ENERGY-EFFICIENT BUILDING DESIGN AND OPERATION: THE ROLE OF COMPUTER TECHNOLOGY

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INTRODUCTION

Most commercial buildings designed today will use more energy and cost more to design and operate than necessary. Energy savings of more than 15% could be achieved with little or no increase in first cost. Even greater savings of 30% to 60% could result from considering energy performance early in building design and by using building system integration techniques. However, most building design teams do not consider the energy impacts of design decisions adequately to achieve these savings. Furthermore, energy-efficient performance requires proper building operation and maintenance. Operation practices intended by the designer are often not adequately transferred during commissioning for use as guides during building operation. Compounding the problem, building operators frequently overlook degradations in performance and opportunities for more efficient operation.

EVOLVING COMPUTER TECHNOLOGY

Computer technology is constantly changing; computer speed and computational power are continually increasing. Relatively inexpensive computational power enables us to develop new tools to assist designers and building operators.

Capabilities evolving from the fields of artificial intelligence, advanced database technology, computer graphics and visualization, and system integration are now beginning to allow computers to provide assistance that was impossible a few years ago. Knowledge-based systems are already used in small subdomains, such as safety-glazing selection and heating, ventilating, and air-conditioning (HVAC) equipment maintenance. Capabilities currently evolving from research into automated planning, qualitative modeling, and machine learning will allow computer systems to carry out functions that require reasoning about qualitative as well as quantitative information. Computers are evolving from machines that "crunch" numbers into sophisticated systems that intelligently process and manage information.

Using sophisticated computer graphics and visualization techniques, designers can now generate realistic renderings of the interiors and exteriors of buildings. These capabilities allow architects and their clients to actually view realistic depictions of buildings even at the earliest stages of building design. Sophisticated computer capabilities are being adapted to study important qualitative design issues, such as the integration of electrical and natural lighting and its effect on illumination.

These and other evolving computer capabilities provide new opportunities to use computers to promote the design and proper operation of energy-efficient buildings. The U.S. Department of Energy has initiated the Advanced Energy Design and Operation Technologies (AEDOT) project to develop advanced computer-based tools that do just that. Led by Pacific Northwest Laboratory, a team of researchers is beginning to develop the first prototype which will illustrate some of the intended AEDOT capabilities.

THE PHILOSOPHY BEHIND THE APPROACH

Computers and humans should provide complementary functions; they are good at different things. Computers manipulate large collections of numbers in complicated ways quickly and efficiently, while humans experience difficulties and are slow in manipulating all but the smallest whole numbers without the assistance of a calculator or computer.

Humans possess imagination and creativity, while computers are not creative and are not likely to become so in the foreseeable future despite advances in some areas of artificial intelligence. As a result, our approach is to create a partnership in which the computer assists humans in designing and operating buildings energy-efficiently.

INTEGRATING THE BUILDING LIFE CYCLE

Today, the phases of the building life cycle--design, construction, commissioning, operation, and rehabilitation--are relatively distinct. The constructed building often differs from the original design. These differences are not recorded on as-built drawings for future reference. Whether the changes violate key principles or the designers' performance assumptions may not be considered at the time the changes are made. The designers' intentions are not adequately conveyed to the building commissioners and operators. As a result, the building may not be operated as the designer intended it to be. When novel systems or conservation measures requiring operator involvement are part of the design, they may never be properly used as intended by the designer. Later in the building's life, when changes are made, the interaction of various systems may be neglected. For example, new interior partitions may create inadequately heated or cooled offices if the HVAC zoning is not considered. These are all problems that could be alleviated through better information transfer between the phases of the building life cycle.

Computer technology could be used to promote the transfer of information from the designer to the contractor, commissioner, building owner, and operator. Changes during construction could be assessed and recorded electronically as part of a building-specific database. Building operation could be improved by making this building-specific database resident in the computerized operation system of the building. Computer technology could also be used to provide feedback on building performance (e.g., energy performance) to the building design team and computerized design assistant. Performance feedback could be used to update the knowledge incorporated in the computer system to improve the design team's judgement in the future. These information links would help ensure the proper energy-efficient operation of new buildings.

DESIGN ASSISTANCE

Energy impacts are frequently not considered during the design of commercial buildings. Most design teams do not have sufficient in-house expertise to identify and exploit the many energy-conserving opportunities available. Fee structures do not usually permit the hiring of an energy specialist, nor do they provide for the cost of energy analysis.

Knowledge embedded in a computerized design assistant could assist designers in making informed energy-related decisions at no substantial additional cost. The field of knowledge-based systems provides a number of promising techniques for automating the process of providing design assistance as part of advanced computer-aided design systems. The earlier in the design process that this input is provided, the more beneficial the impacts can be. An example of how energy advice might be provided by a computerized assistant early in building design is shown in the computerized concept demonstration that accompanies the poster presentation of this paper. Early in the design process, energy advice might be based on heuristic rules. Later in the process, the computerized assistant might run sophisticated energy simulations automatically when the designer makes changes to the design to assess their impacts. The system would then reason about the results of the simulations, reach appropriate conclusions, and provide advice to the designer in an easily understood form. If the designer wanted to investigate the details of how the system reached the conclusions, the system would provide that capability. The system would even allow the designer to run the simulation programs manually, but it would not require the user to investigate any deeper than the advice automatically provided (and even that could be suppressed).

The primary purpose of a computerized design assistant would be to make the results of many years of building energy efficiency research readily available for the broad range of firms involved in building design. Advanced computer technology will play a key role in achieving this objective.

OPERATION ASSISTANCE

Today, energy management and control systems implement prespecified control strategies, monitor systems, and provide alarms when variables are outside prespecified bounds. Using methods from artificial intelligence, computerized operations assistants will go far beyond today's capabilities by diagnosing problems, identifying opportunities for operation improvements, and providing recommendations to correct problems and take advantage of these opportunities. Rule-based systems already can be used to diagnose problems that are identified *a priori* in a system's knowledge base. Evolving methods, such as qualitative reasoning, will extend the capabilities of computerized operation assistants into the realms of detecting and diagnosing problems not preprogrammed into the computer.

Emerging data storage, management, and presentation capabilities (such as hypermedia or multimedia coupled with video disk technology) will allow operation assistants to contain detailed information about each piece of equipment and system in a building. A computerized on-site operation assistant will automatically access relevant information on recommended repair and maintenance procedures. This will eliminate the need for the operator to locate and page through volumes of manuals. The computerized concept demonstration includes a simple example of this capability.

CONCLUSION

Computer technology provides many opportunities to improve the energy performance of commercial buildings throughout the entire building life cycle. We are faced with developing those technologies to put the results of many years of buildings research into the hands of building owners, designers, and operators.