PLAYING AROUND WITH ARCHITECTURAL SCIENCE

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ABSTRACT

There have been many recent developments in the field of building performance simulation and analysis. The associated software is becoming increasing sophisticated and, at the same time, somewhat more user-friendly and intuitive. However, the focus is still on the use of these tools at the end of a project, and then mainly for final design validation purposes.

Only very rarely are performance modelling tools used at the earliest, most formative stages of design. Past research (Marsh, 1996) has suggested some reasons for this, however it is becoming increasingly clear that the concept of 'play' is a fundamental part of the explanation, and a component missing from many such tools.

This paper is part of a series that have tackled this problem and presents the latest in a range of software tools specifically intended for the conceptual stages of design.

INTRODUCTION

The conceptual stage of the design process occurs right at the beginning, when the brief is still being analysed and decisions regarding geometry, materials and site are in the process of being made. These three aspects of the design are arguably the most important determinants of overall building performance, making this the most crucial stage for many projects.

This is also the stage most ignored by traditional building performance analysis and simulation software, primarily because hard quantifiable data describing the building simply doesn't exist. However, analytical feedback at this stage can be of great benefit to the designer, helping guide the decision-making process right from the start towards more efficient and effective design solutions, as well as avoiding potential abortive work. This paper presents a general update on the development of a range of software specifically intended for this purpose and outlines their use and possible application.

CONCEPTUAL DESIGN AND PLAY

Conceptual design is an iterative process involving the generation of ideas that then need to be tested and evaluated, to be rejected immediately or made the subject of further refinement. Traditional methods of testing design ideas involve quick perspective sketches, simple geometric analysis on a drawing board, or even small hand-calculations. The main criteria for such tests is most often speed. The ability to quickly reject unsuitable ideas can save significant time and effort.

A major part of this testing process is play - simply playing around or experimenting with an idea until it can be shown to work or not. For software to contribute at this stage, a high degree of input flexibility is required as many of the parameters defining a problem will still be quite fluid. However, fast and accurate feedback based on whatever information is known is still possible, and highly desirable as often it is only through playing with the various parameters of a problem that a true appreciation of their inter-dependence is gained.

RECENT DEVELOPMENTS

Climatic Analysis

One tool vital to any pre-design analysis provides for the visualisation of climate data. This tool builds on the work of Murray Milne at UCLA in the development of *Climate Consultant* (Milne, 1992) and on Balcombe's *WeatherMaker*, a utility program for use with the Energy-10 design software (Balcombe, 1999).

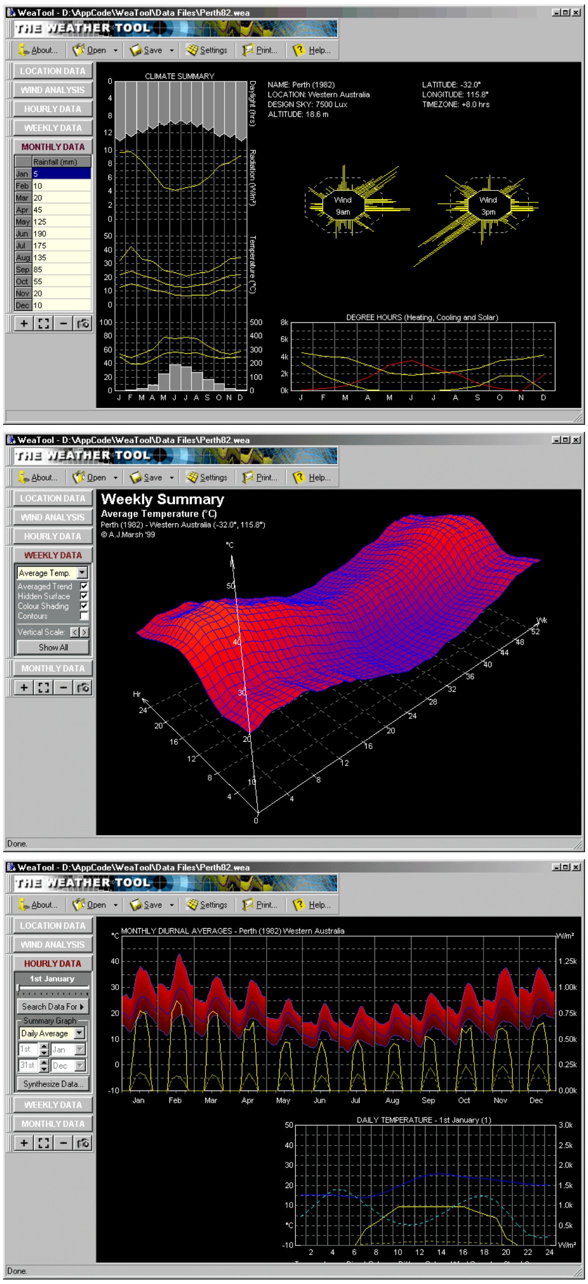

Figure 1: Some examples of the range of visualization options within the climate data analysis package.

Using this tool, data can be viewed in a number of different ways, ranging from a monthly summary with wind roses after Szokolay (Szokolay, 1982), to simple hourly graphs, or even interactive 3-D surface plots. Hourly data can be imported from a wide range of file formats including TMY, TMY2, TRNSYS TRY files, Australian Bureau of Meteorology LST files, CSIRO and NatHERS climate data as well as ASHRAE WYEC2 format. Custom formats can also be defined and saved within the software.

The tool also features a new form of wind analysis graph developed by the author to simultaneously display speed, direction and frequency over any date/time range. Wind speed is shown by the distance of each block from the graph centre whilst frequency is indicated using coloured shading. Temperature, relative humidity and rainfall can also be overlaid on these graphs, as shown in Figure 2.

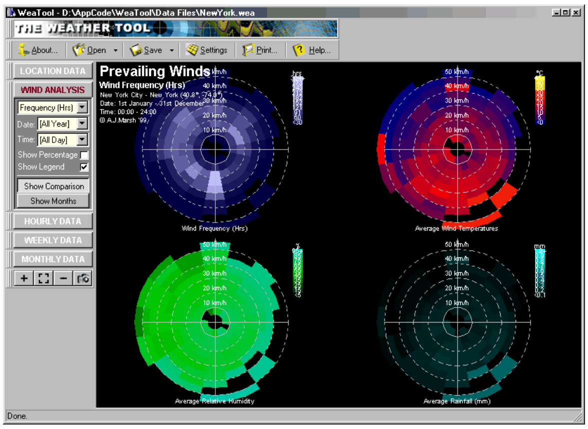

Figure 2: The comparison of wind related data showing speed and direction against frequency, temperature, humidity and rainfall.

Additional research is currently underway to develop a methodology for rating the suitability of various design strategies to the specific climate data loaded. This will include an assessment and recommendation of shading periods, natural ventilation suitability, mass/insulation levels, glazing ratios and the most appropriate passive solar design techniques. It is hoped that much of this work will be completed before the final presentation of this paper.

Comfort Conditions

The prediction of human comfort levels under various conditions is also important to the building designer. At the pre-design stage this is somewhat confined to the establishment of internal mean radiant temperature and ventilation rates given a set of clothing and activity levels, however these can have a considerable impact on the overall design.

A tool has been developed to overlay Predicted Mean Vote (PMV) values on the psychrometric chart, as calculated using ISO 7730. This overlay updates interactively as the sliders for clothing, activity level, air velocity and radiant temperature are adjusted. This allows the designer to quickly investigate the most appropriate strategy to achieve maximum satisfaction under a given set of internal conditions.

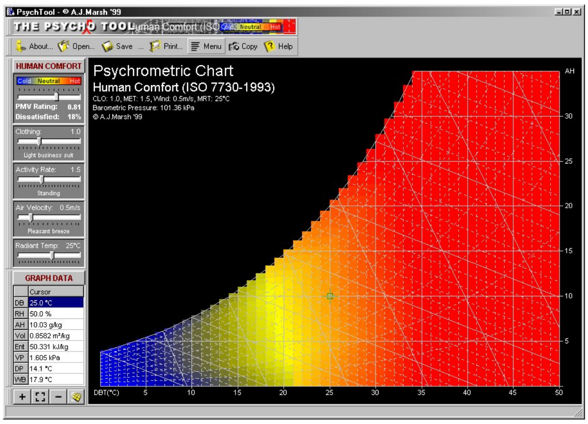

Figure 3: Psychrometric chart with comfort overlay based on ISO 7730.

Noise and Noise Control

Noise is an important design consideration in many urban and suburban areas. The ability to predict noise levels and quickly assess the effectiveness of various control strategies is therefore of great benefit.

A simple tool has been developed to recommend the specific material constructions required to meet various internal Noise Ratings (NR values) given an outside noise level. The tool includes a traffic noise prediction methodology developed by the British Research Establishment as well as sound propagation and barrier effect calculations.

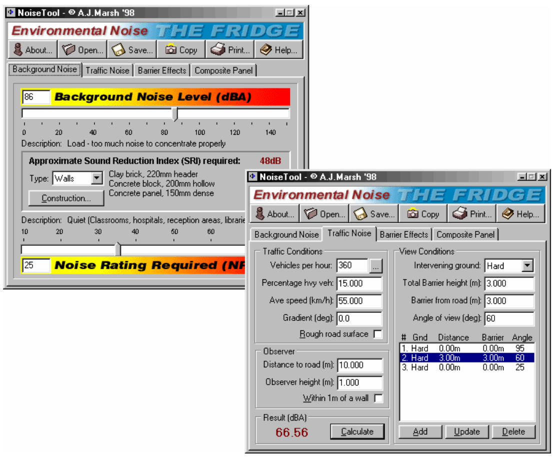

Figure 4: Noise analysis tool showing predicted traffic noise calculation and materials required to achieve specific NR value.

The user can also define composite constructions to determine the overall area-weighted sound reduction index of a partition.

Sun Position and Overshadowing

Orientation and the placement of functional spaces within a building are often influenced by the position of the sun at various times of the day and year. For designers to interact with and investigate sun position and overshadowing, a solar analysis tool has been developed. The main window of this tool displays either a stereographic or orthographic sun-path diagram, or a solar table.

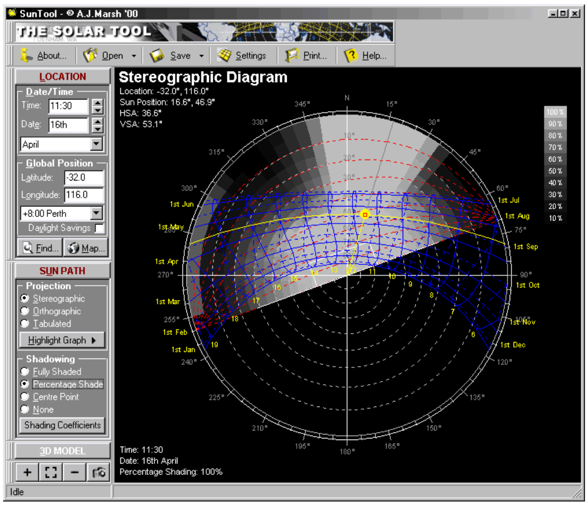

Figure 5: Detailed window overshadowing information plotted on a stereographic diagram.

The overshadowing pattern shown overlaid on the stereographic diagram in Figure 5 is derived from the simple window model shown in Figure 6. This shows the percentage of the window in shade at a range of azimuth and altitude angles relative to the window plane.

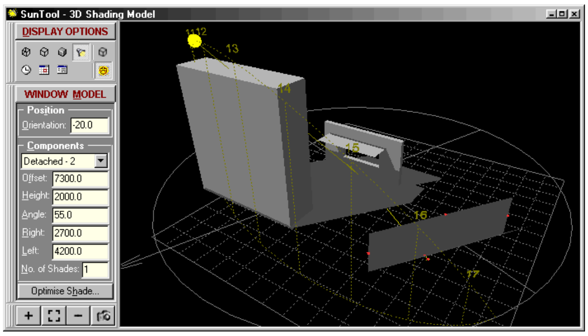

Figure 6: The simple 3-D model window utilises OpenGL to allow interactive manipulation of shading components and sun position with real-time shadow generation.

This model is intended to be very simple and interactive, but still allowing for the application of any number of vertical, horizontal and detached shading devices to a single rectangular window of any dimension. The simplicity of the model means that, using an implementation of OpenGL (a 3D graphics language originally developed by Silicon Graphics), the user can interactively manipulate any object in the scene or drag the sun to change the date and time, whilst shadows and overshadowing are regenerated and redisplayed in real-time.

More Complex Overshadowing

More complex overshadowing is possible using the Ecotect software. This software has a more general application to all stages of the design process, however even before there is a building to model it can be used to assess and investigate overshadowing by surrounding buildings.

Geometry can be imported from most CAD packages or created within the software using its own modelling system. Shadows and reflections at any date and time can then be generated quite quickly, fast enough in the model shown below to be regenerated in real-time as the user drags the sun back and forth. Both shadows and reflections can be cast on the ground plane or on any set of complex geometry.

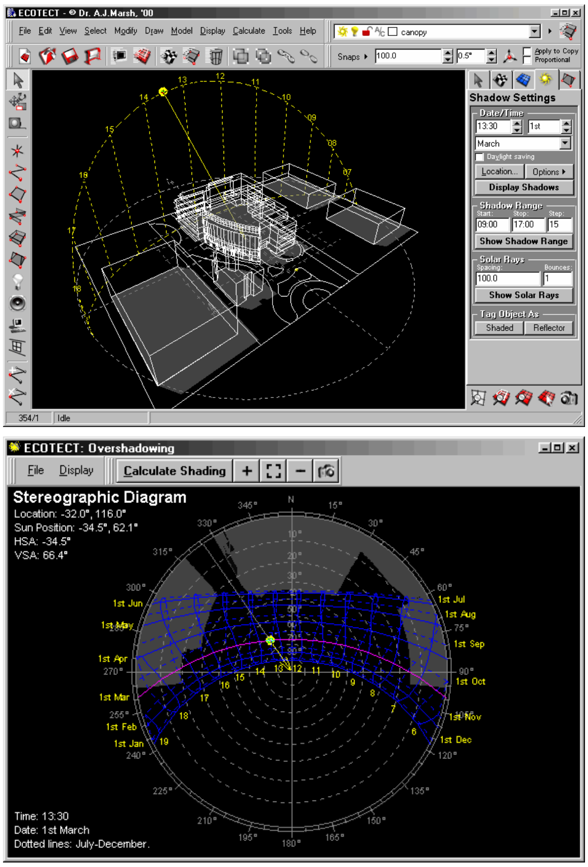

Figure 7: The overshadowing of an example object by a relatively complex model displayed in 3-D as well as on a stereographic diagram.

Overshadowing of specific objects can also be displayed on a stereographic or orthographic sun-path diagram. This is an interactive diagram that automatically updates as different objects are selected or when the selected object is moved. This makes a real assessment of the overshadowing at many points within any sized site both possible and practical.

The display of overshadowing on a sun-path diagram is an effective way of assessing dates and times of obstruction, however it is not easily and directly quantifiable. In the case of legal disputes over solar access or the comparative effects of different situations, it is often necessary to calculate the total incident solar radiation on an object taking into account the obstruction and/or reflection of both diffuse and direct radiation by surrounding objects.

A methodology has been developed in this software for the calculation of total annual solar access for any planar surface in a model. The percentage shading is calculated each hour and applied to the beam component of either recorded or synthetic radiation data to give the direct value. Diffuse values require the generation of a shading table similar to that shown in Figure 5, however this time applied to diffuse solar radiation values or based on a selected sky distribution. The result is both a graph and table of total incident energy values for each month as well as average shading percentages, allowing for the accurate quantification of a range of overshadowing effects.

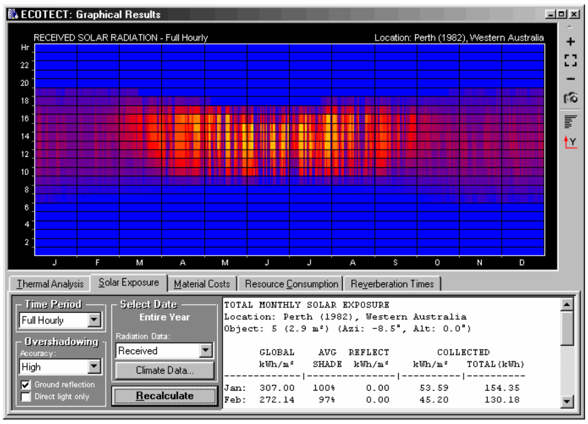

Figure 8: Hourly solar exposure calculations can be performed for any planar object showing total incident radiation after obstruction and overshadowing.

Optimised Shading Design

An additional pre-design feature of Ecotect is the ability to automatically generate optimised shading devices. Given a rectangular window at any orientation, it is possible to derive the exact shape and size of the shading device required to completely shade that window up until a specified date.

This is important as it illustrates the extent of the shading problem. Using even the simplest of models, as shown in Figure 9, it is possible to generate shades for a range of conditions at a specified location. Even though the exact shading devices resulting from this exercise may not be used directly, the designer quickly gains an appreciation of the scale and extent of the shading requirements for each façade, which is then used to inform the actual design as it takes shape.

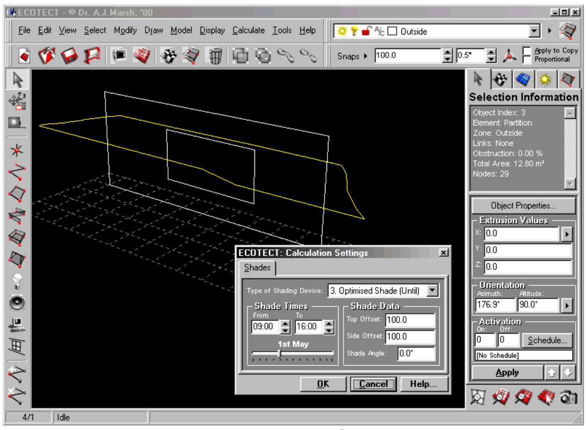

Figure 9: The generation of optimised shading devices for any rectangular window.

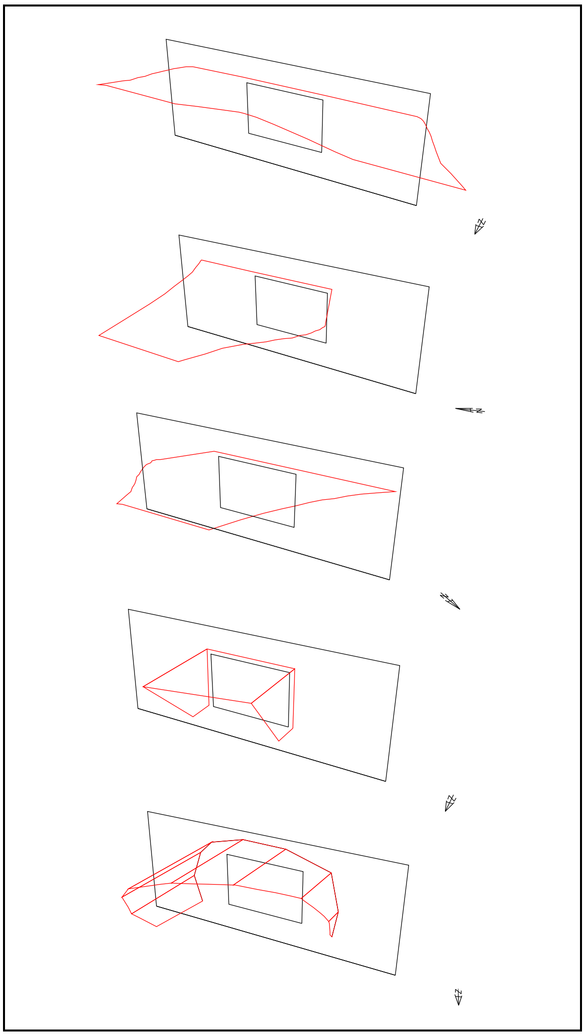

Figure 10: Some example optimised shading devices generated at various orientations to provide complete shade from 9:00am to 4:30pm until the 1st of May in Perth, Western Australia.

The same techniques used to shape shading devices can also be used to shape the solar envelope of sites when overshadowing restrictions must be adhered to. This is simply a matter of projecting solar-cut lines from specific points within the adjacent site onto the vertically extruded sides of the development site at the limiting dates. The resulting profile defines a sometimes complex shape below which overshadowing of the adjacent points will not take place.

Conclusion

The software presented represents the results of ongoing research into the development and application of conceptual design tools. A number of new data visualisation techniques have been implemented, and the level of user interaction and manipulation of input data greatly increased since the last paper in this series.

However, the onus is still very much on the designer to correctly interpret the results of their 'playing around'. Some work is currently being done by the author on the summation and comparison of preliminary results in order to formulate reasonable design recommendations. This will be the focus of future research in this series.

Additional research is also being carried out into the response of architecture students to this approach. The basis of this enquiry is to determine if the tools more clearly illuminate the basic physical processes, or simply get in the way and distract from the required learning.

References

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