CRAFTING THE VIRTUAL SENSORY ENVIRONMENT

Building performance simulation visualization as an enabler for creating sensory environments

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Abstract. The sensory virtual environment is defined as a cognitive method leading to a mental model of potential value in gaining insights of how building spaces may perform to enhance the sensory experience of occupants. For architects, creating a sensory and experiential space is the holy grail of design endeavours. So far, the results of the experiential and sensory success of buildings are dependent on the architects' own experience and judgment of materials and compositions within the space. Currently the use of tools such as 3D Max provides an ocular experience of the crafted virtual space, rarely giving indications of daylight and possible sensory experiences of the indoor thermal and acoustic conditions. In practice testing the thermal, daylight and other environmental performances of buildings at design stage is within the remit of building services consultants for conformity regulatory checks, and is dominated by extensive 2D (graphs) information exchanges. There is a need to include other formats of visual information exchanges to facilitate decisions on sustainable buildings and to achieve performing sensory environments This paper presents an exploration of endeavours to test the virtual sensory space through visualizations of building performance and aims to provide recommendations on how to fuse endeavours to disseminate knowledge within the design team while creating an information exchange mechanism that captures experts' explicit and tacit knowledge. Case studies will be presented on how building performance simulation tools are used to provide matrices of relations to indicate the building performance, thermal comfort, daylight and natural ventilation and were used as an aid for architectural design decisions to create sensory environments.

1. Introduction

The practice of architecture presents a continuous oscillation between crafting the abstract and the real, the drawn space to the social space, the application of knowledge space and the actual built space of living, the virtual and the physical. In this paper, a sensory environment is defined as an experiential dynamic environment that stimulates the primary senses of auditory, visual, olfactory, tactile and the vestibular system while reducing stress and anxiety. It is argued that well designed environments for wellbeing, that also takes into account minimizing the building's environmental impact and energy consumption, are a design challenge.

The crafting of a sensory virtual space using building performance simulation tools extends the creation of the virtual architectural space complementing other media of architectural communication and project conceptualizations such as 2D paper space and 3Dvisualizations and physical scaled models. Sensory environments are a design goal to maximize occupants' productivity, contentedness through the design of experiential dynamic spaces. Delivering sensory spaces that work for their occupants passively (through good design) while enabling an adaptive response to the environment.

For decades the use of building performance simulation tools was the realm of building services engineers and extensively used in sizing building air conditioning systems. This research argues that these tools can be valuable to architects to explore how the whole body and the senses will experience the building virtually. A virtual exploration that extends experiencing the virtual space as discrete instances of pixels translated into spaces, textures and surfaces that are molded to please the eye into the realm of a total virtual sensory experience that goes beyond the senses of vision and touch to thermal, daylight and sound levels in the space. The role of experts in building performance simulation tools is vital in providing reliable predictions but also in communicating these results to the other design team members, and stakeholders. The levels of knowledge and understanding of predictions varies in these teams highlighting the need for experts to use a plethora of information exchange methods and visualization tools

This research presents some of the current attempts to present building performance sensory information to developers, as well as professionals in a design team. Similar to the early publications on using animations and immersive virtual reality research in architectural design, virtual sensory environments are still limited in the information conveyed. It is well acknowledged that building designers' existing forms of spatial representation require intellectual abstraction and offer only limited views.

The inability to enter a 3D model or a computer virtual animations of spaces however 'dynamic' and as 'close to reality' they may be described are effectively an expert's choice of a pre-determined path to convey information for decision support. Simulations can be very effective in representing spaces; however, their misperception can result in erroneous judgments. This is exaggerated in the case of decision making for sizing, positioning of façade elements, their materials, and their effect on daylight, thermal and acoustic environments, as well as sizing of building services equipment. Williamson (2010) warns that building performance simulation is grounded in an empirical tradition which assumes that the world 'out there' is essentially knowable and that there is a 'true' external reality. Williamson (2010) warns that claims made by simulationists can often lead to spurious impressions of legitimacy, with 'accurate' predictions of some aspects of built environment performance being used to legitimize certain design decisions at the building level, and regulations or similar mechanisms at a policy level.

2. Virtual Sensory Environments: the accidental and the intended

A positive relationship was established the integration of the PV array by Studio-E in their design for the Doxford Solar Park, Sunderland, UK (2000),Figure 1.

Figure 1: The PV array as an integrated feature of the south elevation(left), Computational Fluid dynamics showing stratification of heat and design strategy to push it away from occupied space(top right), Building elevation (bottom right)

The intention to present the renewable aspect of the facade was influenced by the building performance simulation of indoor environments leading to extending the facade higher than the building and recessing the floor plates to deal with the heat stratification behind the facade from the glazed areas and from heat generated from the transparent 532 m^2 PV arrays (Figure 1).

The result is a building that is engaging with the daily variations of daylight through the opaque and transparent areas of the integrated PV glass panels and a visual continuity between floors that gives visual access into the building entrance and atrium for both a visual relief and a social dynamic space. A decade onwards, these architectural sensory experiments are increasing reflecting sensitivity to providing an intended sensory designed space. Hamza (2011) analyses case studies of corporate sustainable buildings, where the ethical commitment, combined with ambitious corporate goals, provide impetus for building design teams to push design boundaries, allowing ample opportunity for the use of building simulation tools. An extended discussion of the differences in presenting building performance performance visualization to different audiences with varying expertise (such as developers, design team members and examples of how this is used as a decision tool in the boardroom can be found in (Hamza and DeWilde, 2013).

3.2 Visualisation and Building Performance Simulation

Currently, the role of building performance visualizations is continuously moving from charts and technical graphs into more sophisticated walkthroughs to reflect how the sensory space will perform In building performance visualization (BPV) the role of the image unfolds as the practitioner seeks and discovers linkages between new knowledge and affirmation with accepted scientific rules of thumb. BPV results may lead to new questions and concerns. Dorst (2007) and Spence (2001) argue that the visual can be put to work ‘efficiently and effectively’ adding insight into data in the professional process of knowledge exchange. The rich and close descriptions of the use and appropriation of visual artefacts reveal that images help groups to focus attention, to explore areas of agreement and disagreement, to make implicit knowledge and past experiences explicit to discover new perspectives, and to document or revise decisions.

Prazeres et al (2007) state that communicating building performance takes place among diverse project teams (e.g. design teams, clients, project managers and simulation practitioners) which are often geographically dispersed. They argue that the goal of understanding how the building will perform and the impact of design decisions on end energy demand is hampered by limitations in the presentation of performance data. They go on to suggest that contemporary display of simulation results is often limited to principles that were considered good practice some years ago rather than in ways that maximise utilization of the rich e underlying data. Hamza and DeWilde (2013) through elite interviews with experienced building performance specialists show how tacit and explicit experts knowledge of building performance simulation outputs are communicated and need to appeal to different 'audiences' to aid decision making processes, whether within the design team or in the boardroom

Over the last three decades, rapid developments in information visualization techniques now allows for user interaction, data mining and explorations techniques These developments have not been matched at a similar pace in the field of BPV. Yet, similar to the criticisms of information visualization tools for documents' data sets (Amar and Stasko, 2004), BPS visualizations are inadequate to support decision making due to *'limited affordance'* and *'predetermined representations from the building performance simulation tools'*.

Visualization of building performance simulations facilitates communication and thus holds the key to achieving high performance design goals and minimizes design process waste. Information visualization tools in general and building performance visualizations in specific can transform quantitative models of building physics into qualitative and sensory experiences. This paper provides some examples in section

Sheppard (2012) argues that information processing of issues related to climate change (buildings as contributors to carbon emissions in our case) have to be balanced and professionally crafted based on the receptors expertise, pre-existing knowledge, attitudes and values and the length of time given to this encounter. A desired effect of this encounter would be to affect cognition (knowing and learning). The main goal of using visualizations for building performance and building carbon emissions is to create a positive emotional and behavioural change to motivate the design team and developers into decision making and action towards investment in sustainable buildings. Building performance information visualization needs to be *'technically defensible' and 'culturally palatable' to create a shared space of knowledge exchange and decision making'* (Loukissas 2012:11)

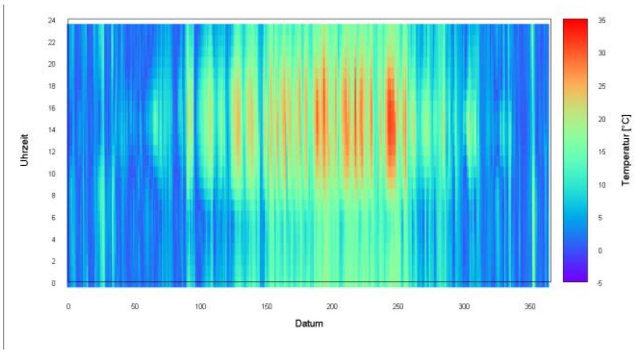

Figure 2: Temperature in Augsburg source www.wikepdia.org

Although 2D and 3D charts are common place in communicating building performance simulation results of natural ventilation, daylight levels, and thermal stratification, there are attempts to incorporate colour and motion and a superimposition of various visualization techniques. Colour is used to catch attention of the audience to possible areas of concern, transmit information and directly affect the viewers' emotions. Incorporating colour in 2D graph is still common place in communicating building performance simulations such as the Carpet Plots (Figure 2) facilitate interpolations as a 2D graph that can contain annual information illustrating the interaction between two or more independent variables and one or more dependent variables. It is argued that presenting information in 3D has a clearer message to team members. Figure 3 illustrates cross sectional thermal behaviour of a shopping mall. Building performance simulations were key in moving the roof upwards

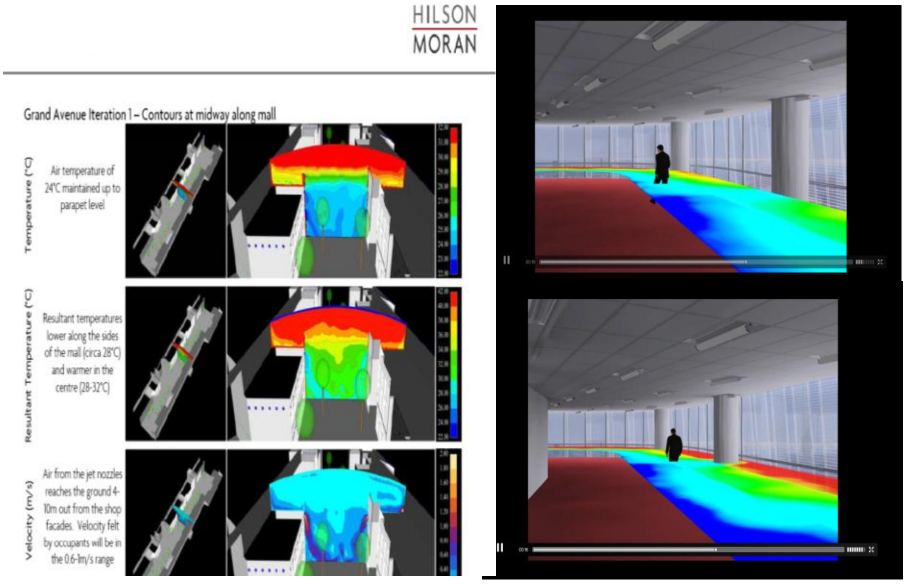

Figure 3: Top indicating CFD analysis imposed on a 3D model of a mall. Left: Walk through daylight levels at different room positions in an office building With permission: Hilson Moran.

leading to the stratification of heat above pedestrian levels and allowing for the air conditioning of the shops to ameliorate the concourse's temperatures (Figure 3; Left), Figure 3 (right) presents a video animation of an office worker at desk level to show various levels of daylight that maybe experienced at different positions. It is evident that more research needs to push the boundaries of computational power to delineate the building performance and predicted sensory environments. The temporal nature of the visualization raises questions on how sophisticated, computationally expensive and time consuming it would be to provide this data for different times of the year and for the totality of the building.

4. Conclusions

1. Architects have a responsibility to deliver buildings that support human wellbeing and satisfaction. Building performance simulation tools offers a chance to test the performance of a sensory environment at design stage. As tools to support regulatory conformity and design decisions in architectural projects, building performance simulation deals with exploring and verifying - as well as communicating - the

transformations in human environments that a certain architectural project is expected to create. Currently, Building performance simulation is undertaken, in the main, to prove to developers and building regulation inspectors that the intended building will meet a checklist of indicators for sustainability and for sizing mechanical building services. In this paper it is argued that these tools can be used as a very effective means for expert knowledge exchanges within the design team and with developers, if the technical 2D charts are combined with more intuitive 3D visualizations forms of representation. The BPV's main role is to extend the use of visual cues to support evaluation, reasoning and decision making on the predicted building performance indicators at a collective team and clients' level. It can be used as an effective tool to access the sensory environments of a building. This could be extended to look at olfactory effects (pollutant dispersion studies indoors), sound propagation in noisy environments, natural ventilation on addition to the now common place thermal and daylight simulations. The challenge is to ease the distillation of vital information from the building model while presenting information that visualizes the relationship between the detail and the whole of the building.

2. Building Performance Visualizations should catch attention, allowing selection of focus while simultaneously avoiding information clutter. It is attested that the level of data abstraction and visualization to focus attention on particular performance aspects requires an expert's judgment. Attention capture can be achieved by the vividness of colour renderings (refer to daylight walk-through when daylight rendering is vivid in colours while the building and its surroundings, as an information subset, are in grey).
3. It is relevant that representation of spatio-temporal aspects are comprehensive and reflect variability in building performance related to the specific building location and performance variations over the day, week, and month or annually and to provide a possible understanding of how changes to building design can impact the sensory environment within Data outputs from the complex mathematical modelling of buildings and their surroundings can create convincing sensorial events for boardroom audiences, showing variability of daylight levels and where very low levels might occur, thermal comfort irregularities and areas that would need acoustical interventions. BPS visualizations can motivate broad consensus through virtual experiences of alternate possible realities and opens opportunities for continual negotiations with BPS experts in the decision making process.
4. As information is presented to an audience with varying experiences and understanding of building performance, a capacity of visualisations to provide first an overview, with the potential to zoom in and filter down to details on demand (such as areas of predicted poor performance in one or various sensory aspects), would be beneficial. Schneiderman (1996) and Lehrer and Vasudev (2010) highlight the need to provide 'a high-level overview with drill-down capabilities, including visualization of end-use energy information, including lighting, plug loads, and HVAC components' with the interactive capability to link cause and effect of performance aspects on demand and in real time in the boardroom. As BPS visualizations only capture a moment in time of data that are highly temporal, it is prudent to allow for focus on any relevant subsets of information that BPS experts would like to highlight and externalize knowledge to inform boardroom decisions. This might take place in the accompanying textual reports as well as in the BPV.

Hamza and DeWilde (2013) research and interviewsd with leading edge building performance simulation companies found that experts actively manage the presentations of data outputs and sometimes 'tweak' and 'tune' it to highlight certain performance aspects.

They confirm that visualizations are sensory and perceptually effective tools to a wide ranging audience in the boardroom. However, BPS visualizations need to be backed up by well-presented textual reports and physical architectural models and drawings when presenting to the boardroom. Visualizations do not normally highlight uncertainties in modelling, nor do they demonstrate the interlinked nature of cause and effect in results. Experts are aware that visualizations of high resolution and data contents may obscure issues of validity and the reliability of BPS results, and that these need to be communicated in boardroom presentations and the final textual reports alike to avoid leading the focus of attention away from the relevant information and to avoid possible litigation actions in the future.

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