Title
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Publication Date
2002-02-06

BRIDGING THE GAP BETWEEN BUILDING SCIENCE AND DESIGN STUDIOS

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Abstract. Design studios and building science courses have been conducted independent of each other, mainly due to a lack of tools that allow quick and easy consideration of building science criteria, such as comfort and energy requirements, during the design process. Existing tools are not user-friendly and their use requires significant effort in gaining familiarity with the input requirements, understanding the modeling assumptions and interpreting the output. This paper is about the Building Design Advisor (BDA), an evolving computer-based tool intended to bridge the gap between design studios and building science considerations by addressing the above-mentioned limitations of existing tools. BDA allows automatic preparation of input files to multiple simulation tools while the user is working in a CAD environment. BDA automatically activates the relevant simulation tools when the user selects performance parameters to be computed and provides the results in a graphical form, allowing comparison of multiple design options with respect to multiple performance criteria. The paper includes considerations for the use of the BDA in the design studio and ends with a description of the current development efforts and future plans.

1. Introduction & Background

Building design studios in most architectural education programs focus mainly on the spatial functionality and the overall form and aesthetic appeal of the building, neglecting the consideration of other performance aspects, such as comfort, cost, energy efficiency, environmental impact, etc. Such considerations are becoming increasingly important in the building industry and, to be effective, they need to be integrated into architectural design from the initial, schematic phases of building design.

Most architectural education programs include building science courses that address performance aspects such as comfort, energy, and environmental impact. These usually include design “exercises” which allow students to better understand concepts, principles, methods and tools. However, they usually focus on a few criteria that reflect the subject and scope of the course, neglecting the spatial arrangement and aesthetic issues.

Currently, there is a lack of courses that allow for integrated building design through consideration of multiple performance criteria, i.e., integrating consideration of comfort, energy, cost, environmental impact, etc., in the traditional architectural considerations of spatial arrangement and aesthetic appeal. The lack of such courses is a reflection of traditional architectural practice, which however is changing, as we become increasingly aware and better informed about the impact that buildings have on our lives, as well as the strategic and technological means available for the design of better buildings.

1.1 TRADITIONAL ARCHITECTURAL PRACTICE

Traditionally, architects have been involved with the initial formulation of the building design, focusing on the arrangement of the spaces called for by the architectural program, in a way that produces a functional and esthetically pleasing building design.

After most of the architectural design is in place, it is passed on to engineers, who address structural, mechanical, electrical, etc. issues and specify building envelop components and mechanical systems that address the heating, cooling and ventilation needs of the building to provide comfort and indoor air quality. However, if heating, cooling, lighting, etc. were considered from the initial, schematic phases of building design, the resulting design could have significantly reduced loads, providing increased comfort at reduced cost, e.g., by reducing the size of mechanical and electrical equipment.

1.2. BARRIERS TO INTEGRATED BUILDING DESIGN

Unlike spatial arrangement and aesthetic appeal, which can be evaluated directly from the traditional architectural drawings, most building science performance considerations such as thermal, luminous and acoustic comfort, energy requirements, environmental impact, etc., require significant effort for the computation of the values of their performance parameters.

To address such computation requirements, a number of computer programs have been developed, usually referred to as simulation programs, such as DOE2.1E (Birdsall et al. 1990), TRNSYS (Klein et al. 1976), Radiance (Ward and Shakespeare, 1998), Lumen Micro (http://www.lighting-technologies.com/), COMIS (Feustel, 1998), Athena (Trusty and Meil, 1997), etc.

Most simulation programs have been developed by researchers for research purposes and do not have an intuitive user interface. They require the development of input files that contain the description of the building environment and its operation blending key words and values in carefully organized formats. Moreover, they provide output in the form of alphanumeric tables that are not easy to review and interpret.

Most of the available simulation tools, especially the ones that have advanced modeling capabilities and increased performance prediction accuracy, require detailed descriptions of the building and its operational characteristics, such as construction specifications, occupancy patterns, operational schedules, etc. This type of detailed information is usually not addressed during the early, schematic phases of architectural design, when the focus is mostly on spatial arrangement and aesthetic appeal.

2. The Building Design Advisor (BDA)

The Building Design Advisor is a software tool designed to help overcome the barriers to integrated building design, by making the use of multiple simulation tools quick and easy from the initial, schematic phases of building design. The BDA uses a single, object-oriented representation of the building and its context, where building components and systems are described as inter-related objects that are characterized by lists of parameters (Papamichael et al., 2000).

The BDA software supports links to any number of simulation tools. The current version includes links to DElight (Hitchcock, 1995), a daylighting simulation tool, ECM, an electric lighting simulation tool, and DOE-2, a whole-building energy simulation software (Birdsall et al., 1990).

2.1 USING THE BDA SOFTWARE

The first step to modeling a building in BDA is to specify a project name, a user name and the building type and location. The last two pieces of information are used to determine “smart” default values for non-geometric parameters that are required as input to simulation tools, such as occupancy schedules, weather data, construction types, etc. Weather files follow the TMY2 format (http://rredc.nrel.gov/).

As soon as these project data are specified, the BDA software activates the Schematic Graphic Editor (SGE), which is a simple CAD environment that uses an object-oriented representation of building components and systems. SGE allows users to quickly and easily draw spaces, windows, overhangs, vertical fins, external obstructions and lighting fixtures, as well as work-plane illuminance points for daylight-based electric lighting controls (Figure 1).

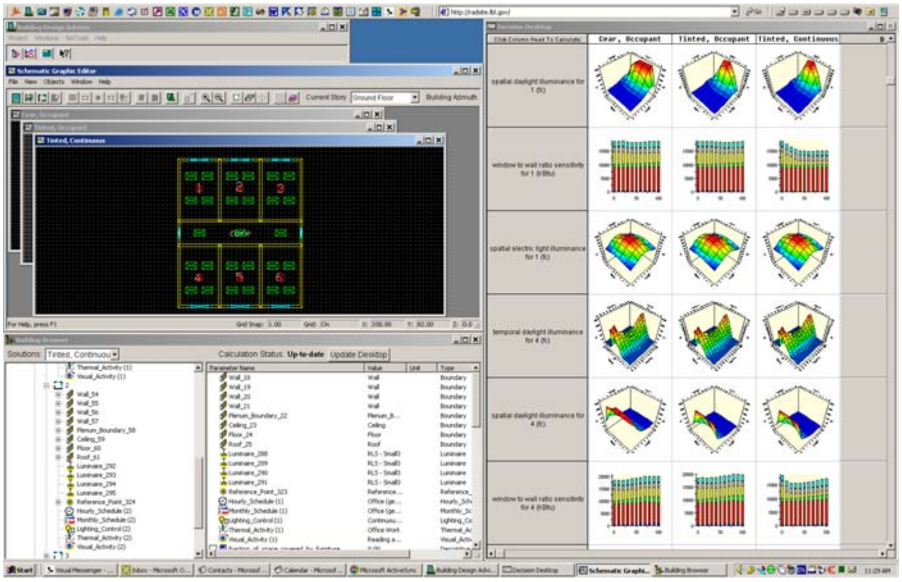

Figure 1. Screen shot of a BDA session showing the Schematic Graphic Editor, the Building Browser and the Decision Desktop. The screen shows comparison of three alternative glazing and lighting control combinations, for a simple commercial building. The computations include more than 60 hourly energy simulations that show the relationship between window to wall ratio and energy requirement for window size optimization. Creating the building model from scratch and performing all daylighting, electric lighting and energy simulations took less than 20 minutes!

To draw a space, users first select from a list of space types and then proceed to drawing the space by drawing the walls that define it. The space type information is used by the BDA to further refine “smart” default values for non-geometric parameters, such as thermostat settings, recommended illumination levels, etc. At any point, BDA users can see the whole project data maintained by the BDA through the Building Browser, which is a user interface element that allows browsing and editing of the values of all objects and parameters in the project database (Figure 1).

2.1.1 The Building Browser

The Building Browser is composed of two side-by-side windows. The left window displays all of the objects in the BDA project database. The display is hierarchical, starting from the site object and unfolding into various hierarchies, e.g., building, story, space, walls, etc. When an object is selected in the left window, the right window displays all of the objects that are linked to the selected object, as well as all parameters that characterize the object. The right window contains columns that display values, units, and value sources for all objects and parameters.

Building object values, such as wall construction, glazing type, lighting fixture, etc., can be changed by selecting alternative options from the BDA object libraries, e.g., libraries of wall constructions, glazing materials, lighting fixtures, etc. Object parameters values, such as thermostat settings, work-plane height, etc., can be changed by direct user input.

To the left of each parameter in the Building Browser is an icon that shows either a computer, or a person. Computer icons indicate that the parameter has a default value, while person icons indicate values entered by users. When a user changes a default value, the computer icon is automatically changed to a person icon and the name of the user is automatically entered as the source of the value. In this way, the BDA allows multiple users to work on the same project, keeping track of updates.

To better support schematic design, BDA continuously maintains a space model linked to the wall objects, which are made up of wall segments. In this way, SGE users can move whole spaces around, while the BDA automatically computes interior and exterior wall segments for proper assignment of construction specifications.

Several "smart" options have been added to the behavior of the BDA building objects, which demonstrate the potential of object-oriented CAD. For example, if a space is moved to a new location that is adjacent to a window, the BDA will automatically remove the window; or if a space is moved to a new location overlapping another space, the BDA will not accept the new position and automatically put it back in its original position.

2.1.2 The Decision Desktop

Decision making requires perception of value, which can only come through comparison of alternative options. To assist decision-making, the BDA supports the maintenance of multiple design alternatives, referred to as "solutions." When users select the New Solution option, the BDA duplicates the "current" design, creating a fork with two identical solutions, both of which can be changed as well as form the basis for more solutions.

The BDA user interface includes an element called Decision Desktop, which allows users to compare multiple alternative design solutions with respect to multiple descriptive and performance aspects. The Decision Desktop is a matrix whose columns correspond to alternative design solutions and rows to parameters from BDA's building model (Figure 1).

New solutions are automatically entered as columns in the Decision Desktop. The parameters that occupy the rows of the Decision Desktop are selected by users in the Building Browser. Users control the display of parameters in the Decision Desktop through a checkbox to the left of each parameter in the Building Browser. If a selected parameter has a value, then the value is automatically entered in the Decision Desktop. Parameters that represent the output of simulation programs, such as DOE2.1E, DElight, etc., do not have initial values. To allow time control, the BDA activates computations by simulation tools only when requested by the user.

When a simulation output parameter is selected for display in the Decision Desktop, the BDA assigns the parameter to a Decision Desktop row without displaying a value. To display values for such parameters, BDA users request computations by clicking either at the header of the Decision Desktop column, or the Compute icon in BDA's main window. The BDA automatically prepares the input for the required simulations, activates the required simulation programs and then displays their output in graphical format in the Decision Desktop.

2.2 MODELING CAPABILITIES

The BDA building model can accommodate spaces of arbitrary geometric complexity. However, not all simulation tools can model spaces of arbitrary complexity. BDA is aware of the modeling capabilities of the simulation tools linked to it and automatically removes output parameters from objects that cannot be modeled by the currently available simulation tools. Both, DElight and ECM, for example, can only model rectilinear spaces. The output parameters of DElight and ECM are automatically removed from the parameter lists of non-rectilinear spaces.

The current version of the BDA software includes several simulation output parameters in BDA's building model. Some of them are computed through the activation of a single simulation tool, while others require the activation of more tools, using the output of one as input to another.

The DElight software is used to compute values for spatial and temporal daylighting illuminance and glare values for rectilinear spaces. The ECM software is used to compute values for spatial electric lighting illuminance. ECM output is further manipulated to serve as input to the DOE-2.1E software, which is used to compute monthly and annual energy requirements by end use, e.g., heating, cooling, lighting, etc., and by energy source, i.e., electricity and gas.

3. Using the BDA in Architectural Design Studios

A greater presence of performance considerations in the minds of architects leads to better design. The current version of the BDA software addresses only daylighting, lighting and energy performance aspects. However, these are enough to start introducing students to integrated building design, i.e., the consideration of more than spatial arrangement and aesthetic appeal from the initial, schematic phases of building design.

The objective of using the BDA in design studios is not to shift the emphasis of design considerations to daylighting or energy. The objective is to practice including them, i.e., to training the mind in considering as many performance aspects as possible while the hand is drawing the lines that define the building's form.

While the BDA software can certainly be used to model whole buildings it can also be used to quickly and easily compare alternative architectural considerations, such as the orientation of spaces and position and size of openings. Such comparisons can be done within a matter of minutes, starting from scratch. For example, it takes approximately 20 minutes to construct an office building with seven spaces from scratch, generate three alternative designs, and obtain results for 6 ECM, 6 DElight, and 63 DOE2.1E simulation runs.

4. Current status and plans for the future

The current version of the BDA software (version 3.0) is licensed free of charge and can be downloaded from http://gaia.lbl.gov/BDA. In the meantime, the BDA development efforts continue.

Current development efforts are focused at making the BDA software even easier and faster to use, e.g., supporting duplication of spaces and stories, adding performance parameters by further manipulating the output of the simulation programs to compute averages, minima, maxima, etc., as well as providing the option to view the graphical data in numerical, tabular format.

Current development efforts are also geared toward preparing the BDA software for use by the building industry. The next version of the BDA, planned for release in the fall of 2002, will include support for user-defined entries to all BDA object libraries. For windows the BDA will adopt the Window5 format (http://windows.lbl.gov/software/), which is used by most US window manufacturers for window-related data. Support for the Window 5 format, along with the currently supported IES format (IES 1993) for electric lighting fixtures, will allow BDA users to import manufacturers' data for actual windows and lighting fixtures.

Longer-term plans include the development of links to the Radiance lighting simulation and rendering software, which will allow modeling of spaces of arbitrary geometric and photometric complexity. Finally we look forward to the opportunity of linking the BDA to one or more of the recent commercial CAD systems that use object-oriented representations for building components and systems.

We also plan to continue offering free of charge licenses for academic and research use of the BDA software, expecting that Universities and Research Institutions will capitalize on the BDA software foundation to further extend and enhance it. Our current development efforts include streamlining of the main BDA code to make extension by other parties easier.

Acknowledgements

This BDA research and development efforts have been supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Building Technology, State and Community Programs, Office of Building Systems and Office of Building Equipment of the U.S. Department of Energy; the Public Works and Government Services Canada and the Panel on Energy R&D of the Federal Government of Canada, through Enermodal Engineering Ltd. of Kitchener, Ontario, Canada; the California Institute of Energy Efficiency; and the California Energy Commission.

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