Visualizing Post - Occupancy Evaluation Data

Rationale, methodology and potential of EnViz, a visualization software prototype

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Abstract. This paper introduces EnViz, a software prototype for the visualization of environmental data collected from post-occupancy evaluation surveys. The piece begins by introducing the rationale for the software, and why the authors believe it can be a valuable aid for environmental building design. The development methodology is described and the basic operability and interface are presented. A case study is introduced, and the results from the application of the software on the data from it are presented with accompanying images. Further results are presented, from the use of the software in workshops with undergraduate and post-graduate students, as well as researchers and professionals. Finally, future directions of the software development and the potential of the software are given.
Keywords. Visualization; post-occupancy evaluation; indoor environmental data; 3D graphics.

INTRODUCTION AND RATIONALE

It is now a truism that sustainability in the Built Environment is here to stay. Significant efforts are made by architects, engineers, and sustainability consultants not only to design climate-sensitive, environmentally friendly systems, but also to understand and evaluate the effects of those already in use. In theory, this is a straightforward process: a specific system is used or a design approach is adopted; the environmental consultant conducts a post-occupancy evaluation survey; the results of this survey are analyzed by the architect, the engineer and client; the conclusions feed back into future designs.

One finds however that in practice this is often not the case. A survey may be conducted indeed,

but the conclusions are not always applied. A variety of factors contribute to this, but it seems there is one with greater importance. The data is rarely meaningful to non-experts. Considerable amounts of information, with complex methods of analysis are not always easily understood by the client and/or the decision maker. Furthermore, the architect has little, if any, use for tables upon tables of numbers who do not integrate in the design process and the presentation format.

This situation results in a number of problems:
· Architects and associated designers avoid engaging in the particulars of building science research, treating its outputs as difficult to com-

prehend and of little immediate use. A primary reason for that is the lack of data outputs that can be integrated in the design process.

- When designers do engage in an environmental study for a particular design, the output of this study is treated as a unique case, and the research data for this are not widely distributed under a commonly accepted standard, and hence are rarely studied, verified or re-used.
- Architecture students who wish to embark on environmental design research find it difficult to present their findings in a way that is meaningful within an architectural context.

In this context, it appears that the development of software tools that would be able to bridge this gap would be not only useful but necessary, if environmentally efficient building design is to be truly achieved.

ENVIZ: AN APPLICATION FOR VISUALIZATION OF POST-OCCUPANCY EVALUATION SURVEY DATA

The software presented in this paper is a first step towards this aim. The software is called *EnViz* and it generates procedurally digital 3D models that are visual representations of the environmental research data. Typically these are collected from data loggers which record specific attributes (e.g. temperature, relative humidity etc) at standardized time intervals (e.g. every 20 minutes). The researcher can get the full volume of the recordings for specific periods in software, firstly in formats native to the data logger and then exported to spreadsheet format. The main functionality of the software is to import a 3D model of a building, as well as the data logger recordings and, using those, create 3D visualizations.
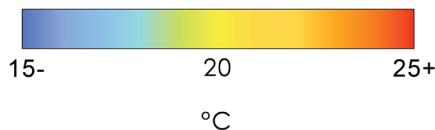
Software development

From a technical perspective, the software was developed in Java SE, utilizing the OpenGL programming interface for the 3D graphics, while two third-party libraries (SWT and LWJGL[1]) were used to supplement the development. The choice of Java as the main programming language was considered a satisfactory compromise between the development capabilities provided by a modern, powerful OOP language, without the complexity of C++ (Horstmann and Cornell, 2007). The third-part Lightweight Java Game Library was selected after testing a small range of libraries that implement the OpenGL interface for Java, as the one providing the most diverse capabilities and delivering the most robust performance.

With regard to the data input formats, the 3D models are in COLLADA[2], while XML[3] is the format for the data logger information. Both formats are considered industry standards and are accessible and editable via freely available software, such as Google SketchUp for COLLADA and Notepad++ for XML. This was considered of importance as the development team did not want to tie the use of the software to any specific 3D modeling package. In addition, as both file formats are text-based and thus human-readable and lightweight, they can be easily used for web-based applications, allowing for easy migration for extensions of the software running on a browser.

Visualization methodology

The visualization methodology required the creation of temperature and relative humidity color maps, which correspond to numerical values (Figure 1). Typically a single data logger is placed in each space so the visualization is single color. However, there
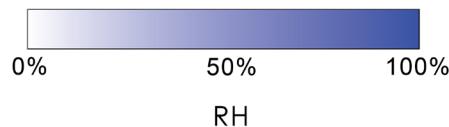

15-   20   25+

°C

0%   50%   100%

RH

are occasions where two or more data loggers are placed in a single space, so it was considered important to develop a system for the calculation of intermediate values from two or more inputs. The current version incorporates a sample process for visualizing the diffusion of temperature and humidity in the building spaces.

Specifically, the intermediate temperature is calculated as:

$$T_v = T_0 - \alpha d_v$$

where:

T_v	the temperature at a vertex V
T_0	the temperature reading at the nearest data logger
α	a weighting and unit conformity factor, taken as $\alpha = 6.35$ °C / mm
d_v	the distance between vertex V and the nearest data logger

$$H_V = H_0\ e^{\frac{17.502\ T_V}{240.97+\ T_V} - \frac{17.502\ T_0}{240.97+T_0}}$$

The relative humidity is assumed to be a function of the temperature at vertex V, and the temperature and relative humidity at the data logger, as shown below:

where:

H_v	the relative humidity at a vertex V
H_0	the relative humidity at the nearest data logger
T_v	the temperature at vertex V
T_0	the temperature at the nearest data logger

Note that these equations are not meant to provide a rigorous mathematical modelling of the diffusion of temperature and humidity in a space, but a largely accurate indication of the conditions. Also, they intend to illustrate the potential of the visualization platform for equation-based parametrization, which can be expanded further to conform to strict physics models.

User Interface

As EnViz is directed mostly towards non-experts in environmental design, an easy, intuitive user interface was considered of primary importance. To that effect, attention was paid during the development so that the number of steps required from the user is kept to a minimum. The process for a typical visualization is as follows:

1. Import a 3D volumetric model of the building (model appears on the *Model* pane).
2. Import the data from the loggers (data appears on the *Loggers* pane).
3. In the *Plan 2D* pane, drag and drop the loggers on their correct locations.
4. Select From/To dates of interest.

Then by pressing either *Run Analysis* or *Play*, the user can see a static visualization and an animation respectively. The illustration below shows the application's User Interface.
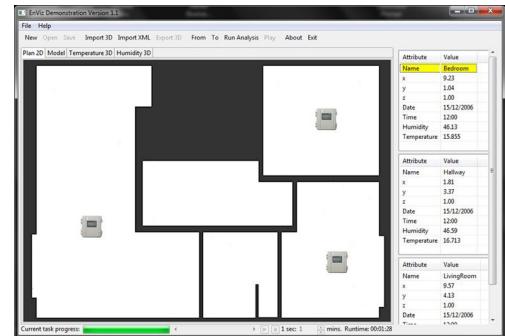
APPLICATION ON A CASE STUDY

In order to evaluate the effectiveness of the demonstration version of the software, a few case studies was selected and the software was tested extensively on those. In order for a case study to be suitable to evaluate the software, it needed to have the following characteristics:

- Availability of a wide range of indoor environmental data, so it could be proven that the application could deal with significant data loads.

- Design with emphasis on climate-sensitive design, tying it to the core concept of the application.
- Standard layout, so non-experts would be able to appreciate the results of the visualization, and relate them to their understanding of the built environment.

A case study which fulfilled all these requirements, and on whom the most extensive testing was done,is the "Accent Homes" project, developed by the Accent Group Ltd in northern England. Based on the "Grow Home" concept developed by Prof Avi Friedman (2001) of McGill University, the Accent Home is a a highly innovative concept, designed to provide flexible, low cost homes with a near-zero carbon target and emphasis on indoor environmental quality.

The project was highly successful. The house designs were submitted to the former Deputy Prime Minister's "Sixty Thousand Pound" house competition [4]and the solution was the only one to meet the Excellent Rating in the Building Research Establishment's EcoHomes assessment procedure (BRE, 2006). However, in dwellings such as these, where the energy losses are minimal, there may also be the possibility of the dwelling overheating in warm summer periods. Given that the "Accent Homes" project was developed as a pilot project to guide future design, the importance of effective post-occupancy evaluation becomes paramount.

To that effect, detailed post-occupancy monitoring was carried out between the years 2006 and 2009 by the BEAU research center at the University of Sheffield [5]with an aim to inform the future designs to be further developed in order to ensure that they are zero carbon emitting and are viable for the needs of society when global warming issues are at center stage. Several research papers (Altan et al, 2009; Altan, 2010) have disseminated the findings of the post-occupancy studies undertaken in these first pilot homes.

For the purposes of this study, an interior model was modeled in SketchUp, based on the 2D drawings. Using these two sources (2D Plans and 3D model), users were asked to make a volumetric 3D model on SketchUp. The aim of this was to gauge the demands placed for the source model on a non-expert user. As expected, these were very low and even users with minimal SketchUp experience were able to draft the volumetric models in less than 30 minutes. The XML files from the logger datasets were compiled from the available spreadsheet data.

For the testing process a total of 12,000 recordings were processed by the application and a significant number of visualizations (currently above 500) have been created. A sample of these is presented below (Figures 4 to 6).

ENGAGEMENT WITH USERS

In order to get an accurate initial evaluation of the software, it was considered imperative to have it used in practice by a number of non-experts with no involvement in the development process. To that purpose, three workshops were organized. The first two were at Southampton Solent University (UK) and they involved undergraduate students at
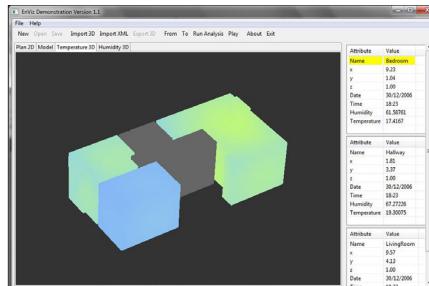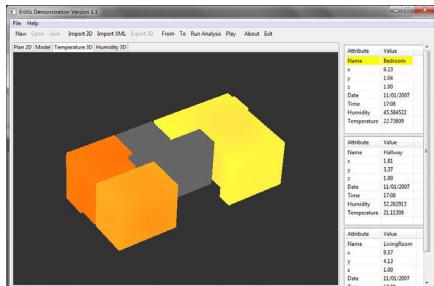

Figure 4
Sample visualizations of high and low temperatures in a dataset with three loggers in different spaces.

Figure 5
Sample visualizations of high
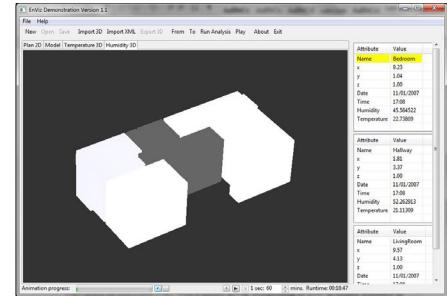and low humidity in a dataset
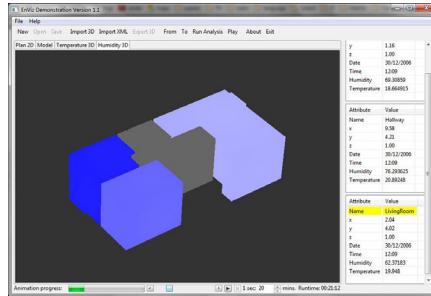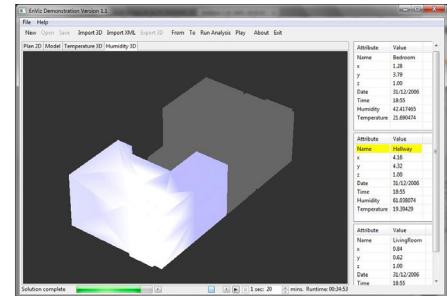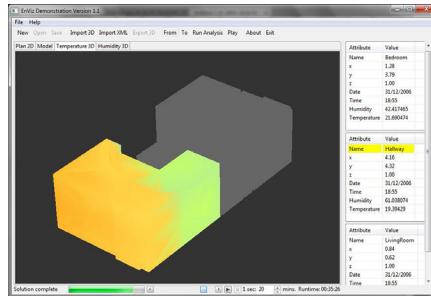with three loggers in different
spaces.

Figure 6
Sample visualizations of
temperature and humidity in
an artificial dataset with three
loggers in a single space.

the university's Built Environment programs. The third workshop took place at the University of Sheffield (UK) with a mixed group comprising of postgraduate students in architecture, researchers, and practitioners. The makeup of these three groups was considered ideal as it fitted the profiles of the user target group of EnViz, specifically individuals who are involved in the Built Environment, with varying grades of competence in IT and environmental design.

Workshop process

The workshop consisted of two separate stages. In the first, the participants were provided with environmental data collected in a specific time period, in spreadsheet format, the standard output of the loggers. This aimed to emulate the typical approach to the evaluation and analysis of post-occupancy survey data. The participants were asked to complete three tasks, in short, timed periods. In the first, they had to evaluate the temperature and humidity in different spaces, at specific points in time. In the

second, they had to provide similar evaluations over a data period of 24 hours. In the final task, they had to evaluate data of a period of one week.

After the end of the first stage, the participants were given a 5-minute introduction to EnViz. This was kept short intentionally, providing the users only with the bare minimum, as one of the main aims of the software is for it to be intuitive and require minimal investment in time and effort prior to adoption. Afterwards, the second stage commenced in which the participants had to replicate the same tasks, for similar time periods.

At the end of each workshop, the participants were provided with evaluation forms in which they were asked to comment on various aspects of the usability of each method, effectively comparing the software with the standard methods currently employed in academia and industry. As the students in the first two workshops are taught by one of the authors, the evaluation forms were anonymous in order to preclude participants trying to appear unduly positive of the software. It was also emphasized in

advance that critical feedback would only help the development team, and the students were encouraged to provide honest opinions and be clear about negative aspects.

In order to gauge the time required to manage the workshop, the size of each participant group differed. The first workshop was run with only 4 participants, the second with 12, and the final with 15. Also, in order to test the robustness of the software in a variety of systems, the first two workshops took place in university IT suites, while for the third one participants were asked to bring their own laptops. Finally, in order to gauge the effectiveness and intuitiveness of the color map, the participants were not provided with the color maps but were either asked to "use their own interpretation" (in the first two workshops), or given very basic information about the colors that represent the extremes (in the final workshop).

Results

The evaluation of the two methods (spreadsheet and software) by the participants consisted of rating each in six categories, on a scale of 1 to 5, with 1 being Very Bad and 5 Excellent. As can be seen from the combined results in Figure 7 below, the partici-

pants were generally more positive of EnViz, especially in the area of "Effectiveness of communicating the data", something particularly important as this is the main mission of the application.

At the end of the evaluation, the participants were asked to comment on their preferred system. As can be seen on Figure 8 below, the results were overwhelimingly in favor of EnViz. It should be noted that the final workshop included researchers with significant experience in the field and a great degree of familiarity with the spreadsheet-based method.

DIRECTIONS FOR THE FUTURE

The development of the first version of EnViz has been a highly rewarding experience and the team believes strongly that there is significant potential for extension and expansion. On the academic side, visualization of different types of datasets, such as energy use, are being discussed. In addition, introduction of computation and simulation elements is currently being planned, such as identification and visualization of comfort zones. EnViz has been envisaged from the beginning as not only a tool for existing data, but a visualization platform that would combine elements of simulation and computation, and the team is working to that aim. Finally, intro-
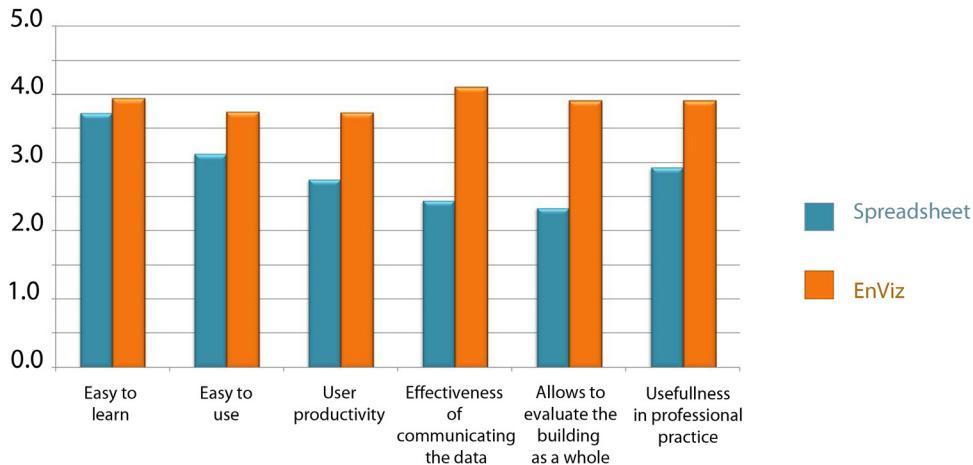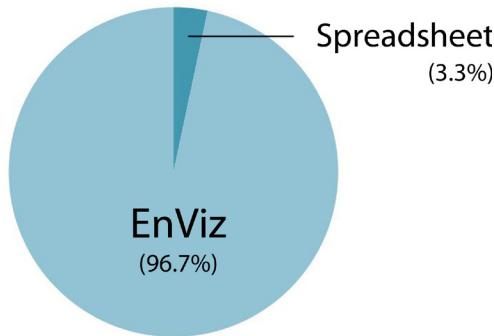

Figure 7
Participants' evaluation of spreadsheet and EnViz methods.

duction of complex, scientifically highly accurate diffusion models is also an intended aim, as this first version has demonstrated the capability of the software to incorporate those.

On the programming side, expansion to different operating systems is considered a primary aim, as the current version is compatible only with Windows operating systems. A range of features that aid usability and user-friendliness, or provide additional capabilities have been recommended by the participants in conversations that followed the workshops, and the team is currently identifying which of those should be prioritized for future development. The potential of a browser-based system that takes advantage of the emerging HTML5 architecture and the WebGL [6] interface

Finally, the potential of adaption of EnViz to further types of use has to be mentioned. This implementation concentrated on visualization of environmental data in buildings, however the system has been built in an open-ended manner and the underlying platform allows for reconfiguration for any type of visualization that is based on a source 3D model and collected data. Professionals and researchers from other disciplines have expressed some interest in different applications, including visualization of hydrological data from lake basins, stress distributions in manufacturing equipment components, and heat levels on electronic circuits.

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Figure 8
Participants' preferred system.

Spreadsheet
(3.3%)

EnViz
(96.7%)