that is, how many? 15… about 18 steps generally.		Expert Advice
M	Okay		Confirmation
H	175 so 1, 2, 3, 4, 5, 6, 7, 8, 9.	Measures and counts	
M	Oh… good God no		Responds to information & counting on image
H	You could wrap it		Expert Opinion
M	Yeah we are going to have to wrap it.		Confirmation
H	Okay		
M	Which way though? It is going to have to be in so maybe we should bring it around this way. Which way is this, that is the little building so, … but that is not up there.	Indicates/gestures turning stair around	Spatial Gestures
	(silence)	H darkens stair, M thinking by looking at drawing.	Examining
M	See, I want the gallery space to be south lit so um.		

Figure 3. Transcript excerpt from design session 1. M = Mind and H = Hand

5.3 Observations from the transcripted protocols

The interaction and subsequent dialogue that occurred between the two protagonists can be categorised as follows: The Mind: Examining, Requests, Gesturing. The Hand: Clarification, Advice, Labelling, and Gesturing. Figure 3 displays an excerpt from the transcripts that illustrate some of these actions.

- Looking and examining

Looking and examining included looking at the hand's sketching activity, and the comparison of images. Information gathered from examining could be seen as cues that trigger decisions or further moves. Looking and examining usually resulted in requests.

- Requests

This action on the part of the mind included requests for information as well as requests to see particular drawings (or marks on a particular drawing). Requests usually entailed asking for distances and heights. This happened more frequently in session 1. Information gained from requests was used to make design decisions that related to "existing" elements.

- Gesturing, Pointing or touching image with hands

Pointing at the image and moving the hand over it to indicate spatial and directional movement (like movement through a door) usually occurred when participants referred to a physical element.

- Clarification

During the experiment, the hand would repeat pieces of information uttered by the mind. This usually occurred when placing elements for the first time.

- Advice

The hand, for the most part advised or questioned the mind as to aspects of the design (especially

when the practitioner was hand) that might not work. This usually included information that could only be known when drawing and measuring.

- Labelling

The hand would use text labelling to identify elements e.g. stair, void, studio and drew furniture to provide context for the mind. Concrete decisions by the mind were "darkened in" i.e. made bolder to depict and emphasise that decision.

5.4 Discussion of results

The protocols confirmed similar observations from previous experiments (Suwa, Gero and Purcell 1998; Do 1997). These observations found that designers labelled spaces and used graphic symbols, illustrated design contexts by dimensional reasoning and furniture, sketches tended to be orthographic (two-dimensional), sketches served as external memory that were revisited and provided visuo-spatial cues for thinking about functional issues. The protocols also provided the following observations:

- Designers preferred seeing drawings side by side. This was important (especially between floor plans) although some tracing of information took place (this was more a shortcut than anything else).
- Designers wanted as much information as possible put on individual drawings. The information quality of the practitioners sketches tended to be a lot richer than that of the student.
- Designers looked around the room to determine relative sizes. They then related sizes and dimensions of immediate surroundings to existing elements in drawing.

In addition to these, other interesting events occurred. For instance, the student was a little intimidated by the practitioner and so in the case of being the mind did not totally control the situation. The student also hesitated to make many changes that required a lot of redrawing and erasing but when practitioner designed there was no hesitation to try ideas.

Little concurrent verbalisation took place by the mind while waiting on the other subject to draw. It was observed, though, that the subject was still thinking by looking at what the hand was doing whether or not this (drawing operations) helped the thinking is an area to be examined. Reciprocally, the hand had difficulty keeping track of spaces and elements despite interacting closely with drawings.

6 Discussion and Future Work

The information processed by the designer during the activity of sketching is both interesting and complex. We have suggested an important relation between sketching and the design process. Sketching is seen as a "conversation" that the designer engages in with the use of images (and related information). The designer makes a statement by making marks on paper, responds by examining and criticising this statement, makes further marks and so progresses in design. We have implied that there are two players in the activity of sketching – the hand and the mind. By literally employing two separate individuals in this conversation we are able to take a closer look at the communication between these two players in the design process.

Our empirical studies involving 2 subjects while confirming similar research (Do 1997; Suwa, Gero and Purcell 1998) have also shown that there is a certain give and take that is necessary when sketching. It also shows that designers spend time during the process questioning and interpreting the functional implications of their ideas in broad terms. It revealed that designers rely on dialogue and interaction with images to produce.

Besides providing a platform to understand the sketch further, this experiment can also point the way to the development of design aids for education and practice that constantly question the emerging design.

6.1 A design tutor

Research in this direction could lead to the development of teaching aids in which students (who have limited design vocabularies) allow the computer to deal with the practical issues leaving more time for the development of ideas. An application of this kind could alert students to the myriad of issues involved in design. Further investigations into this issue could take place in the design studio where a new kind of relationship between student and tutor is developed, analysed and compared to existing techniques.

6.2   A design partner

Further investigations could also look at the practitioner with an experienced partner (instead of the student) and examine the performance and response then. It may reveal the need for a design support application that is more interactive than present offerings.

6.3   Conclusion

To take a stronger position on this issue more substantial and analytical results would be needed. Other factors could be investigated separately. For instance examining the effect on subjects if the session wasn't face to face but instead behind two workstations (Gabriel and Maher 1999). The preliminary observations presented in this paper are not enough to make a concrete position. What we have seen however gives some value to advocating moving the sketch from being less passive in design to a position where it prompts and cues the designer. The computer should be able to answer your questions and supply the answers in such a way that aids critical thinking. Employing the computer in this way allows the designer the opportunity to communicate on one aspect of the problem while the computer examines other domains in relation to it. This *intelligent sketch* is important for designers (especially inexperienced ones) to grasp the issues being investigated better.

Sketches usually are about possibilities and should not be seen as final objects (Laseau 1989). Energy therefore should be directed towards providing tools that interpret, respond to and question therefore enhancing the designers understanding of the design situation rather than automate it or transform it (the drawing). The importance of the handsketch as a means of communication, inference of things, and aid to critical design thinking should be preserved when using the computer in design.

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