A DYNAMIC HYPERMEDIA INTERFACE MODEL FOR ENERGY DESIGN IN BUILDINGS

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ABSTRACT

Dealing with issues of acquiring and accessing design knowledge in the conceptual stage of the design process is the focus of this research. This research starts by presenting a brief background about the limitations of the available energy-based CAAD tools. It then provides an illustration and description of the entire architecture of the conceptual model, identifies its different components and explains the relationships and interactions among these components. It identifies the necessary types of knowledge needed in this stage, such as general strategies, design guidelines, and rules of thumb, and develops an appropriate access structure for integrating the knowledge bases with the user interface. The developed structure incorporates a simple sketching tool that supports automatic creation of links between nodes of access and nodes of knowledge.

INTRODUCTION

Energy optimization in buildings is an applied scientific field that is very relevant to architectural practice. Early decisions involved in site selection, building orientation, and space zoning would clearly benefit from reliable information concerning the energy consequences. Several studies have discussed the limitations of the available energy-based CAAD tools and proposed solutions (Brown and Novitski, 1987; Brown, 1990; Degelman and Kim, 1988; Schuman et al, 1988). The lack of integration between the different tasks that these programs address and the design process is a major problem (Schuman et al 1988). Because these tools do not help designers to consider the knowledge of the leading experts and they are complicated and time consuming, designers rely on intuitive methods that do not deal with all aspects of the design (Degelman and Kim, 1988). Also, the available tools do not provide effective means to access the full range of computer capabilities. Flexibility and random accessibility are two important factors that should be considered in designing of the structure of these tools. The development of an interactive software model for managing architectural information can improve the design environment, by making it more desirable to architects and making the process less tedious. The primary objectives of this study are to identify the necessary types of knowledge needed in the conceptual stage of the design process and to develop an appropriate access structure for integrating the knowledge bases with the user interface. Utilizing the capabilities of hypermedia in accessing information (e.g., through the use of buttons embedded in different objects of a building as nodes to access information) and controlling program navigation in a nonlinear way are most useful method for developing such structure.

A definition of hypertext is given in Schuman et al (1988)." It 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." The recent major advances in microcomputers, optical disc, video, and audio technology, in parallel with the development of innovative authoring software, has resulted in a unique opportunity to enhance the way individuals teach and learn (Sullivan et al, 1990). This multidimensional learning environment is called "interactive multimedia" or "hypermedia" It can provide non-linear interactive techniques that complement each other and expand the teaching and learning environment.

CONCEPTUAL MODEL OF ENERFACE

The model consists of four main parts: the user interface, the knowledge bases, the databases, and the energy simulation program (see figure 1). All parts of the model were developed within the HyperCard environment in the Macintosh (HyperCard, 1993), except for the energy simulation program which is written in Basic. There was no need to create a new energy simulation program since the researcher used *EnerCAD* as its energy analysis engine. EnerCAD uses a simplified energy analysis method known as the Variable-Base Degree-Hour Method to estimate the annual energy performance (Degelman et al, 1991).

User Interface

Through the *user interface* , the user edits information as input to the program or receives calculated information as output from the program. Design of the user interface, combined with the methods to access information in the knowledge bases and databases, is the most important part of the EnerFace model and the main focus of this research. It contains three conceptual subdivisions: the *design creation* module, the *design revision* module, and the *results revision* module.

The *design creation module* is considered as the main part of the user interface and the heart of the EnerFace program. It provides the user with the required tools to quickly create, or sketch, a building. The design creation module does not only create a visual description of the building, it is also intelligent enough to do the following:

- change size of objects (e.g., walls and windows) according to design criteria and rules of thumb;
- choose best values for design parameters of objects based on the building type; and
- build access nodes for linking the objects to their information and to knowledge bases and databases.

The design creation module provides dialogue boxes for the different types of objects through which the user enters, or just checks, values of design parameters. When the user clicks on an object, its dialogue box pops up displaying all the information of that object and offering controls to manipulate its parameters. Using the direct manipulation style provides a great deal of flexibility and non-sequential ways of entering new values. Shneiderman (1991; 1992), and Rubin (1988) described in detail the direct manipulation style and presented its advantages and disadvantages. The direct manipulation style provides a visual representation of the "world of action" that includes selectable displays of the objects and actions of interest (Shneiderman, 1991. It provides a relatively rapid learning with high retention over time and high user satisfaction. Errors can often be prevented because of the straight forward way of accomplishing tasks and because typographic errors are eliminated when the user selects from a set of displayed objects. Exploration is often encouraged in direct manipulation environments, especially when reversibility of actions is ensured

The main responsibility of the *design revision module* is to help the user during the analysis mode of the design process. After the user creates a design, not necessarily a complete one, using the design creation module, he/she needs to review it before running the energy analysis. The revision process usually involves verifying the design data with energy standards and setting design criteria. At this stage, the user needs to view a large number of variables of the different components of the design on a limited viewing area; i.e., one or two screens. The main purpose is to help the designer to get a general sense of the weighted impacts of design variables on the energy performance. Implementing the design revision module in a hypermedia structure, allows non-sequential access to information and provides effective means for integration between this part of the model and the other parts.

The *results revision module* provides the user with the final results that have been produced by the energy simulation program EnerCAD. It allows the user to review the results non-sequentially by using navigational tools or sequentially (i.e.; in logical order) by using browsing tools. The concern of providing the easiest and fastest way of communicating the design feedback information dictates the need for presenting the results in graphical formats. Graphics are much easier and more powerful means than text or tables in conveying information, especially during the early stages of the design when most of the concepts are still being developed. It facilitates the use of the Building Energy Performance Standards (BEPS, 1979) to set criteria for the yearly total whole-building energy consumption.

Knowledge Bases

The first type of knowledge bases is the knowledge bases that are integrated within the main modules of EnerFace. This group contains the types of knowledge that are procedurally oriented and can somehow be automated, either totally or partially. It can be divided into two groups: programs that aid the synthesis activity of the design process and programs that aid the analysis activity of the design process. The first group contains intelligent rules that set values of the different design parameters based on the guidelines of specific building type or its geographical location. It also contains rules that have effect on changing the size of design objects based on certain rules of thumb (i.e.; sizing windows based on daylighting rules of thumb). The second group contains knowledge to verifying design data and results with energy standards and setting design criteria. This includes ASHRAE/IES standards 90.1 and BEPS (ASHRAE, 1989; BEPS, 1979).

The second type of knowledge bases is the knowledge bases that are independent from the main modules of EnerFace. This group contains general advice and strategies, phenomena explanations, and case studies. The general advice and strategies includes knowledge that help the user to make decisions about general issues such as the building form, the rankings of energy use, the negative effects of daylighting and the methods to overcome them. Phenomena explanation provides an educational environment for users that lack knowledge in specific areas; for example, heat transfer through a wall can be visualized in an animated three-dimensional graphic for users who lack the physics background. When the user needs to see how the guidelines are applied for a specific building type in a specific geographical location, he/she can refer to the case studies. Case studies can be images or drawings of real buildings.

Interactive Databases

The *weather database* of EnerFace currently includes weather data for 197 cities within the USA and its design allows updating of current data and adding new cities. It is designed as hypermedia-based, highly interactive, and graphically oriented database with direct manipulation style that allows easy access to information. The user selects the desired location by following the steps described later in section *Change-Building-Location.* The use of visual representations has significant effect on reducing the mental load on the user.

Currently, there are three construction databases: *roof constructions* database, *wall constructions* database, and *window constructions* database. Similar to the weather database, they are designed as hypermedia-based, highly interactive, and graphically oriented databases with direct manipulation style that allows easy access to information. While the user is exploring the appropriate values of thermal parameters in the design creation module, he/she will often need to visit these databases to view catalogs of standard constructions supported by graphical descriptions. Through simple actions of mouse clicking on icons, buttons, or pull-down lists, the user can manipulate the default values of these constructions' thermal properties, within standard selectable options, until he/she finds suitable ones.

DESIGN STRUCTURE AND ACCESS STRUCTURES

In discussing the activity of design description as part of the design process, Papamichael (1991) wrote "Control variables are usually specified in an object-oriented fashion. The will-be situation is defined in terms of objects, which have attributes and may be children or parents of other objects, and can be seen as hierarchical, treelike structures." This definition supports the authors' view of choosing the hierarchical structure as the appropriate one for organizing information of energy building design (Al-Sallal and Degelman, 1994). Another important support for the appropriateness of such structure comes from the theory of information chunking, discussed previously by Akin (1986) and supported by Al-Sallal and Degelman (1994). A primary strength of this theory is that it accounts for the limitations of short term memory span and supports the hierarchic and multirelational organizations of information.

The design creation module provides the user with tools to generate such hierarchical structures of objects (i.e.; designs) represented by two dimensional plans on the screen. The existence of this structure only begins after creating the first space of a design (i.e.; the first object in the hierarchy); before that, this structure does not exist at all. It develops gradually and hierarchically, as the user creates new hierarchical trees of objects of spaces, walls, windows, doors, roofs, and skylights. It can also contract when the user deletes objects, by removing these objects and their children objects from the hierarchy.

Retrieving information of design objects and accessing knowledge bases depends on information access structures. Access structures provide tools for following links from node to node. The design creation module creates access nodes and embed them in the plan view representations of design objects. When a new object is created, the program automatically builds the required links to connect it to the different knowledge bases and databases. The access and end nodes of these links depend on the type of object being created. For instance, when a new wall is created, the program automatically builds a link from the wall dialogue box to the appropriate wall construction in the wall constructions database. This wall construction is selected automatically by the program based on the building type that was selected previously by the user.

LINKING TO DATABASES AND KNOWLEDGE BASES

With contrast to the highly dynamic design structures, created by the design creation module, the access structures of databases and knowledge bases are totally static. This means they do not grow or diminish. Once the user leaves the dynamic design creation module and connects to one of the databases or knowledge bases, his/her navigation is limited to the predefined paths of these structures. In other words, their paths are predeveloped by the authors and neither the user nor the program will be able to modify these structures, or even expected to do so. However, the information within these structures could be changed, with or without automation, with some restrictions.

The access structure of the weather database is a combination of a linear list and a tree (only one level of branching) structures. The linear list allows the user to browse forward or backward through the weather database using the browsing tools. This will provide a facility to compare weather data for cities located in the same state and a tool for learning. The one-level branching tree structure includes nodes embedded in a map of the US that allow to access the weather data for any city by simply pointing at the city. This provides the advantage of quick and easy access to information (see figure 3 and 4).

Similar to the weather database, each construction database of EnerFace has a combination of a linear list and a tree (only one level of branching) structures. The linear list allows the user to browse forward or backward through the construction database using the browsing tools. This will provide a facility to compare different constructions and a tool for learning. A link is created automatically by the program between a design object in the design creation module and the node of one of the constructions, based on the building type that is chosen by the user.

The knowledge bases are physically independent from the main modules of EnerFace but they are linked to them. They are implemented as hypermedia-based library of design documentation that are hierarchically and conceptually based, and accessible from design variables' nodes in the design creation module.

LINKING TO DESIGN SYNTHESIS

Linking the access structure of the design analysis information to the access structure of the design synthesis information will facilitate continuous updating of design information between the two structures. One of the major problems faced in linking the two structures is the highly dynamic nature of the design synthesis structure compared to the analysis one. Although both structures are partially linked in the current version of the program prototype, it is planned in the future research to incorporate full linkage. The full linking of both structures is a challenge and when implemented it will provide great flexibility during the design process. That is because the designer will have the potential to start the design from either the synthesis or analysis structure; then, proceed to the other one and repeat the process until the design is completed. When the design process goes from the synthesis structure to the analysis structure, a method of design called generate-and-test (or abbreviated as GAT) is being activated; and, when it goes from the analysis structure to the synthesis structure, another method of design called induction is being activated. Akin (1986) explained both methods in detail and based on two protocols study he found that the most popular method of design was generate-and-test, accounting for 56.1 % of the data, and the next popular method was induction, accounting for 31.7% of the data.

EXAMPLES OF INFORMATION PROCESSES

Change-Building-Location

The user changes the building location by following this process (see figures 2, 3, and 4):

- Click on the button that has the icon of the US map in the building information window. The program opens the graphical weather database displaying a screenful image of the US map with state names on it.
- Click on a state name. The program pops up a list of cities for the this state.
- Click on the desired city.
- If you want to view the weather data, click on the magnifier icon; otherwise, click on the EnerFace program icon to go back to the main program. The program stores the location name (city and state) to be used later in retrieving its weather data for running the energy analysis.

Change-Roof-Construction

The user changes a roof construction by following this process (see figures 5 and 6):

- Click on the pop-up list button that has the label "Construction" of the space information window and keep the mouse button down. The program pops up a list of roof constructions.
- Select the desired roof construction then release the mouse button. The program displays the last one chosen, indicating that it has picked up this roof construction.
- If you want to view its information, click on the button "Database". The program opens the graphical roofs database displaying an image of the roof with its thermal data. At this point, you can go back to the main program or you can browse through the database to search for another roof.
- When you find the appropriate roof, click on the button "OK" (or on the button "EnerFace") to go back to the main program. The program displays the roof of the last screen in the pop-up list button, indicating that it has picked up this roof construction.

CONCLUSION

The study discussed briefly the limitations of the current energy-based CAAD software. These limitations are related to the complicated nature of the CAAD tools, the isolation among design tools, the lack of standard means of evaluating design decisions, the focus on the computer control, and the poor access to information. It provided an illustration and description of the entire architecture of the conceptual model, identifying its different components and explaining the relationships and interactions among these components. It also identified the necessary types of knowledge needed in the conceptual stage of the design process.

The study proposed using the *hierarchical structure* as an appropriate structure for organization of the energy design information. Based on two theories in *design process* and *information chunking*, it supported this view by showing the cognitive benefits that could be gained when using the hierarchical structure. It also showed how the *object-oriented model* and the *direct manipulation style* can be beneficial in implementing this structure. It distinguished between two types of structures existing in EnerFace, the highly dynamic hierarchical structure that is formed of the design objects and classes and the static information access structures of databases and knowledge bases. These databases and knowledge bases are physically independent from the main modules of EnerFace but they are linked to them. They are implemented as hypermedia-based library of design documentation that are hierarchically and conceptually based, and accessible from design variables' nodes in the design creation module.

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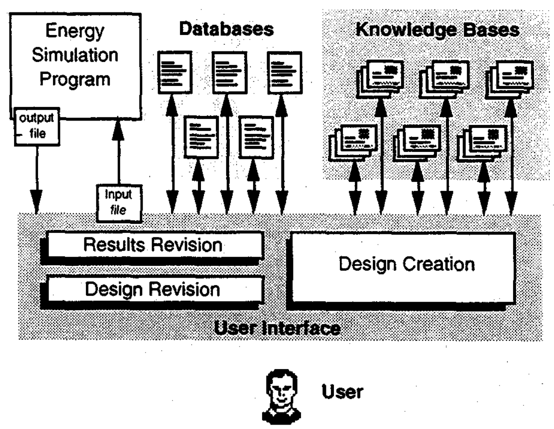

Fig. 1 A conceptual model for the proposed tool.

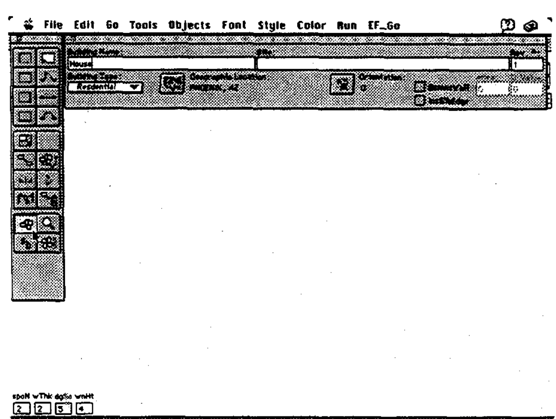

Fig. 2 Getting the building information window by selecting the building information tool in the tool bar.

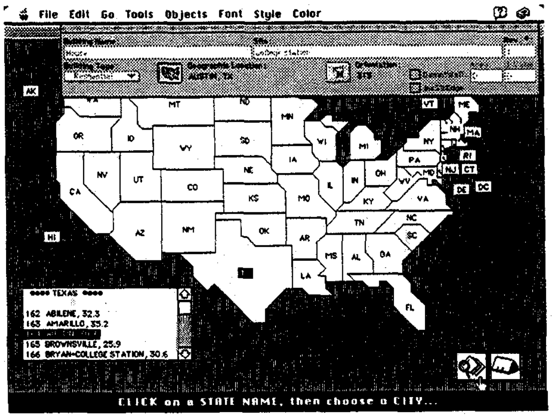

Fig. 3 Selecting the desired state and city from the USA map that exists in the first screen of the weather database.

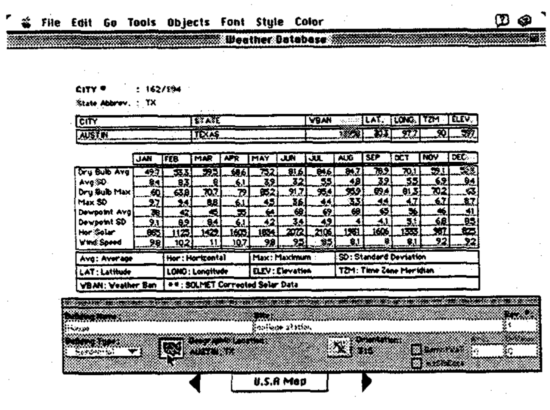

Fig. 4 A sample of one of the city's weather data (Austin, TX) in the weather database. The user can browse through the screens of the weather database by using the browsing tools located on the bottom.

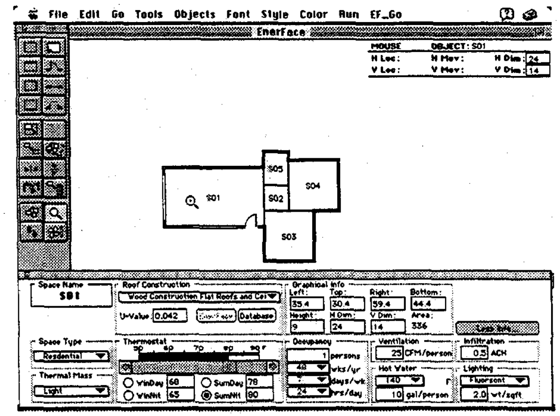

Fig. 5 Getting the information of a specific space by selecting the get-info tool, then, clicking on a space. The space information window pops up to allow controling its attributes and accessing the roof constructions database.

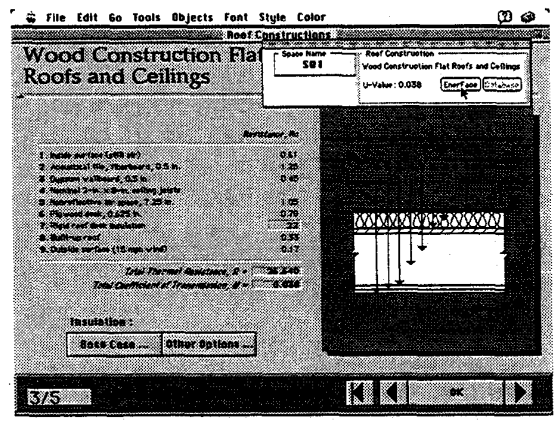

Fig. 6 A sample of one of the roof constructions in the roof constructions database. The user controls the R-value of insulation by clicking on the button "Other Options..." that gives a pop-up list of standard types.