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## A Sunlight Design Tool

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**Abstract:**

*Computer-based techniques for Environmental design tend to be analytical. They are aimed at the Engineer who takes a previously designed building and then analyses the environmental performance of the building so as to be able to give performance requirements for servicing plant. Thus the building has been designed by an architect using experience and some broad background knowledge of environmental performance, but it is usually not until the analysis stage is reached that the building's environmental performance is accurately assessed. A sunlight design program (application) has been written to address this problem. This program is aimed at the designer and should allow them to assess quickly the sunlight characteristics of their building. The intention has been to produce a tool which is easy to understand and use: a tool which is interactive and in which data can be changed easily. Thus the tool can be used to check the effect of design changes on sunlight performance. The tool is meant to be both an aid to design itself and to the understanding of the environmental performance of buildings. This paper describes the application and the use of it by architectural students. We describe the application, assess it and evaluate its educational value by comparing students' estimations of sunlight performance in their own buildings with performance predicted by it. We look at how students interact with the program to modify their design in response to this interaction and report on their evaluation of the application during a controlled exercise.*

*(Note: D.J. Wood developed the Sunlight Design application under the direction of Prof. G.Z. Brown at the University of Oregon. The program is available on request from the author.)*

This paper describes a Macintosh application which models patches of sunlight cast in a single room. The application is intended to be a design tool: principally a sketch design tool. The tool was written to do two things: first, to allow the user to model and manipulate the behaviour of a particular building early in the design process; and second, to facilitate the understanding of sunlight behaviour. The experiments described in this paper were designed to find out how well the tool achieved these ends.

## Background

Take a sunlit field. Build a single-roomed rectangular building in the field. Make a window in one of the sunlit sides of the building. A ray of sunlight will shine through the window. The ray will illuminate a small patch on the inside surface of the room.

For a particular set of sun angles (i.e. a particular date and time), there is a one-to-one correspondence between the window and the patch of sunlight. Given a window, you can calculate the corresponding patch, and *vice versa*.

The application models this situation. It draws a representation of the building's walls and floor on the screen. You can draw in the walls and floor: either a window on one of the walls or an illuminated patch on the floor. If you draw a window, the tool will draw the corresponding patch: if you draw a patch, the tool will draw the corresponding window.

In fact, the tool allows the user to superimpose the effect of more than one window at a time, and more than one date and time at a time, and it has several controls to alter the variables concerned.

The tool is interactive and we have aimed to make it user-friendly. It runs on an Apple Macintosh computer, was written in Pascal, and uses the Macintosh Toolbox to create its interface. All the commands are invoked with the Macintosh's mouse: no keyboard skills are necessary. We feel that these characteristics make the tool ideal for the early stages of design, and for users who have little computer experience.

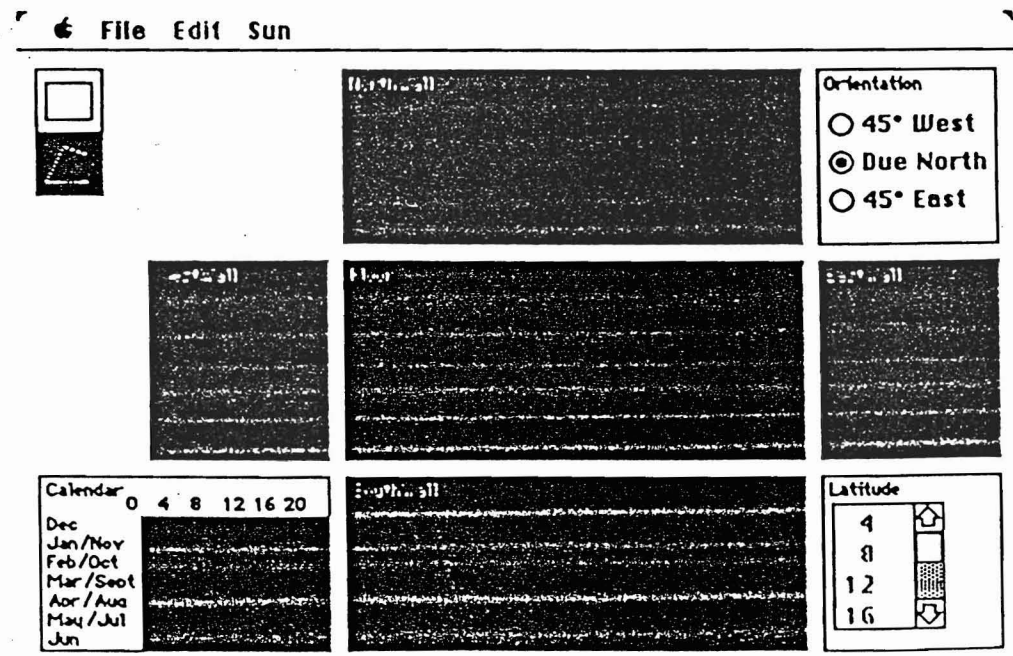


Figure 1 Screenshot showing the application interface.

Figure 1 shows a picture of the screen. The majority of the screen is covered by a cross of black rectangles which is the representation of the building: a simple box with the walls folded flat outwards. The application is driven from a combination of pull-down menus at the top of the screen and subsidiary controls which reside in boxes in the corners of the screen.

Normally, the mouse pointer is an arrow. Moved into the floor rectangle, it changes into a white square which is used to build up patches of sunlight. Moved into any of the walls, it changes into a cross which is used to draw windows.

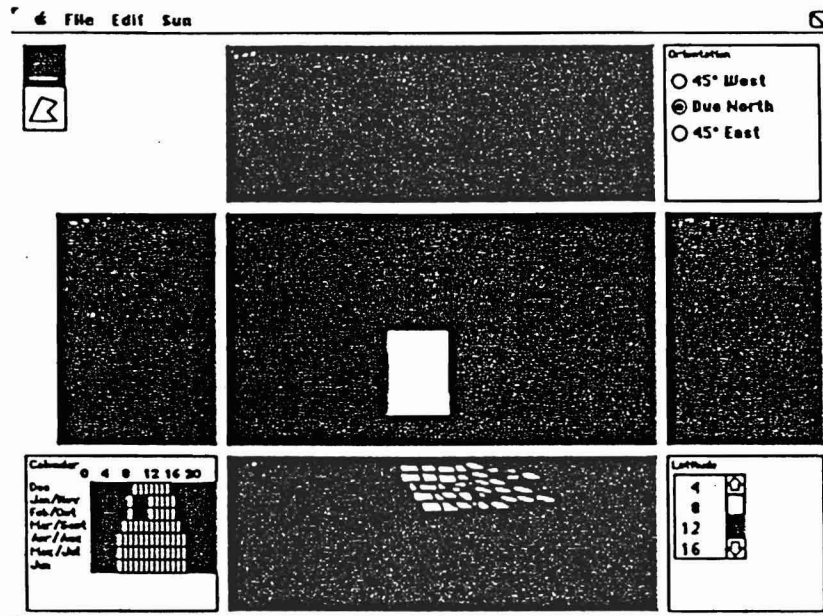


Figure 2 Screenshot showing the window shape needed to produce a desired patch of sunlight. The patch of sunlight was built up using a group of white squares as described above.

### *The subsidiary controls.*

The tool has seven subsidiary controls: The calendar control, the latitude control, the orientation control, the window shape control, the table height control, the clear all control and the outlines control.

The calendar control allows you to study the sunlight patterns for a particular period. You can choose from 288 possible periods throughout the year (24 hours by 12 months). Some of the periods are during the night, when the sun is below the horizon. Ten of the months double up: The sun's path on 15th January is the same as that on 30th November. You can select just one time or a set of times.

The latitude control is self-explanatory. The orientation control allows you to choose between having the south wall facing due south, or facing 45° west of south or 45° east of south. The window shape control allows you to draw either rectangular windows or polygonal ones.

The table height control makes the floor work as if it were at the level of a table top. Activating this option causes the projected windows to appear a little further from the floor, and the projected patches a little closer to the walls.

The *clear all* control erases all the windows and patches, putting the walls and floor back to their original state. The *outlines* control toggles the outlines around the projected windows.

## The Experiments

We decided to try the tool out on a group of first-year architectural students. They were readily available as experimental subjects and had some appreciation of what building design was about. The experiments were optional: we believed that the opportunity to experiment with computers for the first time in the School would be sufficient to draw enough support.

There were two experiments. We did one on the first day and one on the second. The twenty-eight students were divided into four groups with a maximum of nine in a group.

The first day's experiment was aimed at investigating whether using the tool improved understanding of sunlight behaviour. There were three parts to the experiment: In the first part, we tested the subjects' ability to predict sunlight behaviour; in the second part, we let them use the program freely; and in the third part, we tested their ability to predict sunlight behaviour again. We did not forewarn the subjects that they were to be tested a second time.

We devised two sets of test papers, one for the first test and one for the second test. Both papers had the same sorts of question, but the specific questions were different. Each paper consisted of four sheets. On each sheet, we had drawn the cross-shaped diagram of the one-roomed building. On two of the sheets, we had drawn a square patch of sunlight, and on the other two we had drawn a square window. The subjects were asked to guess the location of the corresponding window and patch of sunlight, respectively. Each of the sheets specified the time and the date. A typical test sheet is shown in figure 2.

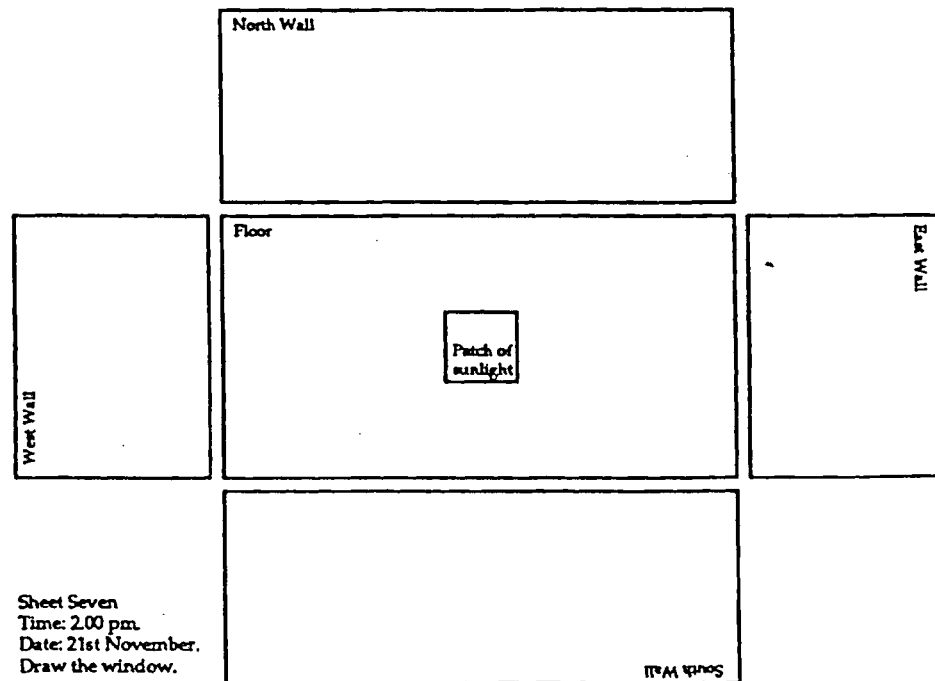


Figure 2 Typical test sheet

The subjects had all just designed a building with a special emphasis on the internal environment. We asked them to redesign their building using the new information from the design tool.

At the end of the second day's session, we gave the students a questionnaire to find out their general reactions to using the application.

## Results

Each experiment produced its own set of results. The first set was the completed test papers. The second was the completed questionnaires.

To analyse the test papers, we compared the subjects' guesses at the locations of the windows or patches with the correct locations. We made a transparent overlay for each question. The overlay showed the location of the centre of the projected shape, and around that a 'target' of two concentric rings (see Figure 3). We estimated the centre of each subject's guess, and decided which ring of the target it came into. We scored two points if the centre of the subject's guess came within the inner ring, one if it came within the outer ring, and nothing for anything else. We added up each subject's scores for each of the two tests, giving two scores out of eight points. Finally we plotted the results in two bar-charts, one for each test.

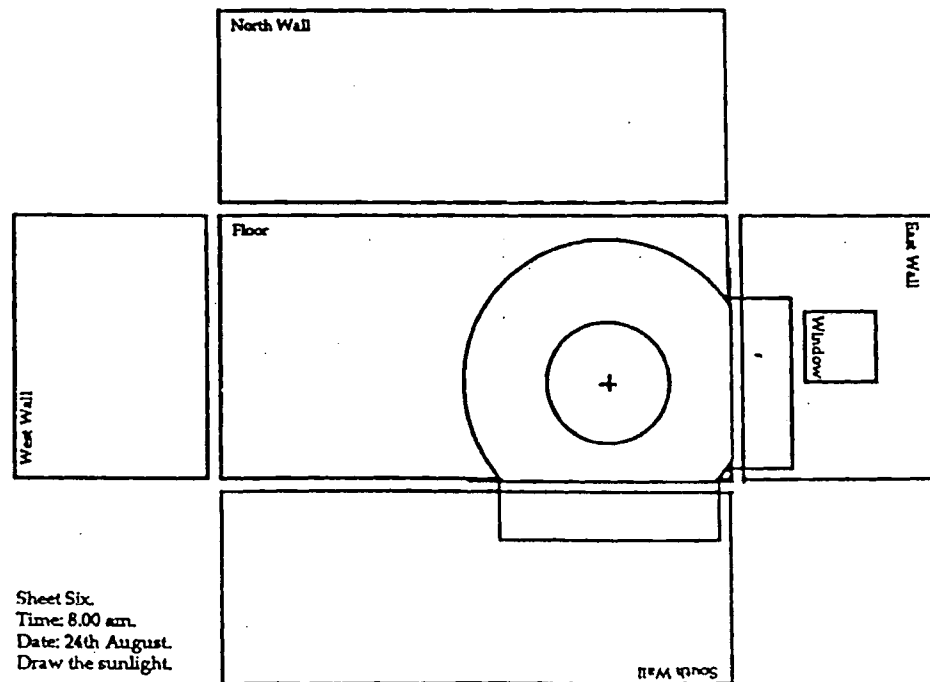
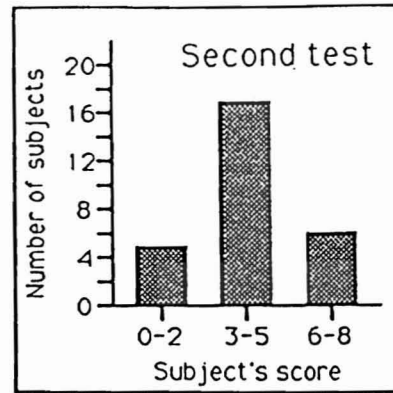
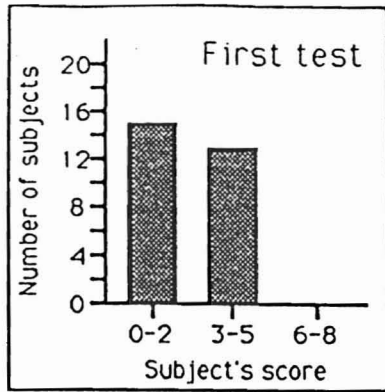


Figure 3 Target system used to assess accuracy of students' guesses

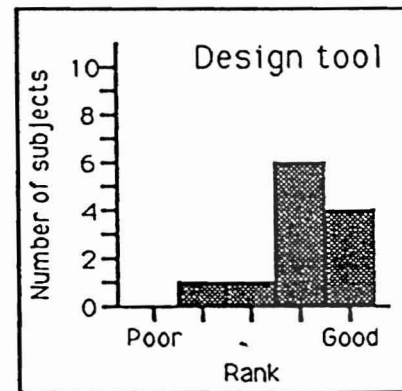
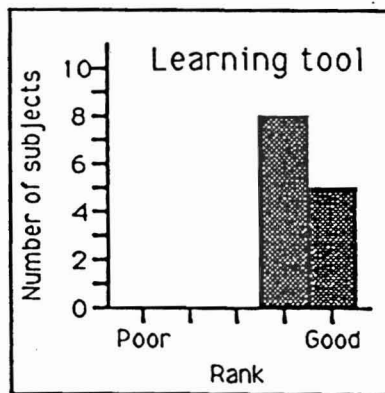
Given all of the obvious reservations about the nature of the experiments undertaken such as group size, the need for a control group and so on, the results are nevertheless interesting. We were surprised by the consistency of the improvement in understanding fostered by the use of the application which these initial results indicate.

Using the scoring system described above the students' guesses before and after



**Figure 4** Test scores before and after using the sunlight application

There may well be other factors contributing to the evident improvement in performance. We intend carrying out a further set of studies in a similar way to that described here but with a control group to measure improvements in performance against. The students' responses also indicate that the application helped them understand sunlight behaviour. We gave them a questionnaire to elicit responses on how they rated the application as a learning and design tool. Their ratings are summarised in Figure 5.



**Figure 5** Student ratings for the application

We emphasised to the students that they should be critical if they identified weaknesses in the application. However, the rankings shown above give a clear indication of the good, positive response which we obtained. We also obtained further written comments from the students concerned. These comments contained a mixture of points which we expected (such as the limitation on room geometry and no provision for roof lights) and points which we did not expect but which will help in developing the application.

## Conclusions.

The application described here is intended to be a user-friendly aid for the early stages of building design and for education. The application addresses itself to the questions 'If I make modifications to my building how does the building respond to the change?' and 'If I want a specific performance requirement what do I need to do in order to achieve it?'

Our experiments with a group of architectural students give preliminary indications that the application achieves some of these aims.

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We would also like to acknowledge the assistance of the experimental subjects from the first year of the Architecture degree at Liverpool University School of Architecture and Building Engineering, 1989.