HYPERSKETCHING:

DESIGN AS CREATING A GRAPHICAL HYPERDOCUMENT

RAYMOND MCCALL, ERIK JOHNSON, AND MARK SMITH
Sundance Laboratory for Computing in Planning and Design
College of Architecture and Planning
University of Colorado

Abstract

There are empirical and theoretical reasons for believing that current CAD does not adequately support the early, conceptual stages of design. Hand-done design drawing has a several advantages over current, CAD-based approaches to generating form in these stages. One advantage is the indeterminacy of hand drawing--i.e., its abstractness and ambiguity. Another is a non-destructive drawing process, where new drawings are created without modifying old ones. A third is designers' creation of large collections of inter-related drawings--i.e., graphical hyperdocuments. A fourth is the unobtrusive character of conventional drawing tools. We have created two prototypes that incorporate these features into a new type of CAD based on sketching with electronic pens on LCD tablets. The first prototype, called HyperSketch, is a stand-alone system that simulates tracing paper. It creates a hypermedia network in which the nodes are sketches and the links are primarily traced-from relationships recorded automatically by the system. The second prototype adds the HyperSketching functionality to our existing PHIDIAS HyperCAD system. This aids design by using the sketches to index and retrieve multimedia information that is useful for a variety of design tasks.

1. Problem

Computer-aided design (CAD) is increasingly used by architects for design. It is are finding greatest use in the later stages of design, especially design development. It is, however, finding far less acceptance in the conceptual and early schematic stages. For these early stages most architects continue to devise solution form primarily by sketching with pencil and pen on paper.

Evidence for this state of affairs was produced in a recent survey by two students from the University of Colorado (Greg Eddy and Scott Saia). They surveyed 30 architects in the Boulder-Denver area to determine in what ways--if any--they are using computers in design. Only two of the architects surveyed made no use of computers for design. Of the 28 remaining, 25 use CAD for design development and 17 use it for schematic design. But, only 7--i.e., only one quarter of those using CAD extensively for design--said that they ever use CAD for the conceptual design. In-depth interviews with a number of the surveyed designers suggests that the use of CAD in conceptual stages is often a minor part of those processes. Most conceptual design is still done by hand-based sketching.

2. Problem Analysis

2.1. MORE THAN A MATTER OF TIME

CAD researchers have long been aware of reluctance by architects to use CAD for design. It has often been said, however, that the solution to this problem is merely a matter of time. Some believe it is "a generational thing," and that when today's computer-literate children grow up they will naturally prefer the computer as a design medium. Others are waiting for Moore's Law to deliver inexpensive, high-powered graphics hardware.

We argue that the problem is more fundamental--at least in the early stages of design--and thus requires a more fundamental software solution. We perceive a mismatch between the graphical processes architects use in early design and the processes current CAD supports. Thus. CAD is unlikely to become the preferred design medium even for computer enthusiasts.

Ultimately, however, the acceptance or non-acceptance of CAD by architects is not the central issue. Far more important is the notion that the form-making processes that current CAD supports for conceptual design are inferior in crucial respects to those supported by pencil and paper. If this is so, then we would hope that CAD--at least in its current form--is not accepted by architects for early design. We are therefore seeking to understand how hand-done drawing supports early design and to use this understanding to devise features for future CAD systems.

2.2. DIFFERENCES THAT MAKE A DIFFERENCE

There are a number of obvious differences between hand-done design drawing and current CAD modeling. These have largely been overlooked--or dismissed as inconsequential--by the CAD community. We take as our starting point the possibility that these differences might represent important advantages of hand drawing for early design. Among these differences are the following:

Hand-done design drawing is indeterminate in varying degrees, but current CAD models are highly determinate. By this we mean that hand-done design drawing is typically approximate, abstract, vague or ambiguous to some degree. It uses thick, wobbly or multiple lines; shapes are often rounded, lines only approximately parallel. CAD models, by contrast, use hard-line drawing and are typically based on precise dimensions and angles. That the indeterminacy of hand-done drawing is deliberate is indicated by the fact that its degree varies systematically during design, generally becoming less indeterminate as design progresses. By being indeterminate, hand-done design focuses on larger issues of design while ignoring temporarily the many detailed issues that arise in determinate drawing. Indeterminate drawing thus enables designers to use a divide-and-conquer strategy for attacking the complexity of architectural design.

Hand-done design Ls based on non-destructive drawing, but all current CAD is based on destructive editing. Devising new solution states with CAD is accomplished by editing one model to create a new one. This is a destructive process in that old states of the solution are destroyed--i.e., modified--to create new ones. Hand-done design, however, generally does not involve destroying old drawings to create new ones. Instead, designers create new drawings--often by tracing over previous ones. Destructive drawing, i.e., by erasure, generally has a small role in early design. Use of nondestructive drawing preserves an episodic history of the project, the episodes corresponding to individual drawings. This facilitates backtracking. It also enables evaluation of the current solution state by examining the solution history.

Hand-done design creates a large collection of inter-related drawings-Le., a graphical hyperdocument-but CAD creates only a single model. Non-destructive drawing, by definition, produces multiple drawings. In fact, a large number of drawings is typical. In one case, we saw more than a thousand sketches created in a three-week period. Often, less than three minutes is spent on a drawing, and rates can exceed 20 drawings an hour.

Our empirical studies show that design drawings are highly heterogeneous. They are at many different levels of detail and deal with many aspects of a building--function, structure, appearance, circulation, lighting, user interactions, views, relation to site and surrounding context. They show and compare alternatives at many different levels of aggregation and abstraction. Many drawings, if not most, are not recognizable as being-even conceptually--edited versions of other drawings. Paper and pencil thus function as more than a "poor man's graphical editor," as has often been supposed.

Current CAD, of course, is designed to support repeated editing of a single model. CAD can, of course, be made to support more than one model. But current systems do not have the database capabilities to manage thousands of drawings. Furthermore, few systems support creation of drawings in under three minutes.

In hand-done design, there are typically important relationships between drawings. Tracing is one source and indicator of such relationships. Some drawings represent alternative solution possibilities to other drawings. Some drawings are done to resolve design problems that arise in doing other drawings; often the former are done in smaller scale on the side of the latter drawings. All of these represent crucial relationships between drawings. In addition, design drawings are commonly annotated with text, arrows, and numerical information. Thus--in addition to small "study" sketches-diagrams, notes, tables and calculations are often found on the sides of larger drawings.

Current CAD systems have not been designed with the hypermedia capabilities needed to represent the relationships between drawings, much less to manage extensive networks of drawings. And, of course, CAD systems do not generally support extensive annotation.

The tools for hand-done design-pencil, pen and paper-are effectively invisible, direct and unobtrusive, but current CAD software is visible, indirect and obtrusive in design.

During traditional, hand-done design, designers effectively devote full attention to thinking about the project--the problem and its solution--while drawing. They do not focus significant attention on the pencil, pen and paper. With current CAD, far more attention must be devoted to the tools for design--the software and how to use it. Even when the CAD software has been mastered, considerable time and attention are devoted to multi-step processes for manipulating form. CAD seldom achieves the "transparency" or directness of pencil or pen. Typically, the computer interface is the computer "in your face." Consequently, interacting with the computer disrupts design thinking.

3. System Prototype

We have created two prototypes that are modeled on the way architects design with pencil, pen and paper. With both systems, designers create form by sketching with electronic pens on LCD tablets. Both systems are based on the idea of designing as creating a graphical hyperdocument--a collection of linked sketches--a fundamental alternative to the CAD paradigm of designing by destructive editing.

3.1. FIRST PROTOTYPE: A STAND-ALONE HYPERSKETCH SYSTEM

Our first prototype was called HyperSketch. Running on PCs with pen-sensitive LCD tablets and using the metaphor of sketching on tracing paper, HyperSketch enables designers to draw directly on the screen. As they create a set of sketches, HyperSkerch automatically links the sketches--e.g., using "traced-from" and other links--to create a graphical hyperdocument having individual sketches as nodes. Stacks of digital tracing paper can be created; and branching of stacks supports generation of solution alternatives. Sets of drawings are organized in projects. Individual drawings can be scaled between full-screen and postage-stamp size; they can also be shown as icons or hidden completely.

We videotaped three professional architects using HyperSketch. All had little experience with computers and a strong aversion to CAD. They were generally unhappy with the slow speed of our initial prototype and the feel of the electronic pen on the tablet. Nevertheless, at several points, *all three architects spontaneously began developing solution form for real-world projects they were then working on.* This happened, furthermore, without prompting from us and within the first hour of system use.

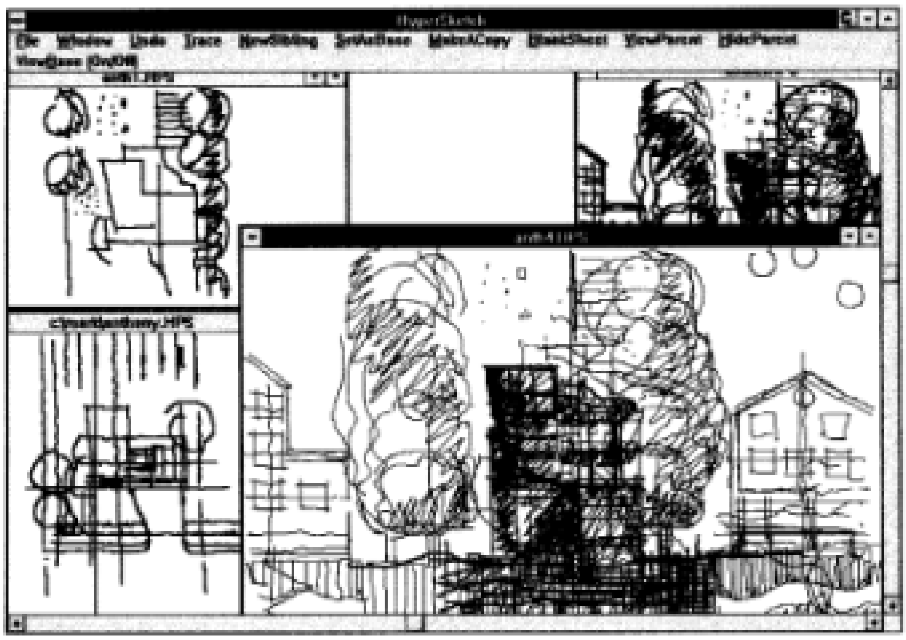

Figure 1. A screen image from HyperSketch. These drawings represent a house that the user--an architect--was designing for himself The drawing in the lower right shows three layers of electronic "tracing paper, "with the darker lines being on the top layer.

3.2. SECOND PROTOTYPE: PHIDIAS WITH INTEGRATED HYPERSKETCHING

We are creating a second prototype by integrating hyper-sketching functionality into our existing PHIDIAS HyperCAD system [McCall, Bennett, and Johnson 1994]--which, in fact, was our intention all along. PHIDIAS has vector-graphics, knowledge-based computation, hypermedia navigation and search; yet it implements all these using only hypermedia mechanisms. Complex vector-graphic objects are represented by composite hypermedia nodes. Knowledge-based computation is accomplished, by semantic networks represented in hypermedia networks. Search uses the node-link structure.

Figure 2 shows a screen image of PHIDIAS with integrated HyperSketching. Here a lunar habitat is being designed. The lines defining a table have been grouped and labeled as a "table." This creates an object (node) with an is-a relationship to the table class, thus associating the sketched object with all information on tables. The sketched table also inherits information from higher classes--such as furniture--inherited by the table class. Double-clicking on the sketched table brings up the associated information for design and placement of tables in the lunar habitat. This includes text, raster graphics, video, and links to external information in Web sites, spreadsheets, word processors, etc.

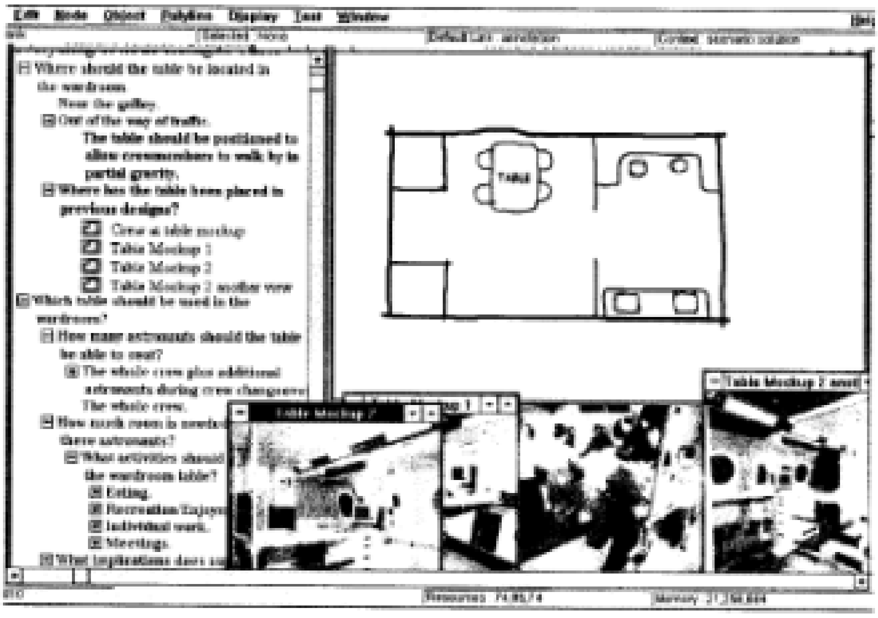

Figure 2. A screen image from the PHIDIAS prototype with integrated HyperSketching The application is the design of a lunar habitat for NASA. The table in the sketch has been labeled and then used to access information for the design and placement of tables.

4. Conclusion

HyperSketching enables users to do conceptual design yet does little to enhance that process graphically in the way that CAD systems attempt to--e.g., by generating sweeps and other complex forms. In this sense it has little advantage over pencil and paper. But unlike pencil and paper--and conventional CAD---PHIDIAS provides multimedia information to aid design decision making. The information can include issues, solution ideas, and arguments, as well as cases of prior design projects represented with text, video, photos, and vector graphics. PHIDIAS with HyperSketching thus provides a fundamentally different approach to aiding design, an approach better suited to support of early design than the approach of current CAD.

References

McCall, R.; Bennett, P.; and Johnson, E. An Overview of the PHIDIAS HyperCAD System. In Reconnecting, proceedings of the 1994 conference of the Association for Computer-Aided Design in Architecture
(ACADIA'94), A. Harfmann and M. Fraser (eds.), Association for Computer-Aided Design in Architecture, 1994, pp. 63-76.