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Integrating Energy Expertise into Building Design

M. R. Brambley
R. C. Stratton
M. L. Bailey

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Pacific Northwest Laboratory
Richland, Washington 99352

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Michael R. Brambley and Rex C. Stratton

Applied Physics Center
Pacific Northwest Laboratory, USA

Mark L. Bailey

Office of Building Technologies
U. S. Department of Energy, USA

Abstract

Most commercial buildings designed today will use more energy to operate, and cost more to design and construct than necessary. Significant energy savings could be achieved with little or no increase in first cost if energy-efficient design technologies were used. Research into integration of building systems indicates that by considering energy performance early in the design process, energy savings between 30% and 50% of current energy consumption rates are technically and economically feasible. However, most building design teams do not adequately consider the energy impacts of design decisions to achieve these savings.

The U.S. Department of Energy has initiated a project, led by Pacific Northwest Laboratory, to develop advanced computer-based technologies that will help designers take advantage of these large potential energy savings. The objective of this work is to develop automated, intelligent, energy design assistance that can be integrated into computer-aided design systems of the future. This paper examines the need for this technology by identifying the impediments to energy-efficient design, identifies essential and desirable features of such systems, presents the concept under development in this effort, illustrates how energy expertise might be incorporated into design, and discusses the importance of an integrated approach.

Keywords

Knowledge-based systems; artificial intelligence; computer-aided design; design automation; buildings; energy efficiency

Introduction

Most commercial buildings designed and built today will use more energy and cost more to operate than if designed to incorporate economically optimal levels of energy efficiency. Conservative estimates, based on research on building energy performance standards, indicate that at least 15% of the energy now used in new buildings could be saved with no additional first costs by using readily available building energy conservation techniques (AIA/RC, 1980). This estimate increases to approximately 30%, if additional measures, with payback periods of less than 3 years, requiring modest additional first cost are considered. Case studies in which buildings have been redesigned to increase energy performance have shown that energy consumption can be cost-effectively reduced by more than 50% in many cases (Stoops et al., 1984; Burt Hill, 1987; NAHB, 1987). When energy efficiency is not adequately considered during design, higher operating costs persist over the entire building life of about 50 years (in the U.S).

The potential benefits of energy-efficient commercial building design are enormous. A total of $50 to $200 billion (1986 $) could be saved in the U.S. alone on energy expenditures over the first 15 years of implementing technologies that effectively promote the design of energy-efficient buildings (Brambley et al., 1988). These savings would persist over the life of the buildings, providing benefits far into the future.

Traditional approaches to technology transfer have had an important but limited impact in improving the efficiency of the commercial building stock. The most effective approach has been the development and promulgation of building energy standards and codes. But codes and standards generally set minimum acceptable levels and don't provide the designer with the knowledge and tools necessary to produce the most cost-effective building. Developments in computer technology and the on-going evolution of computer-aided design (CAD) systems (from tools that primarily support drafting and component specification to systems that support the entire design process) provide new opportunities to integrate energy performance considerations into building design.

The U.S. Department of Energy (USDOE) has responded to this opportunity by initiating the Advanced Energy Design and Operation Technologies (AEDOT) project, led by Pacific Northwest Laboratory. The project focuses on developing advanced computer-based technologies that will help designers take advantage of the large potential energy savings in commercial buildings. The objective of this project is to develop automated, intelligent, energy design assistance that can be integrated into CAD systems of the future. By participating in the development of advanced CAD technology, the USDOE will help ensure that energy performance does not continue as an essentially neglected side effect of building design but that it becomes an integral part of the design process.

The Need

Despite significant advances in understanding building energy use and in tools to simulate the energy performance of buildings, two major obstacles have prevented the buildings industry from taking advantage of opportunities to improve energy efficiency

- designing energy-efficient buildings is complex, involving many different design disciplines and requiring specialized expertise that takes years of study and practice to acquire

- current energy-design tools are not well integrated into the design process and do not provide sufficient assistance in a readily usable form, particularly in the early design stages when decisions have the most significant impact on building energy performance.

Designing energy-efficient buildings is difficult for a number of reasons: (1) the energy performance of buildings depends on interactions among many building components, (2) many design criteria, some that conflict with one another and some that are qualitative and difficult to analyze except by subjective judgement, need to be satisfied simultaneously during design, and (3) many different specialists that perform their duties independently make up a design team and their efforts need to be coordinated better than traditionally done to optimize energy performance. These complexities make energy-efficient building design expensive, except for small projects designed by closely knit teams that already possess the necessary energy expertise.

Most energy design and analysis tools, both manual and automated, have not been assimilated on a large scale into the building design process. The manual methods for energy-efficient design are tedious to use and require a substantial investment of time to master. Most building designers do not have the time required to become proficient in their use (or the value of the methods is not perceived by the designers to be worth the investment required to learn them). Most computer-based tools are not design tools at all but analysis tools. Some very good building energy simulation software packages are available, e.g., DOE-2 (Simulation Research Group, 1989; Birdsall et al., 1990) and ESP (Clarke and McClean, 1986), but most are difficult for the non-expert to use and they are not integrated into the design process; they are stand-alone energy analysis tools.

Opportunities Provided by Computers

In recent years, a number of new capabilities have become available in personal computer and workstation hardware and software: increased numerical processing speed, greater mass storage capabilities using technologies such as compact disks, faster graphics processing using special graphics processors, the ability to generate and manipulate sophisticated visual images, the capability to present information to the user in a variety of forms (e.g., still graphics, digitized photos, computer generated animation, video, and display of real-time television) and new ways to access and manage this information (e.g, using hypermedia and knowledge-base management systems).

These capabilities, coupled with evolving methods from the field of artificial intelligence, will permit developing computerized systems that assist in all phases of design and are integral parts of the building design process. By participating in developing these advanced CAD systems, the USDOE plans to integrate energy-efficiency considerations into the building design process.

The AEDOT Concept

One possible conceptual description of an integrated building design environment is shown in Figure 1. The user communicates with the system through a highly graphical user interface. The Design Executive facilitates and manages interactions between the user and various elements of the system in response to user actions and requests. It accesses and controls several intelligent design advisors, one of which is the Energy Design Advisor (EDA). The EDA functions in coordination with the other

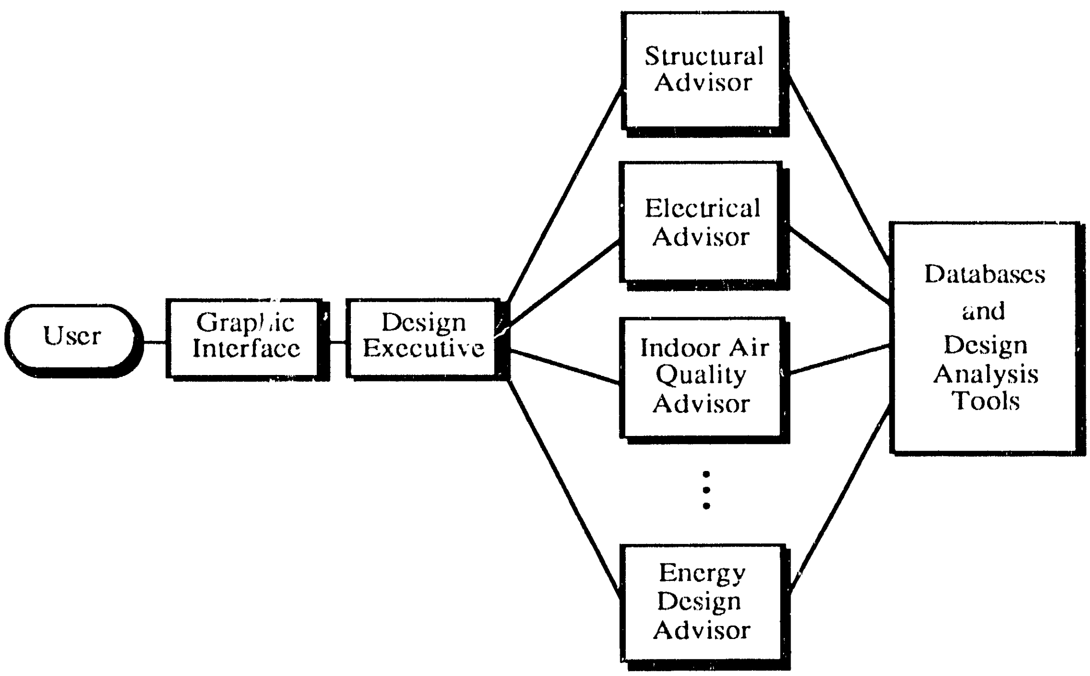

Figure 1. Sample Conceptual Structure for an Advanced Building Design System

design advisors, with control of the process provided by the Design Executive. The design advisors access a set of databases and analysis tools, which reside outside the advisors themselves.

The EDA consists of a set of modules that contain energy design expertise. It automatically assesses the evolving state of the design and provides information and advice to the designer. The EDA modules access and run energy analysis programs (e.g., DOE-2) as necessary to develop energy advice or to provide the designer with quantitative information on performance of the building. The EDA helps the designer identify opportunities to improve energy efficiency and then develop and implement strategies that result in an energy-efficient building design.

The user interface would provide user-friendly, graphics-oriented communications for easy and efficient access to the EDA, facilitating the use of the tool and enhancing the user's ability to understand the output. Advanced computer visualization capabilities would allow the user to visually investigate many of the critical qualitative aspects of design, such as view and glare, in addition to quantitative ones. These issues strongly interact with energy-related decisions and are beyond the scope of simulation models currently available.

Desirable Features

To be effective, a computer-based energy design system should have the following characteristics, which we have classified into five categories:

General Characteristics

The energy design system must

- Be part of a larger integrated building design environment
- Handle a broad range of commercial buildings, building uses, climates, and other conditions.

User Interface Features

The system interface should

- Accommodate the needs of the various professions responsible for making energy-related design decisions
- Accommodate different energy-related skill and experience levels within each profession, providing guidance necessary for use of the system
- Satisfy the needs of users with a broad spectrum of computer

and CAD experience, from the novice or infrequent user to the experienced designer who uses the system daily.

Design-Related Features

The integrated CAD system should provide an environment that

- Facilitates the interactive and recursive nature of the design process
- Supports parallel development of several alternative design schemes
- Supports the visual nature of design
- Provides assistance for evaluating both quantitative and qualitative design criteria
- Encourages interaction among design participants--members of the design team, owners, users, and operation professionals.

Relationships to Other Phases of the Building Life Cycle

To ensure that the building is constructed and operated energy efficiently, as designed, the system must

- Support the transfer of information between design and operation (in both directions)
- Assist the designer in developing energy-efficient operation strategies as part of design
- Provide the links necessary to transfer the designers' operation intentions to the building owner and operator.

Intelligent Features

To meet the needs of the designer and establish the user's confidence, the CAD system should

- Provide advice leading to reasonable conclusions in an uncertain environment
- Include a good explanation facility that can justify the system's advice and decisions
- Include dynamic knowledge bases that can change and grow as additional knowledge and experience are acquired and as new technologies are developed
- Possess intelligent characteristics that allow the system to customize interactions to meet each user's individual needs and method of designing

- "Learn" from past designs and information on actual building performance fed back to the system.

Conclusions

The potential impacts of successfully integrating energy expertise into the design process and making energy performance a primary design criterion are unprecedented in the field of energy-efficient buildings. If designed effectively to meet user needs, advanced, intelligent building design systems will provide the vehicle to make this happen. The USDOE AEDOT project is addressing this need by becoming part of the evolution of advanced CAD systems. The AEDOT systems have the potential for far greater impact in the U.S. than any other building energy information transfer activity to date.

The AEDOT project is currently beginning development of its first prototype. The prototype will illustrate some of the intended features and capabilities identified in this paper. A number of issues associated with providing these capabilities will also be addressed in this work. The project will begin to establish links to other efforts to develop advanced CAD systems by integrating at least one existing CAD package into the prototype, collaborating with other researchers and building designers in a team effort to develop the prototype, and using the products of previous USDOE research. Members of the AEDOT team will expand these efforts by continuing to exchange information within the national and international technical community. The long-term success of this effort will depend on becoming part of a larger cooperative effort to develop a sophisticated building design environment that supports all aspects of design and integrates into the process of design, which is defined not by computer system developers but by designers.

Acknowledgments

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