

## **Delivering Building Simulation Information via New Communication Media**

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### ABSTRACT

Participants in building simulation supported projects are diverse (e.g. design teams, clients, project managers and simulation practitioners) and often geographically dispersed. There is much about conventional approaches to building performance assessments and work practices that reduces productivity and obscures useful indicators of performance.

Often, the goal of understanding how the building works and the impact of design decisions is hampered by limitations in the presentation of performance data. Contemporary results display is often constrained to what was considered good practice some decades ago rather than in ways that preserve the richness of the underlying data.

This paper reviews a framework for building simulation support that addresses these presentation limitations as well as making a start on issues related to distributed team working. The framework uses tools and communication protocols that enable concurrent information sharing and provide a richer set of options for understanding complex performance relationships.

### KEYWORDS

Building energy simulation, multi-media results display, distributed working, integrated performance views.

### INTRODUCTION

Detailed simulation modelling is increasingly being carried out as a design team collaboration, with each member of the team bringing a different set of skills to the process. One member may work to establish a computer representation of the

proposed design based on various inputs from other members relating to material and choices, HVAC system selections and usage patterns. This requires a series of technical exchanges and model reviews, which will often fall short on any number of objective criteria and constrain, rather than expedite, the design process. The diversity within design teams is therefore fertile ground for misunderstandings without the added complication of complex simulation outputs and the considerable challenges of geographically dispersed participants.

### ALTERNATIVES TO THE INTERIM REPORT

There is almost always more information available from simulation tools than will comfortably fit within the constraints of a written report. The act of filtering content introduces risk into the design process, constrains what may be explored and takes time. Conventional reports are less than ideal within the context of distributed design teams. A dispassionate observer would likely notice that reports are largely unread and that report authors are aware of this shortcoming.

Researchers, practitioners and simulationists have, for some time, looked for alternatives. Papamichael *et al* (1999) presented a building design advisor tool allowing use of sophisticated analysis applications from the early, schematic design stage without requiring users to have expert knowledge about each application. The tool was also designed to allow comparison of design alternatives with respect to multiple descriptive and performance parameters. It therefore acts as a data manager and process controller, automatically preparing input to simulation tools and integrating their output in ways that support multi-criterion decision-making.

Meanwhile, Donn (1999) and Donn *et al* (2001) proposed an Internet database of building performance information for quality assurance as well as a simulation veracity test and apposite post-simulation analysis tools. Another study by Stravoravdis and Marsh (2005) argued that scripts to automate the generation of building performance data and on-line databases for storing and managing this data would improve design decision making.

Simulation tools generate a rich set of performance metrics. Almost without exception tools record to file and it is often difficult to understand recorded predictions without reference to the associated model description, if not the author of the model. Often users are required to employ a spreadsheet to display simulation generated data in a meaningful way. Transport of model descriptions and simulation results files is a non-trivial task. Conventional work practices seem designed to exhaust the participants even as it constrains their ability to understand and choose between design options.

This is in marked contrast to decision making approaches in other industries where databases hold large, inter-related data sets and where interested parties may access such data any time, any where and with few constraints on the depth and breadth of their explorations.

A recent comparison of simulation tools (Crawley *et al*, 2005) identified a number of approaches taken by tool vendors to allow users to review the composition of, and relationships within, models for the purpose of QA and as a context for understanding performance predictions. Some tools hide model details from all but the most persistent user, some offer only one view of a model (i.e. what you can see in the interface), some use CAD tools as a geometry viewing agent (but not for model attribution), and some offer reports that make sense only to the chosen few. Dix *et al*. (1998) have stated that task efficiency can be improved when displays are built with complementing human senses (e.g. visual and audio).

Prazeres (2006) has built on the concept of an Integrated Performance View (Hand 2007) to

develop an Internet-based tool termed I<sup>2</sup>PV (Integrated, Intelligent Performance View). This tool has embedded techniques/rules corresponding to task types (exploration, analysis and presentation) and user types. These techniques/rules have been proven in other domains and readily translate to the building simulation. By recognising the different requirements of each design team member, and utilising multi-media techniques, the I<sup>2</sup>PV tool is able to improve the efficiency of the performance assessment task.

## OVERVIEW OF THE FRAMEWORK

To support the concurrent, interactive review of model composition and simulation outputs, the framework should include:

- an interface supporting the comparison of multiple design options using user-relevant indices displayed using multi-media techniques;
- data connectivity allowing real-time communication across platforms and networks (Kim, 2004);
- simulation tools capable of interacting with relational databases and populating such shared resources with semantically rich data sets;
- mechanisms for design teams to register issues to be explored and select criteria for judging acceptable performance; and
- options for establishing the causal links between reported performance information and model composition, which takes into account the skills and perceptions within the design team.

The building blocks of such a framework to support distributed decision making within the design process are largely available.

Hand (1998) argued that dynamic simulation tools are a super-set data model when compared with CAD tools, and that this super-set data model could be used to ensure that semantic as well as syntactic information is shared with all agents in the design process. Simulation projects that combine thermal, visual and acoustic tools for multi-domain assessment are no longer the

exception as they were when the EC COMBINE project (Clarke *et al*, 1998) was exploring early data conflation possibilities.

The framework created by the authors consists of ESP-r (Clarke, 2001) and Radiance (Larson and Shakespeare, 1998) as simulation engines (other combinations are possible), EnTrak (Kim, 2004) as an Internet-enabled data management system and I<sup>2</sup>PV (Prazeres, 2006) as an Internet-enabled results composition tool.

Figure 1 illustrates the connectivity within the framework. For instance, once an initial simulation model is generated by the simulationist, the building's composition, operational characteristics and weather context become available to the other agents within the framework. Later, thermal, visual and other simulation results will populate the data store. The intent of the framework is to allow various types of content, including multi-media objects, to be delivered to Web clients.

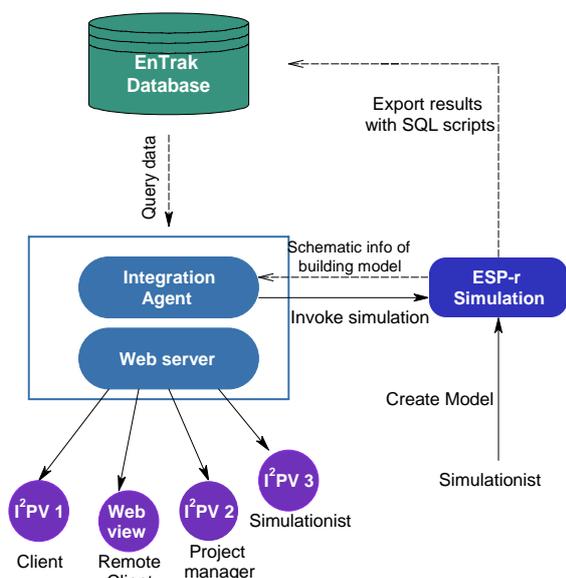


Figure 1: The on-line framework.

Minor adaptations of the ESP-r system were required to enable its on-line system connectivity with other software packages. The issue of granularity (how much and how often predictions are sent) is discussed in a later section.

EnTrak facilitates options for distributing computational and database resources in locations where it makes sense to the design team. It accepts data contributions at virtually any scale, from a single building to an entire city. The framework uses standard query language calls and industry standard communications protocols so that other database agents could be readily substituted.

I<sup>2</sup>PV, the focus of this paper, requires a neutral format text input file (and thus potentially works with any simulation tool) to allow data exploration, analysis and presentation different members of the design team, including the clients.

Figure 2 shows typical I<sup>2</sup>PV displays. A brief description of each interface follows:

*Projects manager:* users can load an unlimited number of projects and respective design options (with information on each option retrievable on the right panel). Colour is used at this stage to differentiate at a glance design options in terms of principal performance parameters such as discomfort risk or excessive energy consumption (with detail feedback on the bottom panel).

*Matrix comparison:* users can compare design options side-by-side, where columns represent the design options being compared and rows represent the different QA/performance entities. The display is fully interactive and dynamic.

*Model viewer for QA:* users can associate problematic results with model parameters such as construction data, glazing properties, zone temperature profiles and the like. QA can be carried out in an interactive way with the building model. (note that some surfaces have been removed to expose the interior).

As reported by Prazeres (2006), different techniques/rules are used to address different tasks. A description of the four principal task types follow.

*Exploration:* In order to explore information, users need to interact with displays in order to view information from different perspectives, to have a close-up look, or to request additional detail. Interactivity is particularly useful when

applied to manipulate 3D geometry, retrieve information using a 'tool-tip' feature, or to control the speed rate of a looped image depicting, for example, air movement.

*Analysis:* In order to make effective decisions the user must be well informed by the information being displayed. This means that the format employed must allow ready appreciation and the inferring of conclusions. Displays must invite the user to make comparisons (e.g. via a matrix of views).

*Internal presentation:* This is similar to a typical PowerPoint presentation but with the added advantage of information interactivity and the structured nature of the information.

*External reporting:* Typically, this would support different views (e.g. graphs, text, images, etc.) that depict the overall performance of alternative design hypotheses.

In addition, targeted displays that address the needs of the different user types are crucial. Based on field research, Prazeres (2006) identified the following user patterns:

- Inexperienced users preferred intuitive displays because it helped them to understand what was actually going on.
- Experienced users were more likely to trade-off intuitive displays for screen-space and computer power resource saving.
- Energy managers should have less display interactivity to avoid confusion and assessment errors.
- Experienced users preferred the flexibility of having both objective and subjective elements when comparing design options (e.g. costs versus benefits).
- Architects appreciated audio based feedback more than other user types. Examples included experiential appraisals for acoustics assessment and voice annotations for project briefings or to provide essential supplementary information;
- Engineers preferred overall values or pass/fail results rather than detailed breakdowns because they were more objective.

- Engineers also appreciated one location to encompass all design option and project-related information with multimedia techniques.

Some features were appreciated by all user types:

- The display of information within a main window with scrolling instead of within separate pop-up windows. This avoids window overlap and saves screen space.
- The existence of toggles to allow the change to a more preferable information format (e.g. from a bar graph to a table) or the selection of a feature to unclutter the display (e.g. to turn off a graphical grid or to include values on a bar graph).
- The existence of suppression techniques to un-clutter displays (e.g. to minimise internal windows in an IPV display).
- The combinations of audio and visual clues benefited users with disabilities.

The integration agent of the framework is a supporting system that manages data queries from the database and co-ordinates data transactions between simulation tools, Web server or I<sup>2</sup>PV. It is implemented as software procedures that have the following functionality:

- The integration agent invokes third party programs as required using an appropriate syntax for each program. In order to make the connectivity seamless, an intermediate process is generally required.
- Users do not want to know, and do not need to know, the operational mechanism of the modelling system. The user interface for the integration agent is designed to hide the complexity of the modelling procedure.
- The integration agent supports the distribution of outputs of the simulation tools to other interested agents within the framework.

## SYSTEM CONNECTIVITY

The data communication between the simulation tools and the database use a Structured Query Language (SQL) based database connectivity.

Fortunately, the time series structure of simulation result data is easily transformed into the SQL format. By using the SQL communication protocol, the simulation tool can use one of several approaches to initiating a data exchange with the relevant EnTrak data table (e.g. building description, energy use, indoor environment, climate *etc.*).

The schematic building information is recorded in an EnTrak database table: basic information on a zone, for example, is sourced from a summary file available in the QA reporting facility of ESP-r. ESP-r's simulation predictions are transferred to EnTrak at each simulation time step to support a network-based modelling process and real-time interactivity (Clarke *et al*, 2002), for example, generating real building control inputs based on predicted data (e.g. the predicted optimum start time as an inputs to a control device).

## MULTI-SENSORY PERFORMANCE DISPLAYS

Displays encapsulating a combination of human perceptions can accelerate task completion and improve understanding. A brief description of each perceptual aspect, as applied in the I<sup>2</sup>PV tool, follows.

*Visualisation:* Colour is a key parameter. The three dimensions hue, brightness and saturation can be applied to increase effectiveness. For example:

- in graphs, matching the element label to a colour helps recognition – red for heating, blue for cooling, yellow for lighting and green for renewables for example (different levels of brightness and/or saturation within each colour can further differentiate elements); and
- in a wire-frame 3D model depth perception is assisted by changing the colour from black to grey on the lines that are furthest away.

The use of animation to activate the ‘automatic human eye trigger’ is also most effective. For example, when crucial information is within a crowded display it is helpful to flash a performance metric or model element.

The idea that too much information can be confusing has its basis in truth. The remedy is to support cognition by facilitating the rapid scanning of multi-variate performance data and the ready redefinition of the focus of enquiry. By limiting the displayed information to what the user thinks is needed will only serve to limit the delivery of an accurate performance picture.

*Sonification:* Loudness and pitch can be used to reinforce different alerts. For example:

- values above a critical value set by the user may have different amplitudes depending on the extent of the departure; and
- dangerous levels could be assigned different frequencies depending on the level of criticality.

Different types of sound may also be used to indicate the nature of an alert or the action that might be taken. Experiential acoustic assessments may also involve the playing of real sound excerpts corresponding to actual indoor environments when subjected to different noise sources.

The above two human senses can be combined to improve communicate by allowing users to ‘walk through’ a model and enquire about its performance and/or element attributes. VRML (Virtual Reality Modelling Language) is capable of representing static and animated 3D and multimedia objects, with hyperlinks to other media such as text, sounds, movies and images.

EnTrak and the I<sup>2</sup>PV tool have been built with Java technology, which benefits communication between all stakeholders because, apart from being platform independent, it allows programs to run as Applets across a network. Further, to implement a multi-sensory performance display, XML, XSL and relational database constructs are required to link components and convert/translate information. XML is used to store design option information in a structured way, which may then be readily parsed and transformed by existing Java APIs.

A relational database is an ideal mechanism to store the default values that may be used by I<sup>2</sup>PV displays. These values will typically relate to:

- best practice energy use (and associated emissions and costs) per building type;
- thermal, visual and acoustic comfort levels, air movement, humidity); and
- safety critical levels for temperature, CO concentration, pollutants *etc.*).

## CONCLUSION

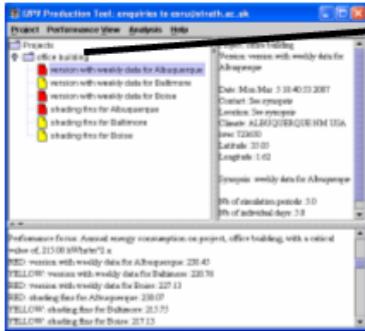
This paper has described a new framework for communicating building energy simulation predictions to distributed design team members. The system has been shown in field trials to improve team effectiveness by providing multiple views of the same data, supporting side-by-side comparison of design alternatives and allowing concurrent information sharing where team members are geographically distributed.

A significant feature of the tool is its ability to accommodate the semantic needs of different user types through the mechanism of display adaptation and the use of visual/acoustic rules.

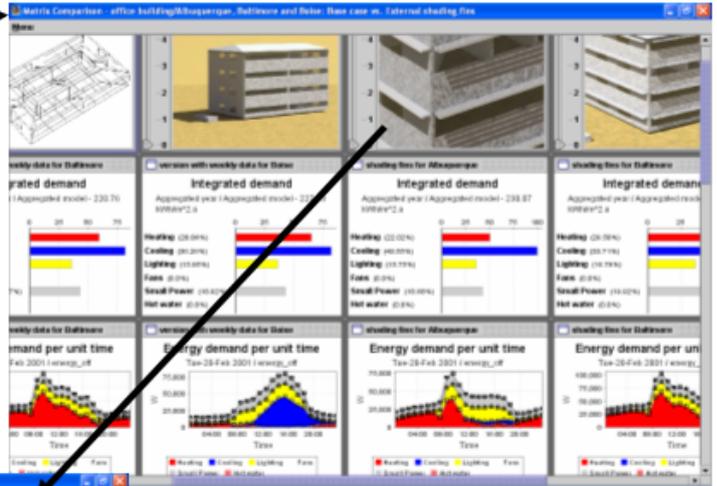
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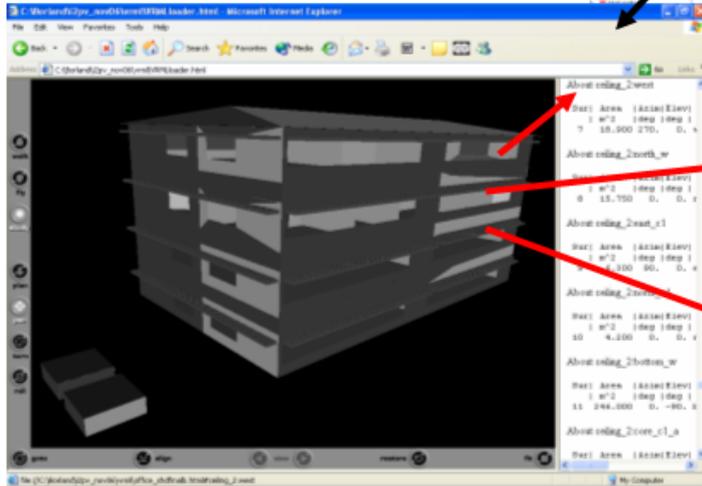
Projects manager



Matrix comparison (office building)



Model viewer for QA (external shading fins)



Model detailed information

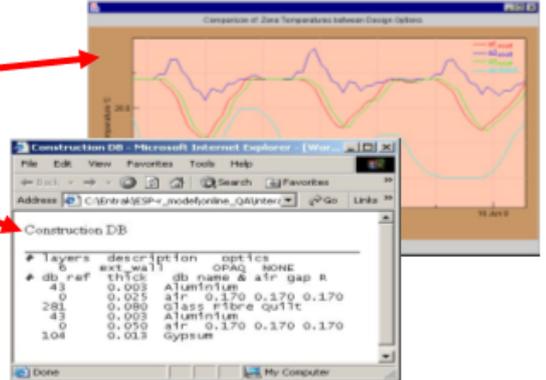


Figure 2: Typical I<sup>2</sup>PV displays (original in colour).