Simulation Before Design? A New Software Program for Introductory Design Studios

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INTRODUCTION

The 2010 Imperative states: "To successfully impact global warming and world resource depletion, it is imperative that ecological literacy become a central tenet of design education. Yet today, the interdependent relationship between ecology and design is virtually absent in many professional curricula. To meet the immediate and future challenges facing our professions, a major transformation of the academic design community must begin today. To accomplish this, The 2010 Imperative calls upon this community to adopt the following: Beginning in 2007, add to all design studio problems that: "the design engage the environment in a way that dramatically reduces or eliminates the need for fossil fuel."" How does the "2010 Imperative" fit into an introductory design studio where the students have limited knowledge of building materials and have not yet taken a environmental control systems class? A new simulation tool was developed to allow students in a second year studio to explore energy use in buildings at the beginning of the design process. This building simulation software will hopefully have an impact on the built environment.

THE PROBLEM

Architecture students who want to design sustainable, green and energy efficient buildings frequently find it difficult or too time consuming to use and learn building simulation software. Building simulation software should be designed to be easy to use in the early stages of a building design. This early design phase is the time when the greatest impact can be made on the energy use of the building.

(Grau and Wittchen, 1999) A tool that helps make crucial decisions at the very beginning of the process would then have the greatest impact.

VERY SIMPLE DESIGN TOOLS

The initial development of this software program was brought about after reading a paper on "Very Simple Design Tools" (La Roche, Ligget, 2001) which are defined as having the following characteristics.

• Very easy to use.

• Easy to Learn

• Sufficient precision

• Accessible to a large number of users

• Permit the flow of information with other Very Simple Design Tools

• Use the minimum amount of data necessary to generate useful results with the simplest interface.

Building on these characteristics, the author developed a building simulation software program called FreeRunner. This program explored the possibility for user interface and building simulation in a "Very Simple Design Tool".

The interface for FreeRunner was built on the following guidelines.

1. Very little information about the building will be needed in order to use the program and get re-

sults. This allows the designer to explore different ideas and configurations of building elements, actually using the software to design.

2. All information (both input and output) is presented in a single view. Nothing is hidden from the user so they can see all of the variables.

3. The manipulation of the data can be explained in a few sentences. The user can master the program in minutes without using a manual or needing any training just to use the program.

4. The input of data can be done with a mouse. This helps to put parameters on the input data. The program can put reasonable limits on the properties of materials, freeing the user from having to know what values to enter.

5. The calculations and output happens automatically and almost instantaneously. This gives the user feedback so they feel free to explore and get a sense of what design changes have the greatest impact.

6. The program should already contain data when the program is opened so the user knows what to expect in terms of input and output. This gives the user an example of how the program works when they first open the program.

ENERGY USE RELATED TO COMFORT

Instead of designing by reducing the amount of fossil fuels a building used by some percentage the program is set up to design a building that uses zero fossil fuels and is comfortable to the occupants. This simplifies the problem by not introducing a HVAC system and the vague concept of what a BTU is and how it would be produced. It complicates the problem because the students think they don't know what makes an occupant comfortable. Also without a HVAC system how can the occupants be comfortable?

The question of why buildings use energy usually gets the reply that it is used to heat, cool and light the building. Heating and cooling is employed to make the occupants thermally comfortable and lighting is used for visual comfort. This leads the students to start thinking about what comfort means. A quick lecture on human comfort can be given defining clothing levels, activities, mean radiant tem-

perature, air temperature, relative humidity and air speed. The adaptive model of comfort should also be discussed where acceptable degrees of comfort are possible over a range of temperatures from 63° F to 88° F, if occupants are allowed to adapt to their surroundings. This temperature range should be the goal for the buildings they design.

FREERUNNER

The program FreeRunner calculates the comfort level in a free running building that uses only solar gain for heating. The interface in this program is a series of sliders that the user manipulates in order to fine-tune the different components of a building.

Figure 1: FreeRunner

The interface is similar to an equalizer on a stereo where one fine-tunes the sound output. The inputs include occupancy, outside temperature, building size, solar aperture, mass, window type, and envelope properties. The output occurs instantly in the form of a graph with one-day outdoor and indoor temperature and the predicted adaptive comfort level. The algorithm used was a simple heat loss calculations and solar heat gain equations where used. (ASHRAE, 2001) . The limitations of Free-Runner are, the simple algorithm was not verified and there was no visual feedback for the building. Also the information was not transferable to a more advanced program.

SOLARSHOEBOX

To address the shortcomings of FreeRunner and to make it more appealing to students a more advanced program was created. SolarShoeBox models a simple rectangular building that is passively heated by direct gain and cooled by ventilation. This tool was based on FreeRunners user interface

but adds an OpenGL modeler and uses Energyplus for calculations. Energyplus is a new generation energy simulation program developed by the U. S. Department of Energy and has been validated. When the simulation with Energyplus is run, a DXF model is created that can be opened in almost any 3D software package. SolarShoeBox also creates an IDF file that can be opened directly into Sketch-up with the OpenStudio plugin. This allows all of the material properties to be transferred so no information is lost. The other difference between SolarShoeBox and FreeRunner is it will run a full year simulation and graph the results. The results graph shows the outdoor or indoor temperature. The indoor temperature is based on adaptive comfort level and is shown in green. Temperatures below the comfort zone are shown in blue and temperatures above the comfort zone are shown in red. The goal for the student is to design a building that would only show green on the graph. Since SolarShoeBox does not have a schedule for different seasons they will usually have to create summer time comfort by increasing the ventilation rate in the building.

USING SOLARSHOEBOX

There are eight main parameters that can be changed when using SolarShoeBox. These parameters can be done is steps with intermediate simulation runs by Energyplus. It takes about 6 seconds for Energyplus to calculate the results and to refresh the graph allowing many iterations to be done very quickly. All of these steps can be performed before the design process begins and should be the basis for the building design. The student should use this information similarly to using the information of how big a column must be to hold up a building; the combination of components given by SolarShoeBox are necessary for their building to be comfortable while using no fossil fuels. It is important for the student to imagine, for example, that a wall with a window that is 50% of the area of the wall does not have to be a single window, but can be many windows arranged in an infinite number of ways. Using the column analogy, a thin steel pipe or a heavy timber post might perform in a similar way but are aesthetically and sensorially very different.

All of the following steps can be done out of order and revisited at any time in the process. The order given is usually the first pass as the student attempts to create a comfortable indoor environment.

Step One: Choose a weather file.

The weather file is selected by a pull down menu. The file is an EPW file type and is available from the internet for 1042 locations in the USA, 71 locations in Canada, and more than 1000 locations in 100 other countries throughout the world. This step is needed for Energyplus to run and it also sets the latitude for sun shading design.

Step Two: Site

The building can be rotated 90° East and West from North. The latitude can be changed but is automatically set by the weather file.

Step Three: Building Geometry

The building height, length and depth are changed using sliders. As the sliders move the OpenGL modeler is updated in real time. The model can be zoomed in and out using the mouse wheel and rotated by click dragging.

Step Four: Wall Components

The insulation value is chosen for the envelope. This differs from most energy simulation programs because it reverses the decision order. Instead of choosing a wall type and figuring out the insulation level, the designer discovers what the required R-value should be and then designs a wall to that specification.

Step Five: Internal Mass

Mass type, area and thickness are manipulated to even out the indoor temperature swings.

Step Six: Windows

Window orientation, type and area as percent of wall area can be changed to see their impact on indoor comfort. The software will be updated when Energyplus version 4 is released to have the variables be U-factor, solar heat gain coefficient (SHGC), and visible transmittance (VT)

Step Seven: Ventilation

Ventilation can be changed from the recommended .35 air changes per hour to a lower value as if a heat
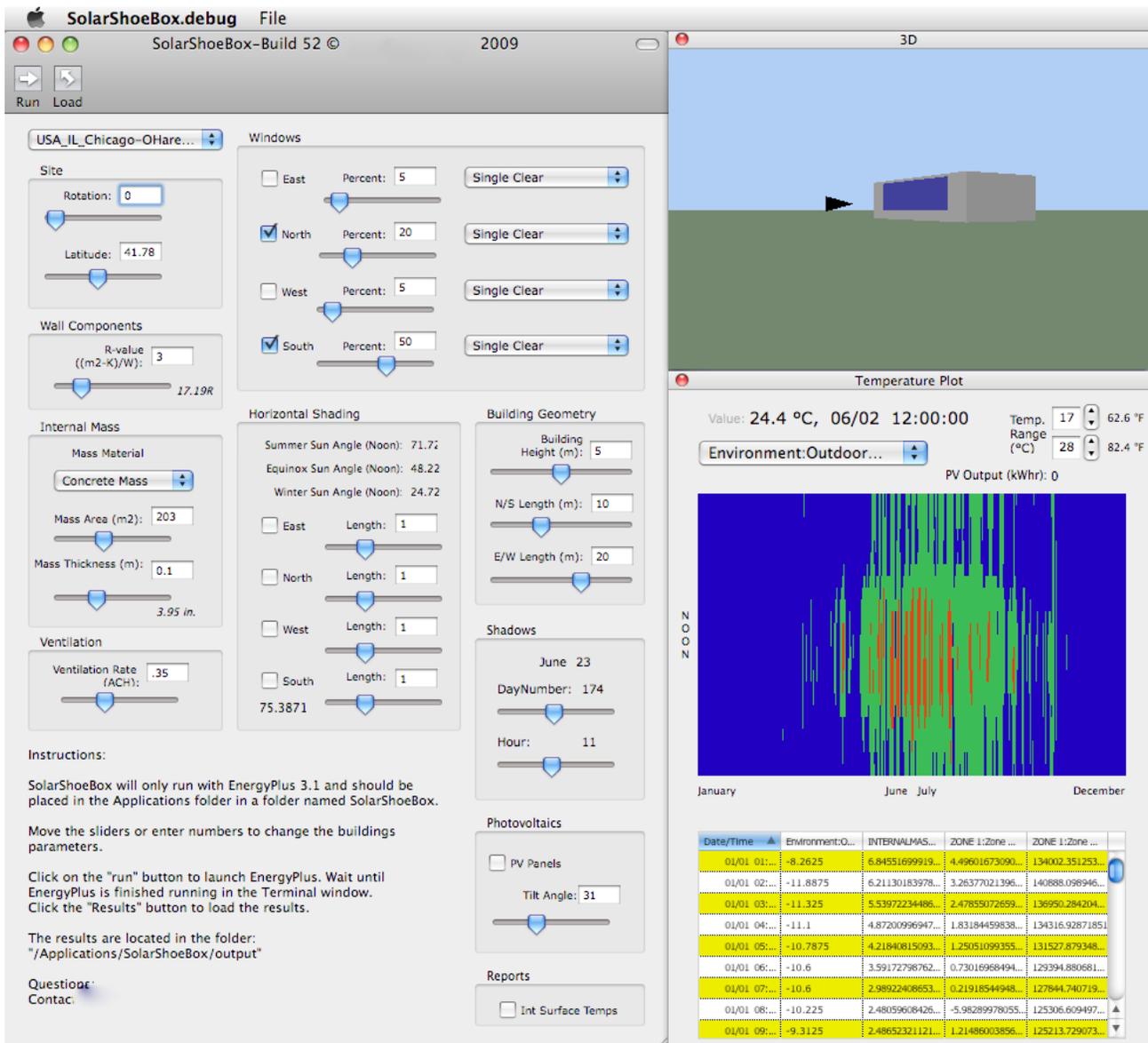
Figure 2: Interface showing parameter controls, OpenGL modeler and results graph with outside temperatures.

exchanger is used. Thermal comfort in the summer is usually achievable by raising the ventilation rate. The ventilation rate is controlled by an electric fan, which is powered by photovoltaic panels on the roof.

Step Eight: Horizontal Shading

Horizontal shading devices can be added to any wall. A slider changes the length of the shading device. Shadows are cast based on the latitude, date and time. The date and time can be changed to visually decide how long to make the shading device.

Bonus Step: Photovoltaics

Since Photovoltaics will supply the energy needed to run the fan for ventilation it can be done as a last step as it has little impact on the comfort level but a big impact on energy use. The angle of the panels can be changed to optimize the electrical output.

When the comfort level is achieved for both winter and summer the student can then import the model to another design program and really start the design process. They should be able to refine

the building shape, design the wall components, window patterns and shading devices. They will need to figure out internal mass placement and roof design for integrating the photovoltaic panels. They will be able to concentrate on design instead of how to make the building more efficient since they know it already is a zero energy building that is comfortable. The model can be carried through the whole design process. SolarShoeBox model can be opened in Sketchup and used with the plugin OpenStudio + Energyplus, the Sketchup model can be used in Revit + Ecotect + Green Building Studio so nothing is lost. This helps the student refine the building while always having access to an Energy Simulation tool.

CONCLUSION

SolarShoeBox makes energy analysis part of the process not just an after thought or additional step. Hopefully, since the initial energy analysis is performed before the building is designed, the students will have a better understanding of the building components that go into a building such as what insulation values and the amount of mass really mean to the performance of their building.

A simple design tool used early in the design pro-cess can have a greater impact on the final energy use of a building than a complex tool used at the middle of the design process. As building simula-tion becomes more sophisticated, it can also be-come more user friendly. When this merger takes place, hopefully more designers will be willing to use building simulation tools at the beginning of the design process. This tool was refined during the summer of 2009 and is being used in a second year design studio for the first time. The software will be made available for free from the Internet.

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