Performance Analysis and Concept Design: The Parallel Needs of Classroom and Office

Dr. Andrew Marsh
Welsh School of Architecture
Cardiff University
Bute Bldg, King Edward VII Ave
Cardiff CF10 3NB
United Kingdom
E-mail: marsha@cf.ac.uk

ABSTRACT

This paper discusses the development path of a computer program originally intended as a teaching aid for architecture students, but now being used by several hundred architectural practices around the world. The tool is quite unique in that it is still quite raw and developmental, with new and experimental analysis features added regularly as research progresses, yet it has been adopted by devotees in many leading environmental practices and used as part of their standard design processes. As such, it provides an almost direct conduit for both the dissemination of research ideas and a continuous stream of feedback from designers as they struggle to apply these ideas to real problems and make sense of the results.

The lessons from this are twofold. Firstly, with the progress of technology and recent shifts in the direction of government regulation, the information and feedback needs of the practitioner in many areas of architectural design are similar to those of the student first entering the field. Secondly, despite a competitive and conservative marketplace, many practitioners are actually quite eager to try out innovative analysis methods and new approaches in their design work. Given their vested interest in the most effective and economical solutions, such practitioners make ideal product testers because they are also the end user.

1. INTRODUCTION

Whilst the software had long been in development as part of a personal research initiative, its initial application was as part of courseware demonstrating building science concepts to undergraduate architecture students. The course for which it was intended was very much self contained, as science subjects tend to be in many architecture schools, with only a limited time allocation and very little integration with other streams. In order to engage students with the concepts being presented, and to demonstrate their direct relevance to design studio, the aim of the software was to enable students to rigorously test the performance of their early design proposals and then make substantive changes based on this new information.

As the limited available contact time within the course was spent discussing fundamentals, the software had to be sufficiently intuitive for the students to be able to pick up as quickly as possible by themselves. The course ran concurrently with their design studios so it also had to be able to accommodate very preliminary 3D sketch designs and allow for easy editing and manipulation as the designs evolved. More importantly, their design issues ranged from shadowing and thermal performance right through to room acoustics and fabric costs - which meant that the analysis capabilities of the tool had to be similarly wide-ranging.

As the software developed to meet these requirements, it became increasingly obvious that these were not too dissimilar to the conditions under which most architects practice. Time is a precious commodity for both user groups, so the speed with which an idea can be modelled and tested is critical. A design can change almost entirely within a few days, so it must be possible to obtain useful information from the computer equivalent of a rough sketch, otherwise it simply won't be used. Both sets of users also work with many competing constraints so the ability to simultaneously test many aspects of performance is similarly important.

2. CONCEPTUAL DESIGN AND ANALYSIS

It has long been understood that the potential impacts of design decisions on overall performance of a building are greatest at the earliest stages of a project. It costs nothing to properly orient the building right from the outset, compared with finding out how it should have been done half way through or even worse, having to remedy it at the end when occupants begin complaining of overheating.

The main aim of the software was therefore to provide useful analytical feedback to support design decision-making during the earliest, most conceptual stages. At this stage it is likely that the actual form of the building has not yet been settled upon, let alone materials or detailed building elements selected. However, traditional analysis tools require very detailed and specific information about the building and its materials as their focus is on accurate modelling and precise results. Such an approach is inappropriate during the conceptual stage, but it is argued here that analytical feedback is still essential.

The appropriate use of performance analysis and numerical simulation during conceptual design requires that both the software tools themselves and the designer take a different view of the process. This alternate view is predicated on the following three ideas:

- At the earliest stages the real information is in the relative accuracy of analysis results, not their absolute values.

- Analytical information is more than just tables of numbers or a graph. Many critical aspects of a building's performance cannot even be measured in these ways. It is therefore necessary to consider a range of analysis information presented in many different ways.

- To derive the greatest benefit from analysis, the designers themselves need a fundamental understanding of basic building physics. It is not enough to leave that aspect up to the environmental consultant as true design insight is only possible if the designer actually 'gets it' and drives the whole process.

The following sections discuss each of these ideas in turn.

2.1 Comparative Analysis

At the earliest stages of design the absolute values of calculation results are of little use to the designer. There is simply insufficient information to accurately model the building or specify many of its parameters. However from a given starting point, the relative effect of making changes to a model can be of real value. Even if the starting point is a single room, the effects of using large areas of glazing in a particular climate can be quickly assessed by simply calculating results for a small window and then comparing them with a larger one. The actual modelled room may never end up in the final design, however an understanding of the area of glazing required to achieve desired daylight levels without losing too much heat in winter can help guide all the rooms that do.

This idea has long been central to the visual design processes of both practitioners and students, as evidenced by the heavy use of iterative butter-paper over-tracing during preliminary massing studies. It's extension to simulation simply means starting with a trivial model and being prepared to constantly compare the results of different analysis, slowly coming to understand patterns and relationships between performance and the model as it is refined and developed. As the design progresses this understanding will be fundamental to decision-making when the layout suddenly has to be completely revised or a new approach is considered.

2.2 Visual Analysis

The architectural design process is essentially a visual process. Ultimately the design must resolve itself into three dimensional geometry that will, to a large degree, be determined by visual analysis. It was therefore considered important in the development of the software that analysis and simulation results be displayed directly within the context of the 3D model from which they were generated. The aim is to establish a close visual relationship between building form and the resulting performance as, in the end, the main role of analysis at this stage is to guide or even generate built form.

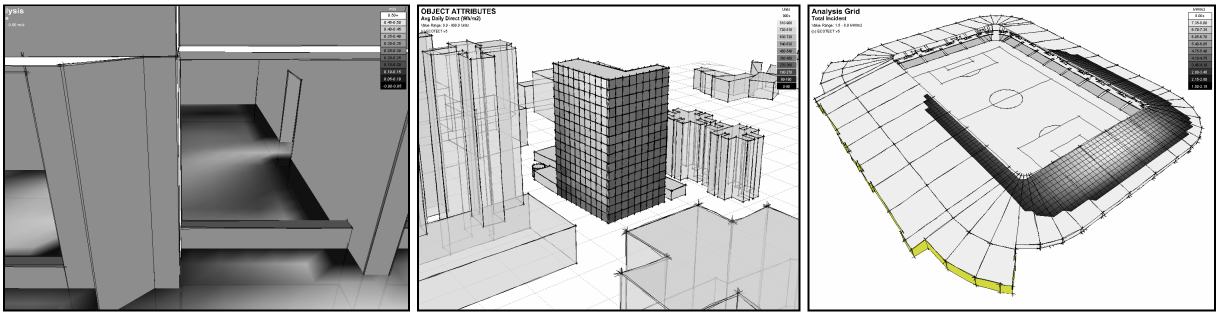

Fig. 1. Examples of analysis results showing internal air flow and incident solar radiation within the 3D model.

For students this was intended to make the performance effects of design decisions more obvious and easier to understand. For practitioners, feedback has suggested that it allows them to more quickly explain the results of their analysis to other design team members and even the client if presented this way.

2.2.2 Sketchiness

A significant issue facing current students is the presentation of computer-related design information. The more astute student quickly discovers that it is much better to trace over preliminary CAD work with a 4B pencil as the design tutor is more likely to invest an element of their own imagination than if presented with a crisp laser-print of four boxes. This is similarly true of analysis results.

Thus, in order to project the impression that the results are preliminary and generated from a preliminary model, the software can be set to generate very sketch-like images, as shown in Figure 2 immediately below. Obviously as the model becomes more accurate and the results more precise, the level of sketchiness can be reduced to project this.

For the student the benefits are obvious. However, as every practitioner knows, the one figure that the client will always remember vividly is the one casually mentioned as a rough estimate at the very first meeting. Thus, rather than being reticent to show and explain early results, many practitioners have found that the use of sketchiness as a visual cue to the preliminary nature of this information is sufficient for most clients to treat it as such, allowing them to become more involved in the development process and feel much better informed.

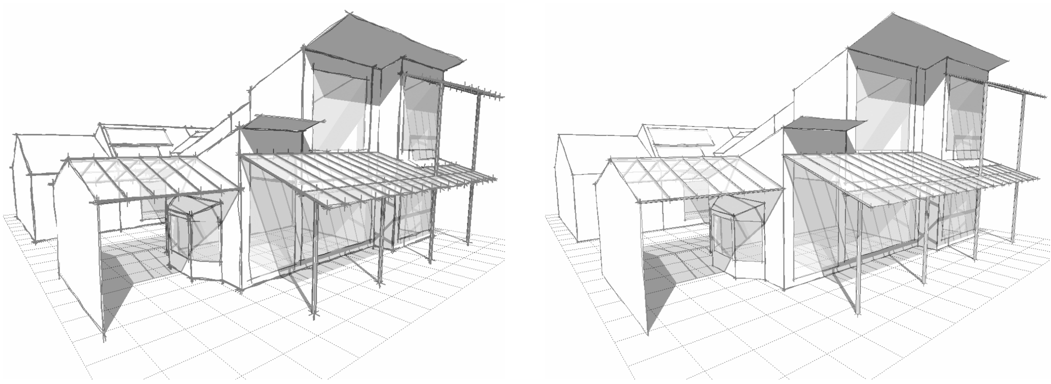

Fig. 2. A sketch-like presentation clearly shows that a model is preliminary, compared with a more precise drawing.

2.3 Understanding Building Physics

Whilst architectural education in general provides a good grounding in building physics, in practice much of this knowledge is quickly lost. There are many reasons for this, primary among them is the perception that architects themselves can never know everything about their buildings and must usually defer to specialists in each area anyway, so a detailed knowledge in any one area is not fundamentally important. This is probably true in situations where the design team comprises a diverse group of specialist working tightly together right from the outset. However, not all projects match this situation, especially on the medium and smaller scales.

Whilst specialist consultants are commonplace, simple economics dictate that it is not viable to involve them in the day-to-day churn of the early design process. This usually means that the designer must generate a reasonably cohesive design solution before obtaining anything more than general directional advice from the consultant, or pay significantly higher consultancy fees. Students, of course, do not normally have the option of calling on a consultant.

For analysis and simulation to form part of the early design process, the designers themselves must be able to formulate tests, carry them out and then utilise the results to make clear decisions. This is relatively straightforward in areas such as lighting, shading and sun penetration. However, confidence quickly falls away when it comes to thermal analysis, incident solar radiation and regulatory compliance. Even though it is possible to generate and test simplified models, extrapolating the results to a larger design context requires a much greater understanding of both limitations in the analysis method and the complex physical processes involved.

In order to achieve the step change in building performance required by both pending EU directives and UK legislation, such an understanding will be required if the architect is to retain control of the design process.

This does not mean supplanting the specialist consultant, it simply means optimising their use. The depth of knowledge offered by an experienced consultant is invaluable at the start of a project. So too their understanding of the more complex aspects of analysis later when detailed simulation is required. However, in order to access this knowledge the designer must be able to ask the right questions and be confident enough to be sceptical of specialist advice against wider design considerations and constraints.

2.3.1 Supporting A Deeper Understanding

In order to promote and support use of the software described here, it has been necessary to provide more background information than would normally be required for a similar application in another field. This was initially driven by the needs of students and the lack of contact time within the course, resulting in the development of a website providing general information on a wide range of building performance issues. This site required both descriptive and quantitative content, providing users with tables of data and small applets from which material, usage and climate data could be read or calculated.

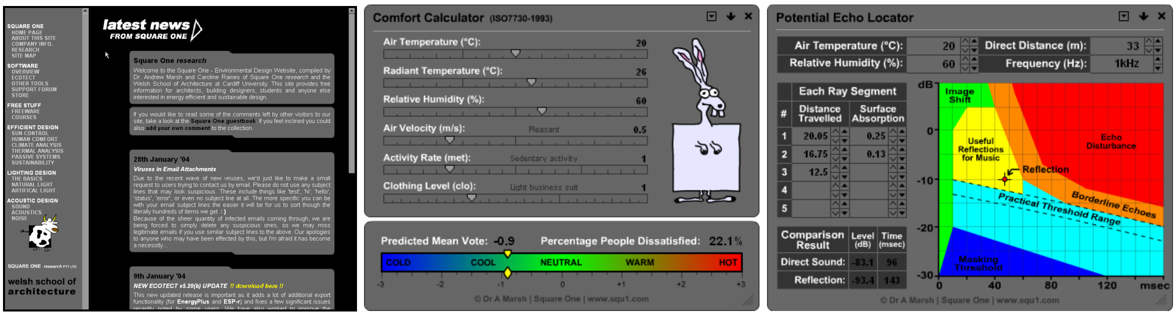

Fig. 3. Website front-page (www.squ1.com) and two example interactive applets used to calculate required data input.

Over time both the software and the website have developed in response to the needs of both student users at other institutions and practitioners. Obviously limited resources means that both have often lagged behind the changing needs of each group, however there are two significant points worth noting from this.

2.3.1.1 Online Courses

In order to ensure a basic level of knowledge, interest in the availability of courses based on site material was expressed by a number of lecturers using the software with their students. This led to the development of freely available environmental design exercises forming online courses in areas such as lighting, acoustic design and thermal comfort. As the system allows course administrators to create voluntary groups which users can join, allowing them to access results, many lecturers have used these as a small part of their overall courses.

This same facility has been used by a number of professional practices to encourage their own designers to revisit long forgotten subject areas. These online courses were approved by RIBA's CPD Providers Network in July of 2002, allowing members double CPD points for completing each course. At the time of writing these courses had just under 2000 users, 36% of whom registered as practitioners.

2.3.1.2 Distinct Patterns

With the development and release of new features, there has been a clear pattern in the dissemination and response of both student users and practitioners. The feature is first implemented within the software and basic operational documentation produced, usually as part of a help-file update. This tends to generate a series of responses and enquiries from which common elements are extracted and used to update the frequently asked questions list.

These common elements feed back into the design of the actual interface to the feature – its dialog boxes, menu items and display parameters – in order to better explain the process and reduce any confusion. At this point enquiries become more general and focus more on the detailed application of the feature. This leads to the development of more detailed technical notes containing more focussed explanations, guidelines and examples. This of course triggers new enquiries regarding the clarity of points made within the technical notes themselves, leading to further refinements and clarifications at each level.

Whilst this is a relatively standard pattern, the widespread inclusion of actual users within the loop is usually only a feature of collaborative public domain or GPL development projects. Perhaps it is the perceived academic nature of the software which leads paying users to accept this raw and direct approach, however it is argued here that it has resulted in a much faster development cycle than would ordinarily have been the case.

Immediately after a release it is very obvious from responses which features are in greatest use, which are the source of most confusion and which are irregularly used. It is the practitioners with deadlines who react first and are very quick to point out any issues or explain what is it they need. Such feedback is invaluable to the development process.

3. CONCLUSION

Such an inclusive system is not trouble free. There are many things that could have been done better, or better not done at all. The ‘release early and often‘ approach has its drawbacks, primarily that there are fewer in-built checks and quality assurance measures. In one release this meant that a new material library included materials with significantly inflated surface reflectance values. This resulted in higher daylight factor values than expected when using the default materials, leading to concern and reduced confidence in the results. Also the management and analysis of feedback has not always been as controlled as it could have been, with louder and more frequent requests being dealt with first rather than via an objective priority system.

However, feedback from practitioners suggests that a more direct involvement in development is greatly appreciated. The potential to have some influence on a process that they can see developing has meant that some users will, on their own initiative, gather information and research a particular feature they wish to have included. Such a direct link between research and practice has proved a significant motivator in and of itself.