the surfaces (especially at the center of the surfaces) can be effectively computed. The occlusion of surfaces by other surfaces also needs to be computed efficiently. The size of the surfaces should also be at the appropriate level of resolution for efficiency in computations. Having many tiny surfaces in the building model will greatly increase the computational resources required for the simulations. Because of the nature of the model, boundary representation and radiation models will be more successful in the performance simulation of global, diffuse effects rather than directional and specular effects.

Conclusions

The performance simulation of computer-based designs of buildings in various performance domains has been difficult because of what has been called the 'integration problem." Researchers trying to use performance simulation techniques with building representations that are not compatible with the simulation techniques have augmented this problem. In this paper, an approach has been suggested that takes a building representation format that is currently being used in computer-aided architectural design systems, and using an enhanced version of that representation format as a basis for an integrated set of performance simulation techniques based on a common radiation model.

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Ganapathy Mahalingham, Ph.D. *is an Assistant Professor at the Department of Architecture, North Dakota State University.*

INTEGRATED DECISION-MAKING: THE BUILDING DESIGN ADVISOR

Vineeta Pal, Ph.D. and Konstantinos Papamichael, Ph.D.

Abstract

In this paper we describe an integrated decision-making environment that brings together several different building simulation tools, and provides the data management and process control required for their integrated use, from the initial, schematic phases of building design. The output of one tool is easily used as input to another, either directly, or after appropriate manipulation to ensure compatibility, which makes the whole integrated environment more than the sum of its parts. A simple graphical user interface, common to all simulation tools, allows access to all building parameters and supports multicriterion judegment by allowing side-by-side comparison of multiple alternative designs with respect to multiple performance parameters.

Introduction

Design decision-making involves selection among multiple design options with respect to multiple performance criteria. This, in turn, involves a) the generation of multiple design options, b) the computation of the values of multiple performance parameters, and c) the evaluation of the design options with respect to the performance considerations.

The Building Design Advisor (BDA) is a software environment that a) allows the designer to easily and graphically generate and maintain multiple design options, b) brings together several building simulation tools to address various performance aspects, and c) provides a graphical interface for the comparative evaluation of multiple designs with respect to multiple criteria.

The task of integrating various building simulation tools into one software environment has proven to be especially challenging. This is because the semantic representation of a building can vary drastically depending upon the aspect of the building being modeled. Furthermore, if we want to model not just individual aspects of building design but also their inter-dependencies, dynamic communication among the various simulation tools needs to be maintained.

The Building Design Advisor responds to this challenge. It supports the integration of multiple building models and databases used by simulation, analysis and visualization tools, through a single, object-based representation of building components and systems. Based on a comprehensive design theory, the BDA acts as a data manager and process controller, automatically handling the input and output to and from multiple simulation, visualization and analysis tools, allowing building designers to benefit from their prediction capabilities throughout the building design process.

User Interface

The Building Design Advisor has a simple Graphical User Interface that is based on three main elements, the Schematic Graphic Editor (SGE), the Building Browser and the Decision Desktop.

The Schematic Graphic Editor (Figure 1) allows designers to quickly and easily specify basic building geometric parameters. Unlike traditional CAD packages, it allows the user to draw specific building components, such as "spaces," "windows," and "luminaires," rather than lines that represent these objects. Objects drawn in the SGE hold semantic information about themselves and their relationships with other objects. Through a default value selector mechanism, the BDA automatically assigns "smart" default values to all non-geometric parameters required by the simulation and analysis tools. These values are selected from databases of alternative building components and systems, based on building location and building/space type. These default values can be easily reviewed and changed through the Building Browser.

The Building Browser (Figure 2) allows building designers to quickly navigate through the multitude of descriptive and performance parameters addressed by the analysis and visualization tools linked to the BDA. Through the Browser the user can edit the values of input parameters and select any number of input and output parameters to display in the Decision Desktop, for any number of alternative designs.

The Decision Desktop (Figure 3) allows building designers to compare multiple designs with respect to multiple parameters, as addressed by the analysis and visualization tools linked to the BDA. The Desktop offers graphic display of data, supporting a large variety of data types, including 2-D and 3-D distributions, images, sound and video. It is structured as a matrix of cells where the matrix rows correspond to the parameters selected by the user in the Building Browser and the columns correspond to alternative design solutions that have been defined by the user.

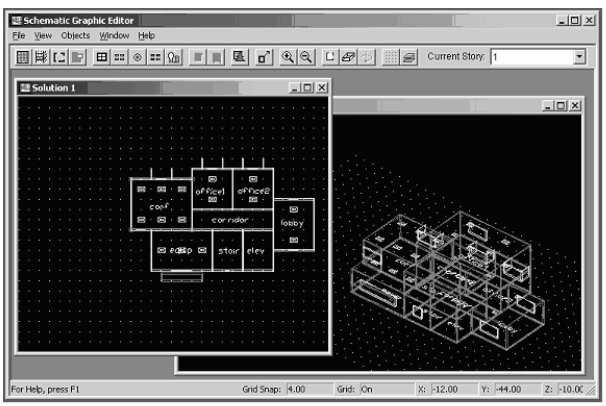

Figure 1: Schematic Graphic Editor

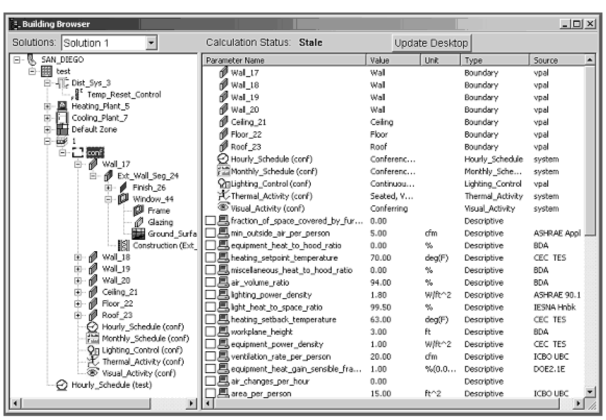

Figure 2: Building Browser

Linked Simulation Tools

BDA 3.0 supports performance prediction with respect to various performance considerations, through links to a simplified Daylighting Computation Module (DCM) (Hitchcock 1995), a new, simplified Electric lighting Computation Module (ECM), and the DOE-2.1E Building Energy Simulation software (Birdsall et. al, 1990).

The DCM calculates illuminance and glare values at a user-defined grid of points within a space. Daylight Factors are computed for standard clear and overcast sky conditions, and for a series of 20 solar altitude and azimuth values that cover the annual range of sun positions for the specific location of the building. Then hourly values for illuminance are computed by interpolation between these values. The window geometry, glazing transmittance, surface reflectances, and room geometry are taken into account in the calculations.

The ECM combines the simplicity of the IESNA Zonal Cavity Method (IES, 1993) with a more analytical approach for calculating the direct component of illuminance. The direct component of illuminance is calculated at each of the grid points on the workplane using the luminaire's candlepower distribution and the geometric relationship between the luminaire and the grid point. The indirect component of illuminance is computed using a modified version of the IESNA Zonal Cavity Method.

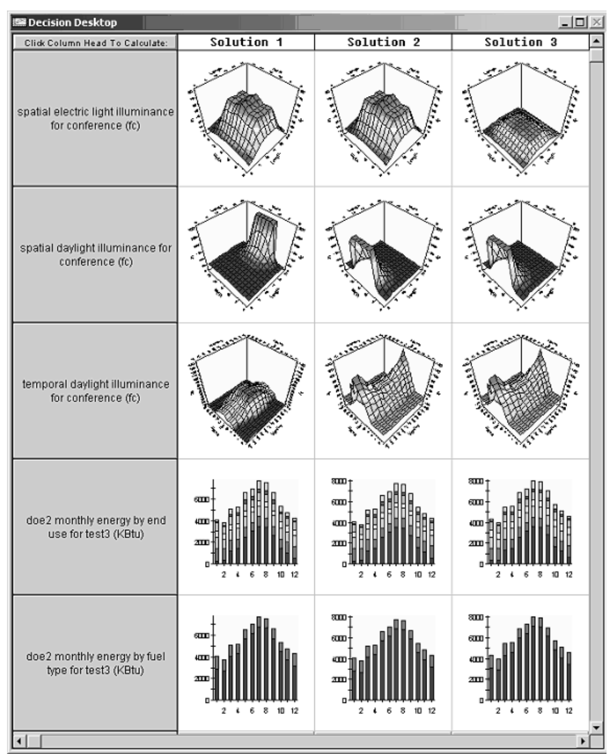

Figure 3: Decision Desktop

DOE2.1E predicts, among other things, the hourly energy use for a building. It requires hourly weather information along with a description of the building and its HVAC equipment and occupancy patterns. Among the factors that it takes into account are weather and solar conditions, electric lighting loads, window geometry, glazing properties, and shading.

Lighting Analyses

For lighting analyses, the user can define spaces and place luminaires, windows, overhangs and vertical fins in the Schematic Graphic Editor (Figures 4 and 5). Spaces, windows and luminaires may be moved or deleted. If a space is moved, the windows and luminaires move with it. Sensor points may be added to observe lighting levels at particular points. The user can select any object to view and modify its properties (Figure 6). The geometric properties can be modified in the Schematic Graphic Editor, while the non-geometric properties are modified in the Building Browser. The user can select various performance parameters to be computed, e.g., spatial illuminance from daylight, temporal illuminance from daylight, spatial illuminance from electric lighting, and spatial or temporal glare values. The Daylighting (DCM) and Electric Lighting (ECM) tools are activated accordingly. The results are displayed in the Decision Desktop.

Energy Analyses

For energy analyses, BDA supplies DOE2.1E with hourly weather information along with a description of the building and its HVAC equipment and occupancy patterns. This information includes the weather and solar conditions in accordance with the city and country selected; the building, space, window, and shade geometry as specified by the user in the Schematic Graphic Editor; the HVAC system and Plant specifications which are provided default values according to building type and location, and which can be modified by the user at any time; schedules for system operation, occupancy, and lighting and equipment loads; and construction specifications for space boundary elements and window glazing. The energy related performance parameters that can be computed include annual and monthly energy-use values, broken down by end-use and by fuel-type. BDA 3.0 also supports DOE2.1E parametric evaluations of energy requirements by end use as a function of Window-to-Wall ratio, allowing quick and easy optimization of window size (Figure 7).

Lighting Controls and Energy Savings

BDA also allows the analysis of control strategies and sensor placement for maximizing energy savings from lighting control while providing visual comfort. To model lighting controls, users can select control strategies, e.g. stepped or continuous dimming, place any number of sensor points, and create lighting zones through links among the various luminaires and sensor points. BDA is set up to allow users to make these associations easily, using "relation objects", in a manner that can transparently be observed and controlled (Figure 8).

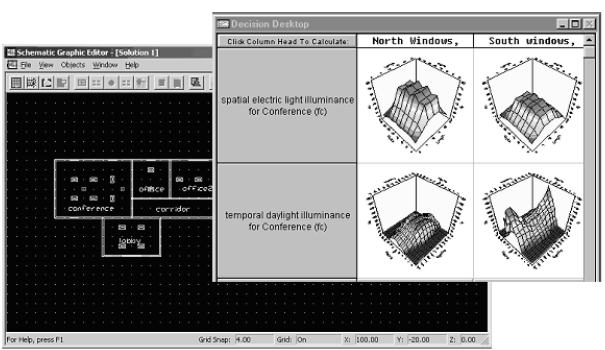

Figure 4: Daylighting and Electric lighting analysis

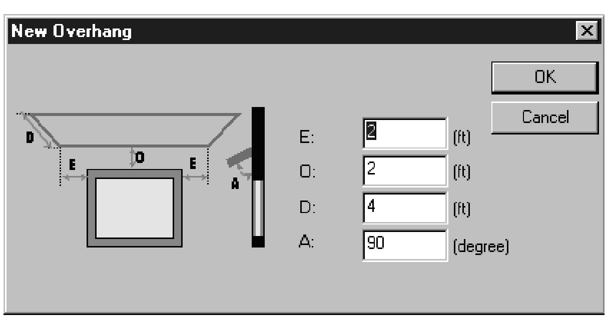

Figure 5: Definition of overhang geometry

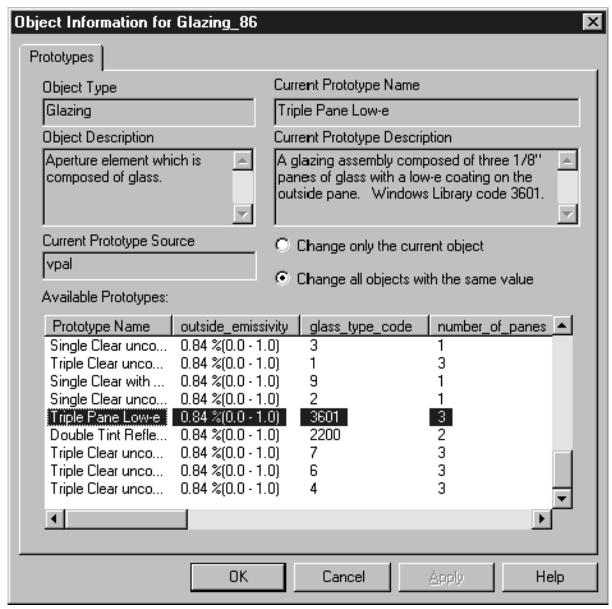

Figure 6: Selection of glazing options

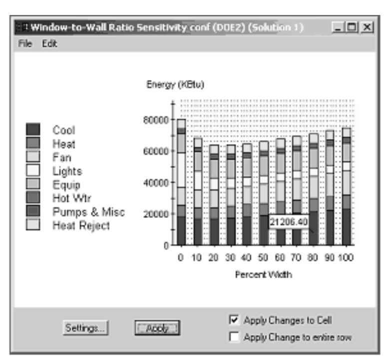

Figure 7: DOE2.1E parametric evaluations of energy requirements as a function of Window-to-Wall ratio

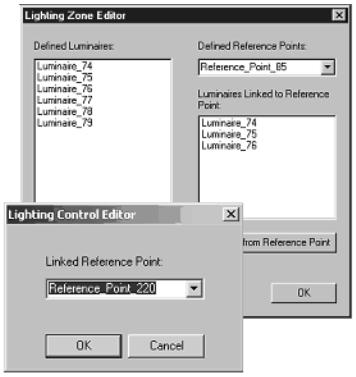

Figure 8: Modeling lighting controls

Current Status and Future Directions

Currently, the BDA software is in its 3.0 release and is available free of charge from http://gaia.lbl.gov/BDA. Main new features since the 2.0 release include a new electric lighting module (ECM), DOE-2 parametric runs for window size optimization and dual unit capabilities (English and Metric). Work is already underway for the next version, which will include links to the RADIANCE day/lighting simulation and rendering software (Ward & Shakespeare 1998; http://radsite.lbl.gov). Plans for future versions include links to additional simulation tools and databases, e.g., cost estimating modules, building rating systems, environmental impact and life-cycle costing modules, as well as links to commercial CAD software and electronic product catalogs from manufacturers of building components and systems.

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Vineeta Pal, Ph.D. *and* ***Konstantinos Papamichael, Ph.D.*** *are researchers at the Building Technologies Department, Lawrence Berkeley National Laboratory*

DESIGN ALGORITHMS AFTER LE CORBUSIER

Abimbola Oluwatoni Asojo

Abstract

Some views of design are the act as puzzle making, problem solving, evolutionary, and decision-making. All these focus on form generation as constructive, therefore characterizing design as a path-planning problem through a space of possibilities. Design problems consist sets of information divided into initial, intermediate, and goal states. Design in its simplest state consist of a set of operators, sequences (or paths) between initial and goals states. In this paper, I present design algorithms for Le Corbusier because of his distinct compositional techniques particularly for his "White Villas" in which some elements have been identified to recursively occur.

Introduction

According to Violet le Duc, "the first condition of design is to know what we have to do, to know what we have to do is to have an idea, to express this idea we must have principles and form that is grammar and language. Design literally has to do with the ability to read and write architecture. The skill of reading is more than just appreciating and intuitively recognizing the formal quality of the object. Reading architecture has to do with the process of parsing or resolving the elements and parts of a building and describing them grammatically. Reading architecture is a prerequisite to writing, constructing or composing it."[1] The impact of computers in architecture is parallel to the introduction of printing and engraving in the Renaissance. With Cad feedback through the storage, evaluation, and manipulation of formal constructs from recent and distant past, the instant interaction, and access of many designers to common but continually upgraded database is possible.

The achievement of computer-aided design (CAD) in the field of architecture compared to other fields may seem trivial to date, but current research is transforming the use of computers in design. Current computer-aided design (CAD) practice is rooted in an approach that utilizes computers as mere drafting and rendering machines, offering little or no insight to design. They advance technically to higher speeds and more intuitive displays presenting little theoretical insight to architecture.

Research currently going on in universities around the world is however establishing the computer as a form generating system. This school of thought defines the design world to be fundamentally characterized by its shapes, vocabulary, and operators, and thus, architectural composition can be segmented into a vocabulary of extensively and finely differentiated relations and functions. Rules for the interrelationship of these parts are defined and the rules are programmed in such a way that the program determines the evolution of the form.

In this paper, I present a grammar for the designs of Le Corbusier (1887-1965), starting from his basic domino system arrangement, the column grid, slabs and stair arrangement to his much acclaimed five points of architecture: the pilotis, roof garden, free plan, ribbon windows and free facade. All these are expressed as rules and algorithms are developed in