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ABSTRACT

Daylighting is an energy-conserving strategy and a lost architectural art. The Windows and Daylighting Group has extensively researched the energy implications of daylighting, and after developing a number of conventional design tools, has recently been considering new electronic design tools to promote its practice. Daylight as a topic sits at the junction of key quantitative and qualitative design issues and works well as an energy-conserving strategy when incorporated into buildings early in the design process.

The application of microcomputer tools in building design has been limited to date, as has been acceptance of such tools among architectural professionals. While computer-aided drafting systems are becoming more and more popular, computer-based design tools are rarely seen. This reluctance in the design world towards the use of computers in the design process itself may begin to turn around with the development of "friendlier" computers and software, and particularly with the increasing interest in and use of hypermedia. The arrival of both the Macintosh microcomputer and its accompanying hypertext program *HyperCard* opens new opportunities for design applications. The Macintosh has been successful in dispelling computer phobia, and hypermedia has potential as a replacement for traditional methods of presenting, accessing, synthesizing and evaluating information pertinent to the design process.

HyperCard can be described as a new electronic information system, more powerful and flexible than traditional written methods. It is characterized by its unique abilities to interlink data in non-linear sequences, radically altering how we use reference tools. Part of the genesis of this software is in a recognized global need for the sharing of information; the parallel to architectural design is immediately seen, as ever-increasing demands on the profession highlight a growing need for accessible reference information.

The Windows and Daylighting Group is currently developing a daylight design guide in *HyperCard*. The intent is to first supplement, and eventually replace, written manuals and other references, which, by their size or structure, are too cumbersome or otherwise forbidding to be used in a typical design process. The tool is intended to be a guide for both design and educational tasks. Currently in the early stages of development, the tool will ultimately take advantage of state-of-the-art multimedia hardware while the software will combine data and expert guidance into a fluid and dynamic design tool.

INTRODUCTION

The rapid pace of building technology development and building-related research today leaves designers with little time or capacity to collect, organize and apply the newly available knowledge. Designers need quick, accessible and effective tools to assist in the application of this knowledge. The great speed and memory of computers has led to their increasing use in architectural practice, but most of the currently available applications are limited to routine and repetitive tasks such as drafting, engineering calculations and accounting. Computer tools have not yet been effectively applied to the conceptual part of the design process, where decisions affecting energy use of the building are best made.

Although there are currently energy-related computer tools available, these tend to address specific tasks and are not integrated in the design process. Architectural design is not a linear process, so the designer must constantly switch from one tool to another, or from the tool to design. Much time and effort are required for input, result analysis, and application to the design. Moreover, many design tasks have yet to be addressed at all by computer tools, particularly those with variables not easily quantified or readily adapted to algorithms.

Another factor inhibiting the effective use of computers for conceptual design is the designer's perception of the value of computer design tools. Designers appear to accept computer assistance for repetitive tasks, but show hesitation regarding the potential role of computers in the creative part of design for fears of deterministic architecture. The development of more appropriate hardware and more interactive software may ease the way for computer tools to become an integral part of the design process.

In the area of daylighting, we have participated in the development of many design tools, several of them computerized. Two recent events have stimulated us to explore new avenues in the search for better computer-based daylighting design tools. One is the popularity of the Macintosh microcomputer, especially among previously computer-phobic designers. The "user-friendly" environment of these computers is a big step towards more appropriate hardware for the design community. The second is Apple's introduction of their *Hypercard* program. This is a flexible and widely-used software environment in the philosophy of hypertext[1]. We see potential in this kind of software for integrating a computerized design tool into the conceptual part of the design process.

The advantages of a hypertext document are many: 1. Size is not apparent to the user. Both the physical mass and the quantity of data in large reference books are intimidating . 2. The structure is dynamic, as opposed to the fixed organization of any written material. The user determines the flow of information, although it is along predetermined paths. 3. Information does not have to be absorbed sequentially, as implied by the nature of books. There are often no page numbers in a hypertext document. 4. The document can have "intelligence" in that links can be structured to best anticipate the user's reactions. One click of the mouse button can take the user to the exact bit of related information, where a traditional document might require much more work with the index or footnotes to move around. The hypertext document can keep track

[1] Hypertext is a term coined by Ted Nelson in the 1970s to describe electronic text that is not bound by the linear and sequential structure of the printed word. In our current "information age" it is also the state-of-the-art data transfer medium, allowing a user to work with linked information in an intuitive, interactive, fluid fashion.

of where the user is at all times, keeping him or her from getting lost and facilitating the back-and-forth movements that make the document so flexible. A design tool resulting from the use of all these features would be part data base, part reference manual, part expert system, and part something entirely new.

The tool is enriched further by adding features of hypermedia such as linking the data with pictures, sound, animation, and video. Among the many possibilities: bringing concepts to life with animation, showing building case study examples, and allowing dynamic manipulation of images in "what-if" design experimentation.

For several years we have been exploring the design and development of "ideal" building design tools, and the project described here is one experimental step toward a larger, long-range goal. We are exploring possibilities for better design tools with today's hardware and software as we watch developments towards more advanced software and affordable powerful computing workstations. This paper describes some limitations of existing tools and concepts behind making a better tool, and also describes our prototype hypertext daylight design guide.

LIMITATIONS OF EXISTING DESIGN TOOLS

Computerized design tools currently available are very specialized and independent of each other and of the design process as a whole. Architectural design is more a procedure of compromise than optimization; many issues have to be considered simultaneously before the synthesis of a final product. Current tools focus on optimization by isolating individual building elements. This does not allow a designer to see the impact of such optimization decisions on other building elements. Current tools are also normally used in the later stages of design, when many of the major decisions have already been made. Both of these limitations make it difficult for a designer to explore an energy-saving strategy like daylighting, which affects many building elements and must be addressed in the early, more conceptual part of the design process.

The specialization of current tools requires particular knowledge and skill for preparation of the input and for effective interpretation of the output of each tool. Learning the individual procedure for each tool is the designer's first hurdle. Each subsequent use is then preceded by a trade-off decision between prospective benefits and investment of time and effort. The use of several independent tools requires time-consuming specialized processes either for formatting the same data in different ways, or for converting the output format of one tool to serve as input for another.

The current generation of computer-based tools emphasizes design parameters that can be readily quantified. A designer willing to make the time commitment to these current tools would still be frustrated by the lack of means for evaluation of such daylighting design criteria as aesthetic appeal, glare potential, and view access. Furthermore, the information that is provided is usually not in the right format to be directly utilized. For example, the output of powerful tools for the evaluation of the interior luminous environment is often in the form of data tables and charts. Effective use of such information by a designer requires specialized knowledge and experience. Tables and graphs are not the standard means for designers to evaluate building design decisions. It is crucial to recognize the visual nature of architectural design, suggesting more extensive use of images in design tools.

The design of buildings requires an enormous amount of data from a continuously growing knowledge base. However, it has been the nature of the architect to rely on individual experience for knowledge rather than on the research of others, partly because there is no effective system in place for the sharing of knowledge in this profession. Current tools do not address this networking problem, where it might be possible to pool the experiences of many individuals, expert advice from specialized consultants, and new technologies and research findings.

WHAT A BETTER TOOL SHOULD DO

While existing design tools are structured in the expectation that the design process will adapt to them, a more appropriate tool adapts itself to the way in which a designer works. It should allow concurrent exploration of many issues and address the relationships between them. The process of design is not one of searching for the most correct answer, but rather it involves the simultaneous consideration and evaluation of a host of ill-matched issues. Exploration and intuition are two key elements of the process that are ignored by existing design tools. Furthermore, the design problem is often fully articulated or understood only during an attempt to solve it. This flexibility in the design procedure indicates a need for similar flexibility in design tools.

Designers are not research-oriented and, in fact, there are few effective means for getting research information. Design knowledge is more typically derived from individual practical experience and from image-based reference sources like architectural journals or first hand observation. Our daylight design guide emphasizes graphics over text, relevance of data to actual buildings, and qualitative assessment, and provides real-life examples.

Data presented by such a tool should be in discrete chunks and in multiple layers of complexity. Data would therefore be available for random access, which means a wide variety of users can get access to different kinds of information with equal ease. Time and budget constraints on the designer also dictate this data breakdown, since information browsing is possible and no major time investment is implied by the use of the tool.

Finally, an ideal design tool is more than just an electronic reference book or number-crunching computer program; it should contain expert consultant advice or guidance. Most tools evaluate existing designs rather than assist in the more difficult process of generating new designs. Most design tools also assume a fully educated user who is looking for a specific answer. A more useful tool, particularly in the early stages of design, accommodates the user who may not know all the parameters to the design problem or who may not even know exactly what the problem is. The expert consultant helps a designer formulate the questions to ask and flags issues or trouble spots in the search for solutions.

A HYPERCARD DESIGN TOOL

The ideal design tool described above may become a reality with hypermedia, a combination of computers, data, graphics, photographs, video, sound, and animation. Hypertext, the software behind it all, has existed in concept since presented by Vannevar Bush in 1945, but is just this year seeing an explosion of development. Several software packages now exist, sharing the common general features of screen-sized blocks of information connected by navigational links. Most existing applications address simple data manipulation; a few have just begun to explore the more difficult task of applying hypertext to a learning or design aid. For our experiment we chose to begin with Apple's *HyperCard*, currently the most available and most promoted hypertext-like package, although we will continue to evaluate other more advanced packages as they reach the market.

HyperCard uses the analogy of a stack of index cards in its terminology. The fundamental unit is a "card," a screenful of data and images, collected into "stacks." A card can have any kind of graphic or text, clickable "buttons" and built-in navigational links to other cards. The user's interaction with the stack is primarily through clicking the mouse. All action taken by the program is determined by scripts, written in *HyperCard's* special programming code. *HyperCard* is a powerful toolbox combined with a kit-of-parts that gives a stack author an impressive creative range. However, one serious limit for an application as complex as ours is the inability to see more than one card at a time on the screen. The program is also limited by poor image resolution and lack of sophisticated graphic manipulation abilities.

The core of our new design tool is a large body of data, ultimately the compilation of all of today's scattered references into one single electronic source. Since data has to be broken down into one-screen chunks, categories were determined and subdivided as necessary. We chose three main branches for subdivision: general "browsing level" information, more detailed "textbook" information, and "how-to" design detail information. For example, the main topic of *Skylights* might have general information screens available in the the areas of *Choosing Skylights, Skylight Components, Lighting Design with Skylights*, and *Skylights and Energy Use*. Each of these screens may, where appropriate, offer *Textbook* or *Design* screens. All of these subdivision screens may further subdivide, depending on the complexity of the topic. The user can go as deeply into a section as she or he likes. Browse cards allow the user to skim a topic for interest; key points are presented along with an illustration, which may pique one's curiosity enough to explore further or be enough information to allow one to move on. (See figs. 1 and 2.) The application of hypertext to this kind of irregularly structured information is ideal, since the body of information is primarily nonhierarchical but highly linked with other data.

The balance of text and image on the screen is important, both for catching and holding interest, and for locking in a concept for the visually oriented user. (See Fig. 3.) Where a screen offers a menu of choices, graphic cues are used as well as text for the menu selection identifications. The user can also click on a variety of icon buttons for peripheral activities. The main links to other related information are identified as bold face words within a body of text on the screen. This is a common and simple hypertext linking technique that profoundly distinguishes the electronic document from a printed one. While both documents use a different type face to alert the reader to an important concept, the hypertext version allows the user to immediately access more information for further exploration of the concept by simply clicking on the text.

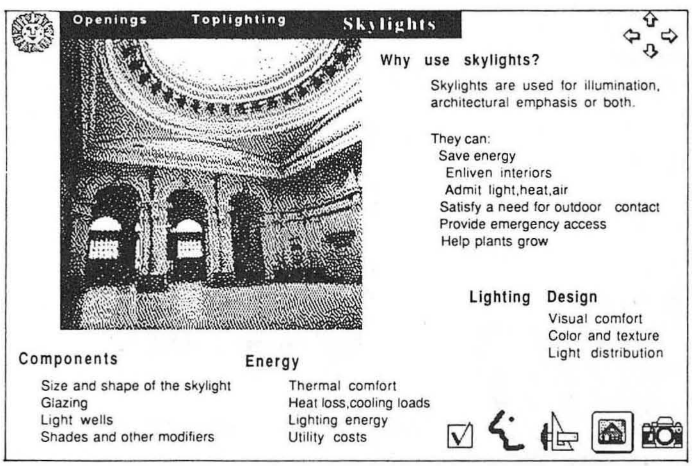

Fig. 1. Sample screen (card).

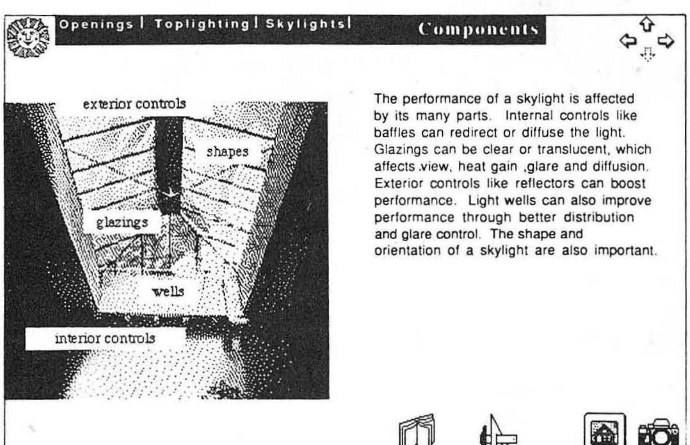

Fig. 2. Sample screen (card).

Other links are identified graphically; for example, the user might click on any part of a picture for more detail about that pictorial element. In the skylight example shown (Fig. 2), various components of the system in the illustration are buttons that serve a double purpose: they provide their own graphic definition while serving as links.

Direct interaction with or customization of the design aid is another rich feature available through hypermedia. Many people like to make margin notes in reference documents, so we have included "sticky notes" that can be attached to any screen, identified by user and project, and can either be visible or hidden. Similarly, architects and others predisposed towards visual note-taking can use the "sketchpad" in the same way. The tool can also be thought of as a three-ring binder in the sense that users will be able to add their own information: perhaps their own slides or case studies, for example. We are also exploring interaction with the video images, where the user can manipulate an image through parametric variations specified by clicking items on the computer screen. This could be an extremely powerful and effective method for visualizing the effects of design decisions on an architectural space, for viewing spaces under different environmental conditions, or for graphically comparing the importance of different design issues.

As our daylighting stack grew larger so did the possibility of losing a user in it. We became concerned with keeping track of the user's path, allowing the user to see the structure of the stack, providing options other than predetermined links for moving around, and allowing the user to retrace a path. A tree map function is available, which is both a key to the structure and a method for the user to move directly to other topics. An index is also provided for direct access to specific topics. A number of peripheral navigational functions are always available to the user for backtracking and checking the current path. Pathways can be saved, identified by a user name and a project name, to be either filed for future project reference or to be continued at another time.

Another "accessory" that begins to explore hypermedia is a case-studies data base. Using a video disk, case studies can include slide shows, building tours, model studies, interviews, and video movies. The data base is fully indexed and cross-referenced, and linked with the daylight design stack so that at any time while reading about a design concept the user can view appropriate built examples. Images from the video disk can be simple illustrations to text, stand-alone video movies, or full color (and possibly active) demonstrations for a concept being diagrammed on the computer monitor. For example, a building tour may run on the video monitor while the computer screen shows the viewer's movement on a plan drawing. (See Fig. 4.) Or the reflection of light from a light shelf can be shown both in diagram and in a real space. Sound can be used where it enhances comprehension of the concept.

After structure, content and graphic format decisions, we addressed pathways, guidance, and expert advice. The stack has to be flexible enough to accept an infinite number of design and learning approaches. While far from offering any final solutions to this difficult task, we have focused on determining some sample

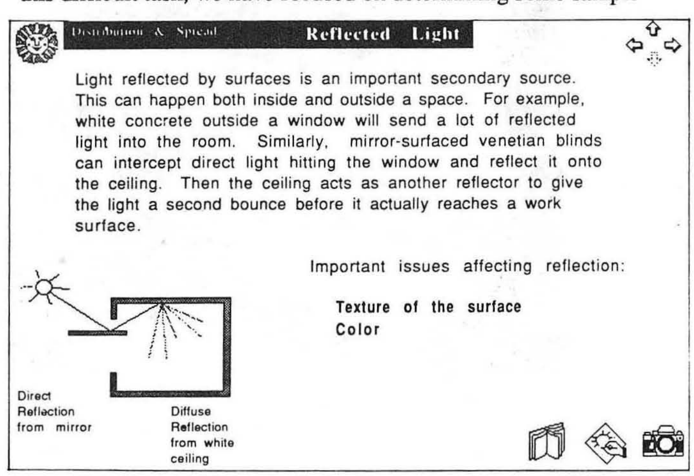

Fig. 3. Sample screen (card).

Fig. 4. A building tour of Mt. Airy Library. The user clicks an arrow pointing to the axonometric drawing for that view on the monitor. (XBB 894-3730)

pathways. One possibility is to request a role identification by the user, then providing a different path for a student, an architect, a mechanical engineer or a lighting consultant. Or pathways might be task-oriented, with the tool helping a user identify the appropriate list of constraints and criteria in solving the problems presented by the task. "Learning paths" might provide knowledge (facts) or judgement ability. "Design paths" might pursue a strategy approach or a building element approach. One difficult issue is giving the stack enough structure to provide help to a user with a specific task while remaining loose enough that exploration, adventure, and accidental discovery are not lost. The prototype stack employs predetermined structure and pathways; however, the necessity for some sort of expert system is evident when one considers the number of such pathways possible. Hypermedia and knowledge-based systems are a natural fit, and we are working on tools of that nature as the next step.

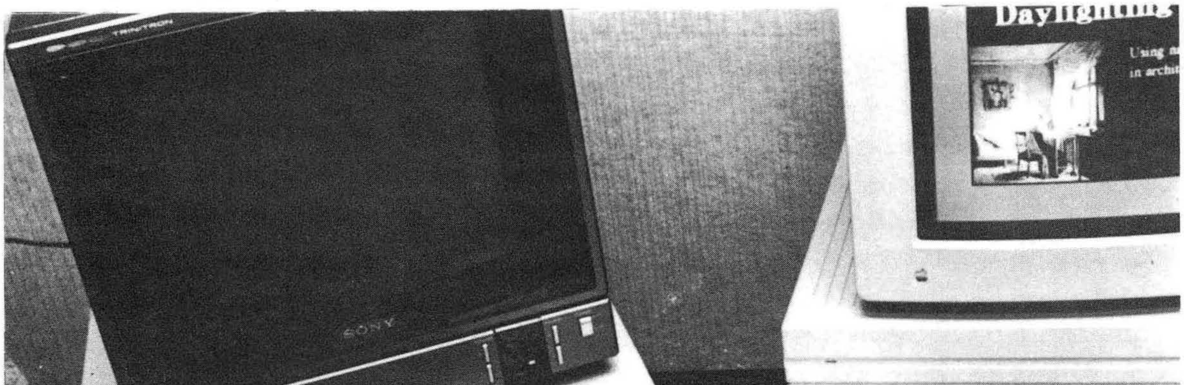

Fig. 5. The workstation today, with 8-inch analog optical disks, magnetic data disks, optical disk player, color video monitor, and microcomputer. Future additions: CD-ROM data storage, digital optical storage, CD audio, and access to central network system. (XBB 894-3731)

SUMMARY AND CONCLUSIONS

This paper has described why we believe current design tools have not been as effective as desired, our methodology for the development of a new kind of computerized design tool, and an experimental prototype for a hypermedia-based daylight design tool. Our goals for this new tool include:

1. Satisfying the needs of many different users with many different tasks.
2. Overcoming the barriers to introducing research results to the design professions.
3. Structuring information in anticipation of any user's needs throughout the design process.
4. Linking data intelligently, so that navigational links provide inherent guidance to the user.
5. Building-in expert consultant capabilities in all areas of expertise.
6. Fully exploiting the power of hypermedia.

Our vision is to the future with this project. A computer-based workstation incorporating interactive video, a current concept in development, is probably the design reference environment of the future. (See Fig. 5.) Full color moving pictures, linked with information and available for dynamic manipulation by the user, will transcend today's reference sources. The ultimate goal is a product that is an electronic interactive combination of a master reference book and a master consultant, enhanced by a full video library. We welcome comments on any of the issues raised here.

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