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ShadowAnalysis : A Visual Analysis Model for the Perfromance of External Shading Devices

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요 약

건물의 외부에 차양을 설치하는 것은 건물이 갖는 냉방부하를 줄일 수 있는 중요한 요인이 된다.

외부차양의 효율성은 차양의 형태, 크기, 태양의 경로, 건물의 방향등과 같은 요소에 의해 결정 지어진다.

그러나, 이러한 요소들이 서로 동적으로 상호 관련 되어 있기 때문에 외부차양에 의한 그림자 투영은 예측하기 힘들고, 따라서 냉방부하가 얼마만큼 감소되는지는 더욱더 예측이 어려워진다. 이 논문은 디자이너가 직접 외부차양을 컴퓨터 그래픽으로 디자인 함과 동시에 그림자 투영을 시각화 할 수 있는 프로그램 개발을 위한 연구이다.

Introduction

Windows are used to provide a visual connection between indoors and outdoors, ventilating and daylighting for interiors and for the reduction of heating energy through solar energy utilization. This solar energy, however, is often so intensive that counter measures should be taken in order to maintain comfortable indoor conditions. Air conditioning is one counteraction. In order to reduce cooling load, it is highly recommended to use shading devices. When shading devices are applied in combination with the glass, they can modify the thermal effect of windows to a very great extent(Givoni 1981). The most effective shading devices on reducing cooling load are exterior types such as overhang (Anderson, 1977).

The effectiveness of an external shading device depends on its geometry, the sun path, and the orientation of the building. Since these factors are interrelated dynamically, it is extremely difficult for the building desinger to predict intuitively how the shadow is cast by the external shading device on the window area, and as a result, it many not possible to fortell how much cooling load can be saved by the projected external shading device. Due to the inherent complexity of the calculations for the shadow cast and energy analysis, the designer needs to depend on existing energy analysis software. Most of the designers, however, seem reluctant to use such software, because most existing energy analysis software have not been developed for the designers, and they require a deep technical knowledge(i.e. thermal and lighting) the designers do not have. The desingers tend to leave even a small problem to energy analysis experts, instead of utilizing the software. For the designers, analysis software should be simple and easy-to-handle like a small calculator at their desk. Since computer graphics could be a powerful visual analysis communication tool in the building design process, the above problem might be solved through a computerized graphical interface in the early design stage.

The research described in this paper involves the development of a computer program which aims the following objectives : 1) to facilitate the description of external shading device's geometry through an integrated graphic input model 2) to simulate the relationship of the external shading device and shadow based on sun path, the orientation of building, 3) to visualize the shadow casting by projected shading devices, and 4) to help building designers to find possible solutions for energy-efficient external shading device.

ShadowAnalysis : a program for shadow analysis

A program has been developed to help the designers who want to intuitively create various external shading devices and to obtain the immediate results of shadow cast by the external shading devices under the dynamic sun's position. The computer program is called ShadowAnalysis. The program is written in C programing language and it is implemented on Apple Macintosh computers. The Macintosh was selected because it is considered to provide computer users with an intuitive drawing environment and highly interactive user interface through the mouse operation. The ShadowAnalysis supports three functions. The first function provides the designers with a modeling environment to create two/three dimensional external shading devices. The designers will use a set of palette of drawing tools such as single lines, polylines, rectangles and circles to create wireframe of the shading devices. Sophisticated and dynamic data structures for the three dimensional wireframed objects were programmed inside. The second function will display the shaded areas by the device on the three facades(South, East and West) of the building under the dynamic sun's position. An existing algorithm which calculates azimuth and altitude angles according to the sun's position was utilized (ASHRAE, 1981). The third function provicdes the areas shaded at a specific hour of the day or accumulated during the day. All of the functions are performed by evoking items in a pull-down menu.

Modeling Environment

The modeling environment consists of four separate Windows on the Macintosh screen : a SouthFacade Window, a EastFacade Window, a WestFacade Window and a SideView Window as shown in Figure 1.

Each window represents an elevation facing the orientation accordingly ; the SouthFacade window represents the south elevation. the SouthFacade window is the working window where all interactive drawing takes place and will be

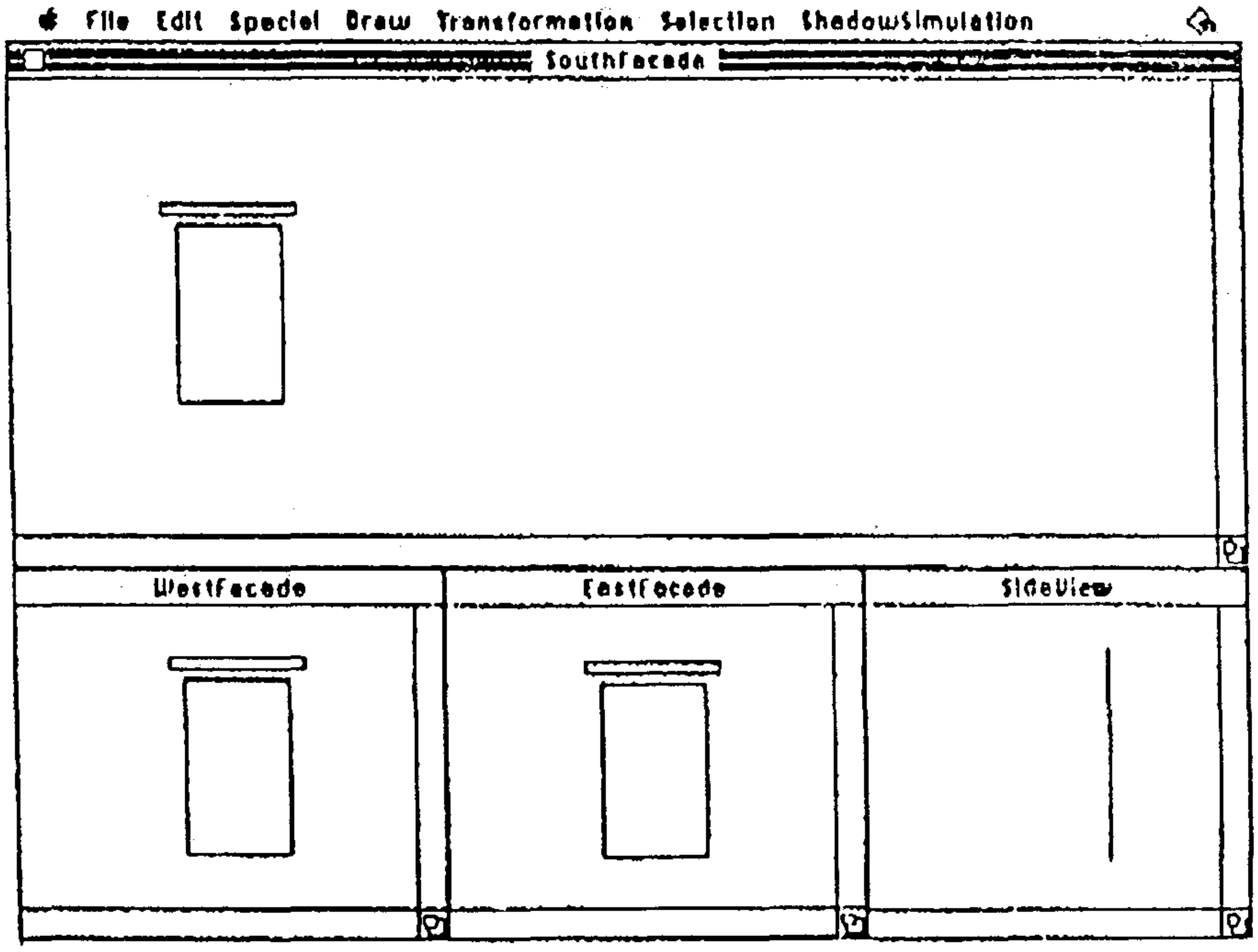


Fig. 1 Shadow Analysis is displaying a window frame and shading device in the three Windows.

used to draw various external shading devices utilizing a very simple palette of graphic tools : line, polyline, rectangle, circle and oval. In Figure 1, a window frame and a shading device (above the window) are drawn on the south elevation of the building in two dimenison using the rectangle tool.

If cast and west elevation have the same external shading device and window frame as the south elevation has, the EastFacade and WestFacade windows concurrently display identical shading device and window frame. Those two windows are automatically updated as drawing takes place in the SouthFacade Window. This might help designers to avoid redrawing the shading device on the south facade at the east and west facade of the building. The SideWiew Window in Figure 1 is empty at the present time, because the window and device are drawn in two dimension on the facade.

Since the external shading device and window frame are drawn in two dimension, it is necessary for the shading device to be a solid object. This is done by extruding the two-dimentsonal shading device drawing from the facade in this program. The procedure for extrusion requires first selection of the shading device consisting of lines or polylines, and secondly to give a thickness for the device through a user interactive dialog box as shown in Figure 2.

Three options are provided for the extrusion. The first option is a perpendicular extrusion or a 90 angle extrusion which can construct horizontal shading devices perpendicular to the facade. The second on is an oblique extrusion which can create the shading device with an angle other than 90 degrees. The third one is a revolution which can create curved shading devices such as venetian blind. A rotation axis and start and end angles should be given for the revolution. The SideView window is used to examine the results of the extrusion. Figure

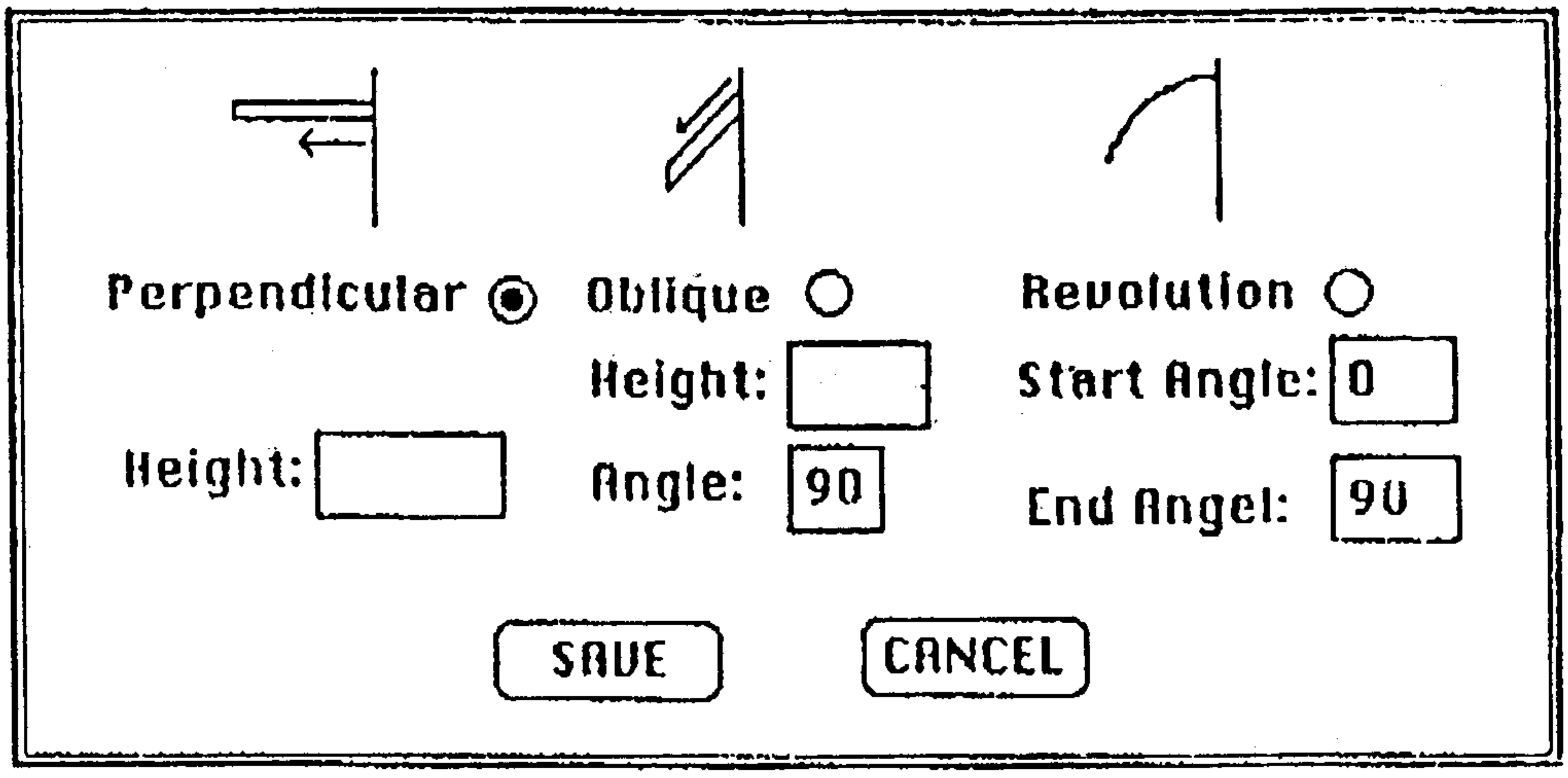
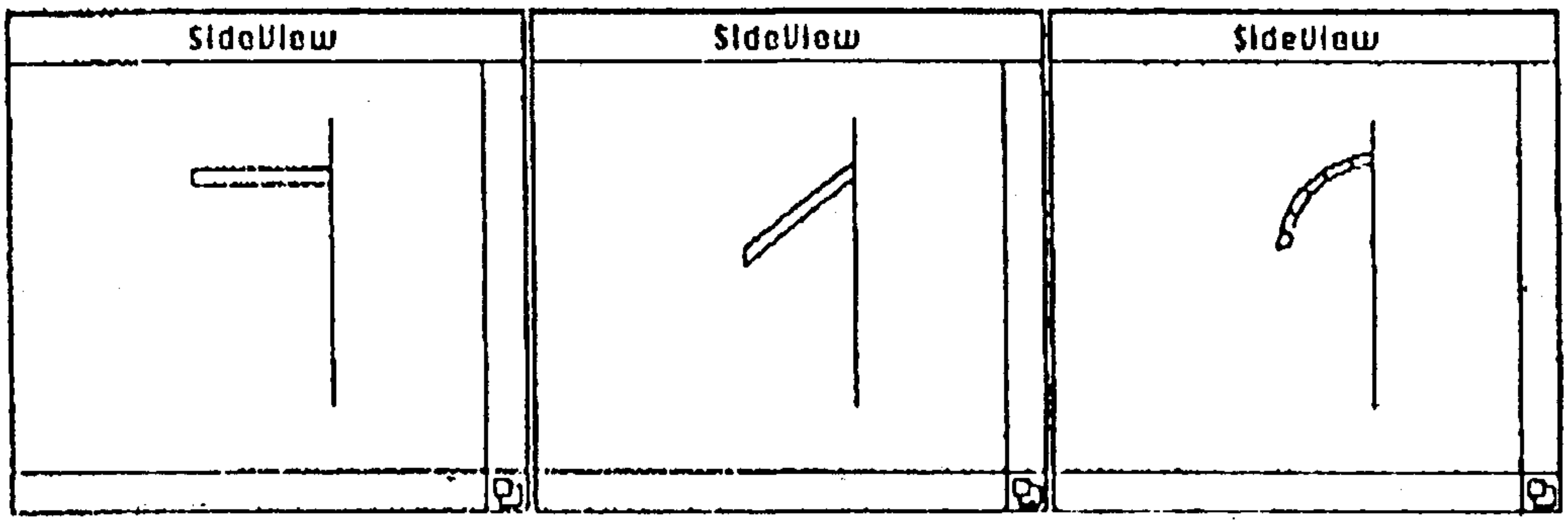


Fig. 2 A user interactive dialog box for extrusion



(a) Perpendicular (b) Oblique (c) Revolution

Fig. 3 Results of extrusion for shading device

3 shows the results of extrusion in SideView window when three options are applied for the shading device shown in Figure 1.

Shadow Cast

The shadow cast on the facade by sunlight can be determined by the solar azimuth and altitude for a given geographical latitude of the building and time of the day.

All these data should be provided through the user interactive dialog box as shown in Figure 4.

The program, then, calculates the current sun position according to the given data and display the resulting shadow cast on the SouthView window. At the same time, the program calculates the shaded area and displays it close to the shading device. Figure 5 shows the shadow cast and shaded area in the SouthFecade window when the shading device is used in Figure 1.

How the shadow will be cast by the shading device during the day is often an important issue. For the case, it is anticipated that the program will be added a function that can animate shadow cast during the day.

In the schematic design phase of external

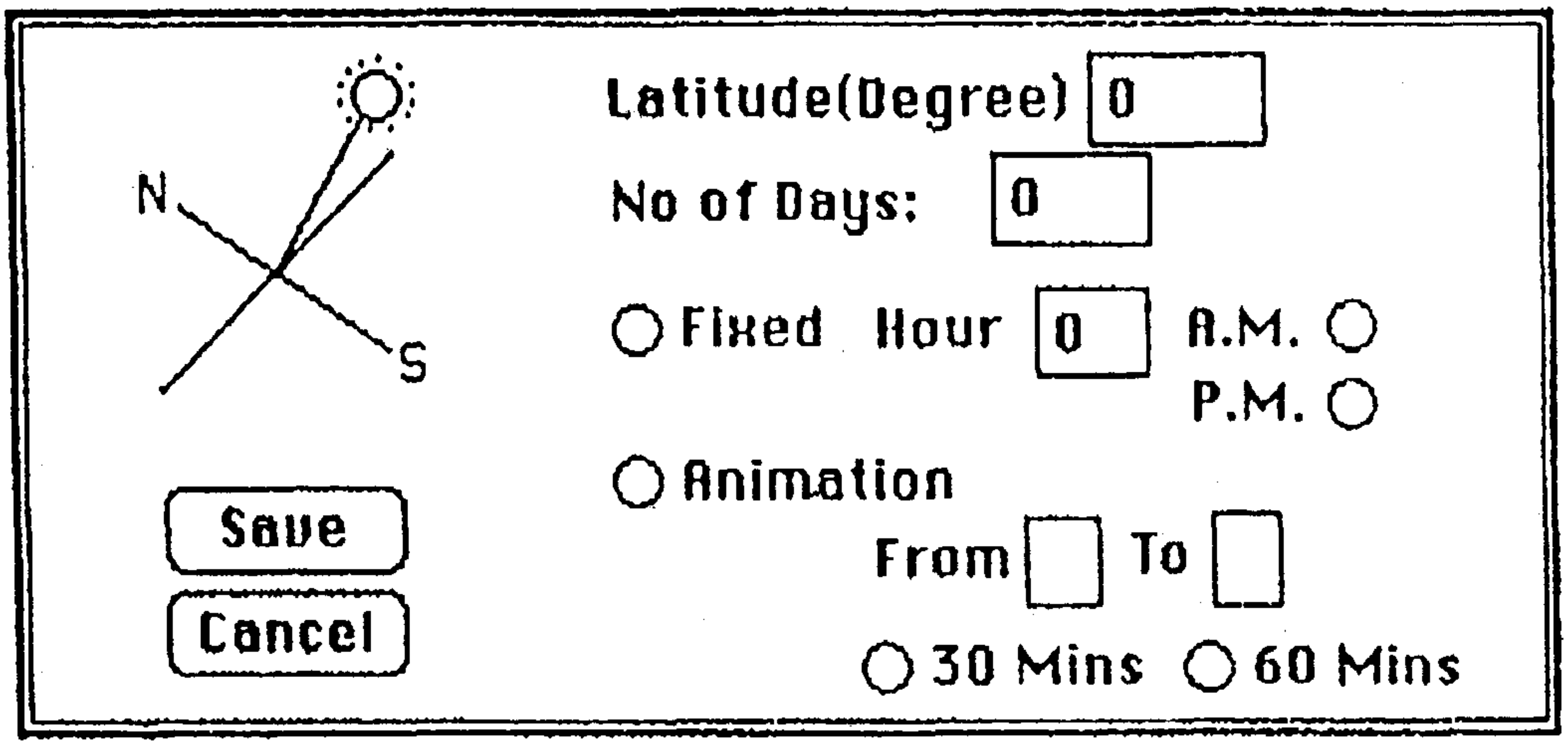


Fig. 4 A user interactive dialog box for determining the solar position.

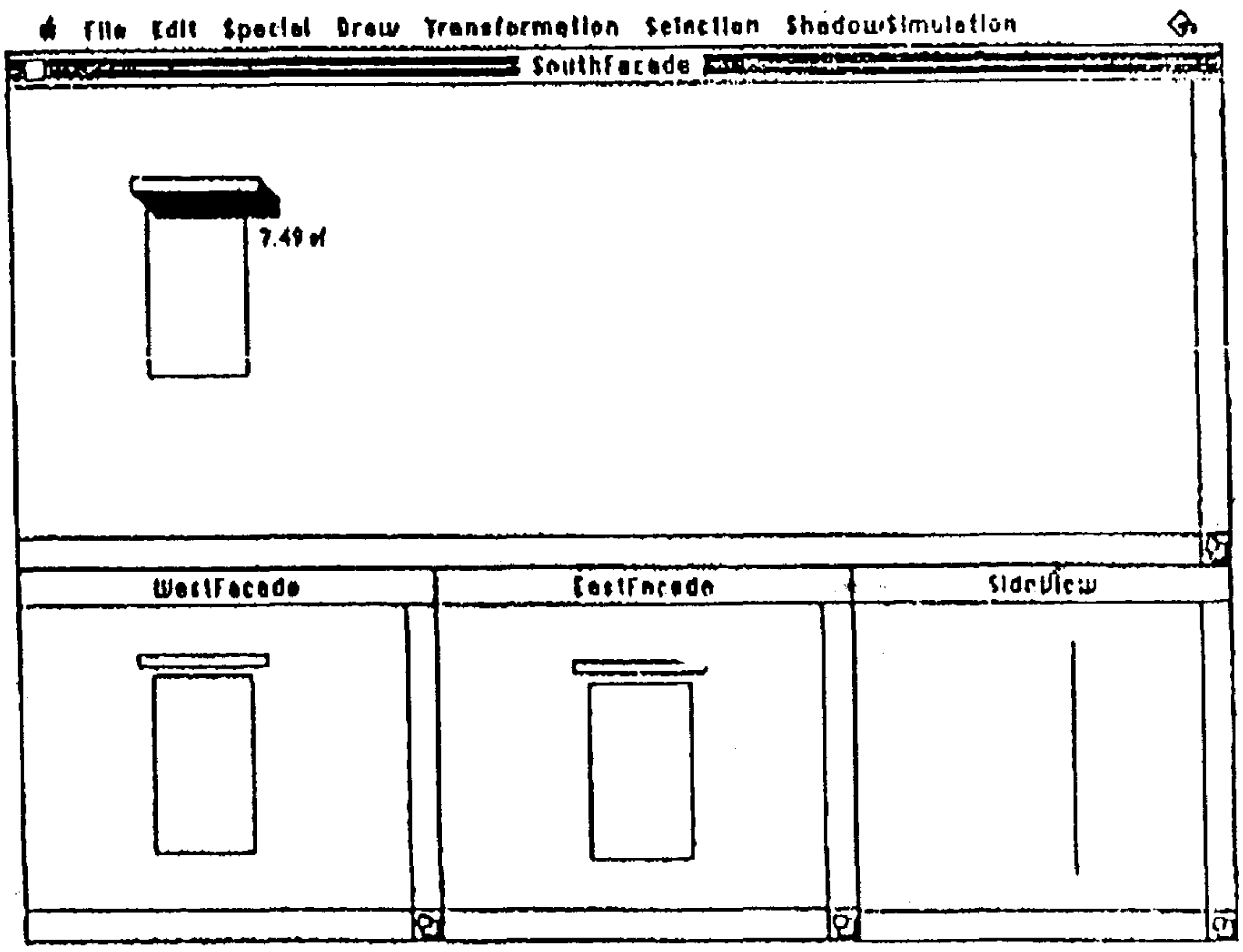


Fig. 5 A-Shadow displays the shadow casting and shaded area.

shading devices, the designer could generate several alternatives/variations within a short time frame and wishes to compare their performance with each other immediately in terms of shadow cast for the alternatives. Figure 6 shows the resulting shadow cast for four different shading devices at solar noon time. Based on the shadow cast of the alternatives, the designer could get an idea which device performs better in terms of shaded areas. The designer may select one of them to conduct further sensitive analysis, for example, by changing the location of the shading device around the window frame.

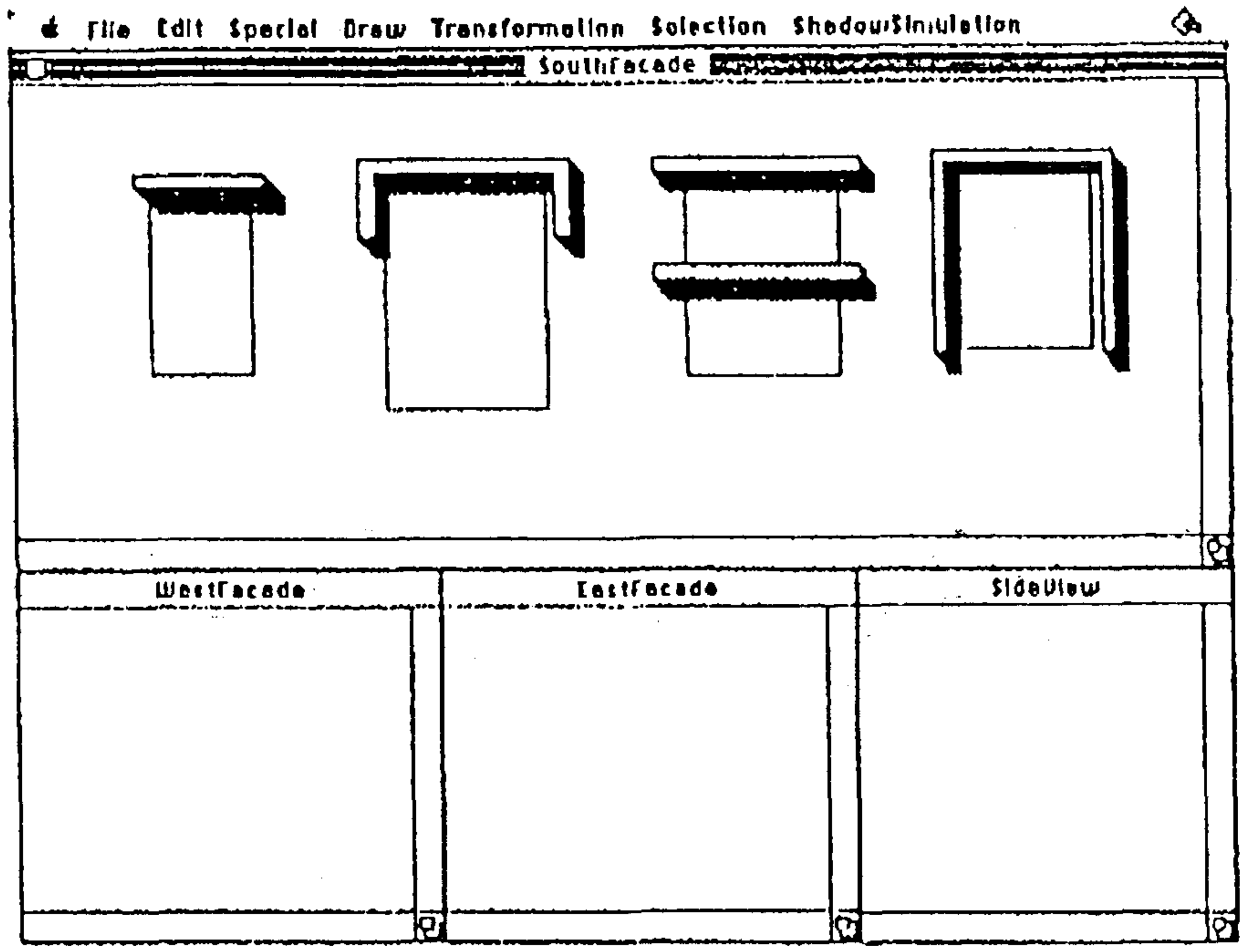


Fig. 6 Shadow castings for four different shading devices.

Output of the program

The designer may need information during the drawing of the shading device. The information could include the dimensions of the window frame and the shading devides, location of the shading devices, and so on. This information may be critical to check issues such as the construction feasibility and initial cost effectiveness of the shading devices. The program has a funetion to provide numerical output for the shading devices the designer generated. The numerical output is mainly orientation, coordinates of the shading device, shadow area at a specific time and accumulation of the day. At the present time, the output is not displayed on the modeling window but in a separate data file(the designers should open the file to look into). It is however anticipated that the output will be on the window when this program is completed. The Figure/shows the format and output for the shading device in Figure 1.

Orientation : South

Coordinates :

point	x	y	z
1	-0.5	1.0	0.0
2	6.0	1.0	0.0
3	6.0	0.5	0.0
4	-0.5	0.5	0.0
5	-0.5	1.0	3.0
6	6.0	1.0	3.0
7	6.0	0.5	3.0
8	-0.5	0.5	0.0

Shaded area :

at Noon : 7.49 sf

accumulation for the day : 15.23 sf

Fig. 7 The format and output for the shading device in Fig. 1.

The program can release the output related to the shading device at the East and West elevation if necessary. When the designer wants to compare several alternative shading devices, the program does not give the output deseribed above, but provides the shaded areas only in the present time.

It should be noted that the values of the shaded area calculated by this program may be different from the values measured in actual situations. The program calculates the shaded area by counting the pixels inside the shaded region on the Macintosh screen. Program does not count pixels if they are on the boundary of the shaded region. This happens when the shaded region is an irregular shape.

Conclusion

The complexity and tedious calculations for shadow cast by the external shading device, even with a simple geometry, is difficult to implement by the designer in the early design stage. Although the ShadowAnalysis program is not complete and still needs development, it shows a potential ability to visualize the external shading device performance according to the dynamic solar position, to contribute toward more energy efficient design in building in the following ways at the early design stage. A designer, even who has little CAD experience(i. e. MacDraw level), can design easily the external shading device using a very simple palette of graphic tools : lines, polylines, rectangles, circles and ovals. Three-dimension wireframe of the shading device is easily constructed through the user interface dialog box. When the designer wants to generate shadow cast, what the designer has to simply type the geographical latitude, the number of days in a year, and time of the day through the dialog box and the program can generate shadow cast either for a specific time or for the day.

As demonstrated above, with the ShadowAnalysis, the designer can easily understand the effect of the shading device on the window area, and visually evaluate its performance. In additions, the designer might have the most favorable external shading device among the alternatives through the visualization.

Students are often at loss when they want to express shadow on elevation or on the site plan drawing. Defining shadow patterns on the elevation would be confusing and difficult, especially when a building has complex architectural elements on the facade. The author will continually develop and extend the capability of the ShadowAnalysis program in order help students for such a problem.

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by the microclimate around buildings. It is the first method to improve energy conservation effect of buildings and the ways to utilize natural energy for the comfortable residential environment that the difference between the microclimate condition and the indoor thermal condition is made in minimum as far as possible. There are many factors to control and minimize the difference, but landscape element is the major one among the factors. In this respect, the report analyzes landscape elements and their function to control microclimate and presents basic data for the desirable landscape planning mehtods to improve energy conservation effect of buildings and to attain the comfortable residential environment

Trends of International Daylight Measurement Programme

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In recent year in many countries with various climatic conditions are becoming very widely used with daylighting system based on maximum used of the Sunlight. This paper will present on trend of International Daylight Measurement program which has already organized by CIE technical committe called TC307.

The International Daylight Measurement Year(IDMY) has been decided to be initiated at the beginning of 1991 to collect various kind of daylight and solar radiation data all over the world.

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그러나, 이러한 요소들이 서로 동적으로 상호 관련 되어 있기 때문에 외부차양에 의한 그림자 투영은 예측하기 힘들고, 따라서 냉방부하가 얼마만큼 감소되는지는 더욱더 예측이 어려워진다. 이 논문은 디자이너가 직접 외부차양을 컴퓨터 그래픽으로 디자인 함과 동시에 그림자 투영을 시각화 할 수 있는 프로그램 개발을 위한 연구이다.