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Parametricising sound for early-stage design: An information design problem?

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Abstract

Parametric environmental simulators, such as Ladybug, Honeybee, DragonFly, and Butterfly, are algorithmic tools that enable designers to visualise and simulate weather conditions, daylighting, urban heat island effects and wind paths in relation to 3D design geometries. These tools are readily used in design processes in architectural education and the profession. By contrast the integrated visualization and analysis of acoustic parameters in 3D modelling environments is less widely practiced by designers and students of design, despite the availability of reputedly algorithmically robust acoustic analysis and simulation plugins. Drawing on a 3rd year undergraduate computational design studio that introduces students to architectural acoustics as part of multi-parameter optimization workflows, this paper reflects on the barriers and opportunities of engaging with parametricised sound in early-stage design. This paper further contributes perspectives on the wider significance of information design for computational tools, and relatedly, how designers prepare themselves to make 'informed' decisions based on complex environmental data.

Keywords: architectural acoustics, acoustic design, computational design, parametric design, information design, Pachyderm.

1 Introduction

Architects and designers often draw on heuristics and assumptions, informed by education and professional experience—in knowing and often unknowing ways—to help make decisions as they design [1-3]. The term heuristics is defined here as a practice of 'educated guesswork' that typically derives from prior experience and draws on common knowledge and values. Donald Schön has famously described how design knowledge is also a form of "knowing in action", that is "mainly tacit" [2] (p.3). He argues that "designers know more than they can say…tend to give inaccurate descriptions of what they know…and can best…gain access to their knowledge in action" [2] (p.3). In other words, it is through modes of 'doing' design, or designing, that design knowledge is both created, reshaped, and called upon to inform design decisions. Heuristic methods also form the basis for how many computational design decision-support and optimisations tools operate [4]. And when architects and designers engage with computational tools in the design process in the form of 'decision support', heuristics and tacit knowledge can influence how designers in turn interpret the outputs of a tool. Perhaps not surprisingly, a designer's familiarity with a topic can impact how well the tool can help them meet their desired goals. But can this explain for example, why architects and design students alike have readily adopted open-source parametric environmental simulators for daylighting, radiant heat, temperature, and wind conditions, but not necessarily the phenomena of sound? Afterall, there are now a range of acoustic computational analysis and simulation tools that are reputedly algorithmically robust and capable of generating reliable data. This paper considers why such tools are not yet as commonly used by professional designers or design students. It does so by reflecting on the experience and outcomes of a 3rd year undergraduate Digital Collaboration design studio that introduced students to architectural acoustics and engaged with the open-source acoustic analysis plugin Pachyderm [14] within the Grasshopper/Rhinoceros 3D modelling environment. The paper draws on the notion of a hermeneutic gap, defined here as the distance between computational tool data output and its capacity to be usefully interpreted and applied in design practice. Accordingly, the following sections of this paper explore the hermeneutical challenges of 'parametricising sound' in early-stage design. The paper concludes by reflecting on lessons learned and future directions and argues for the significance of information design and user experience principles in the design of digital tools and computational workflows.

2 Environmental simulation tools and hermeneutic relations

When interpreting the results of computational analysis and simulation tools designers may connect more intuitively with output in data formats that is familiar to them. For example, in the case of simulations reporting air or surface (radiant) temperature, a designer might draw on their own experience of comfort associated to a temperature range to inform a design decision. Equally, the units of measurement and heat-maps used for representing radiant heat and thermal comfort temperatures that employ the traffic light RGB range are typically familiar to designers and the public more generally. What this points to are the ways understandings of temperature, humidity, and even wind form part of an everyday lexicon. Put another way, understanding climatic phenomena— or the weather— forms part of people's everyday lives as it carries significant implications for how they go about their lives. This is exampled by regular communications about weather status to the public through television, newspapers, online reporting, and dedicated weather apps for smart devices. People's day-to-day decisions, from what clothes to wear, what form of travel to take, to how much energy their house will consume are often highly contingent on weather forecasts. But, while the phenomenon of sound is an everyday and significant experience, the reporting of sound levels or conditions is not as ingrained in everyday discourse and decision-making. Most people, not even designers, are likely aware of the recommended loudness for an office, library, performing arts theatre, restaurant, or highway. Nor would they necessarily be familiar with the unit of measurement for sound and that it is expressed in decibels (dB) along a logarithmic scale, the various evaluation indexes for sound, or the ways that spatial and material design decisions can have a bearing on sound quality. What this suggests is that designers or students who want to engage with the phenomena of sound through computational acoustic simulation tools may need more support within the tool itself to understand acoustic principles in the context of design requirements and to make sense of performance metrics outputs. But to what extent can, and perhaps should, a computational acoustic tool, that is primarily designed to automate and visualise acoustic analysis, also assume the role of informing designers about acoustic principles?

3 From Digitalising to Parametricising Sound

There is significant creative, economic, and environmental value to be realised by reconceptualising sound as a design driver or parameter, as opposed to an issue to be engineered out in design development or addressed remedially during construction or post-occupancy stages [5-9]. With access to suitable custom software tools designers and students can engage more creatively with the principles of sound diffusion and scattering in early-stage design. As the case example in this paper demonstrates, computational acoustic simulation tools offer significant ways for designers and students to explore how local scale, complex surface geometries can influence the distribution of sound and sound quality towards meeting identified and relevant targets [8]. Still, developing acoustic analysis and simulations tools for use in early-stage design and education contexts presents complex challenges that entangle the technical with the informational.

The scientific principles and methods for analysing the acoustic performance of architectural spaces are well established. But for much of the 20th century, predicting and designing acoustic performance in spatial environments relied heavily on the use of physical scale modelling and on known sound absorption properties of materials. In the previous two decades, a wider range of software programs have been developed to translate the scientific principles of acoustics into algorithms to automate processes of acoustic analysis and simulation. Now, acoustic simulation software can crunch data to communicate acoustic performance as heatmaps overlaid onto 2D and 3D models views (Figure 1), as ray tracing in 3D models (Figure 2), as sound energy propagation simulations (Figure 3) and in the form of auralisation. In this way, the acoustic performance of proposed or existing spaces can be calculated, and even heard or experienced in relation to their volumetric, geometric, and material characteristics [10, 11]. These methods afford new ways for designers to incorporate acoustic considerations into far earlier stages of design work to open-up creative potential and to reposition sound as a significant design driver. Engaging with the phenomena of sound in early-stage design can in turn avoid costly re-do work in buildings where acoustics are found to perform poorly following construction and/or post-occupancy.

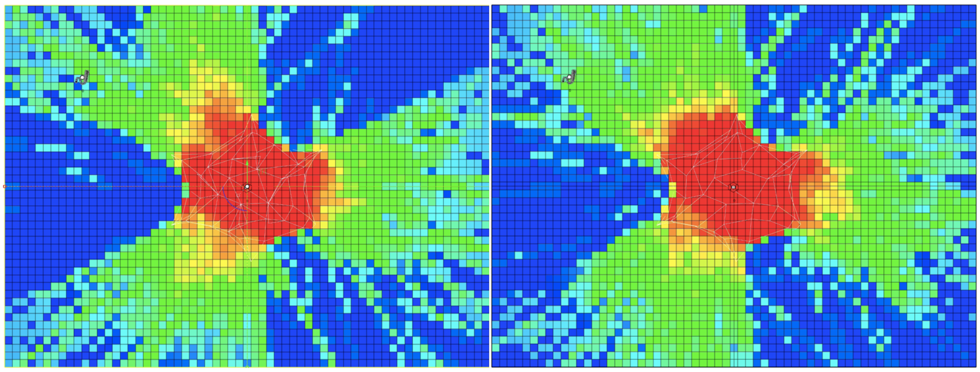

Figure 1 – SPL heatmap (Image courtesy of Ebony Pritchard)

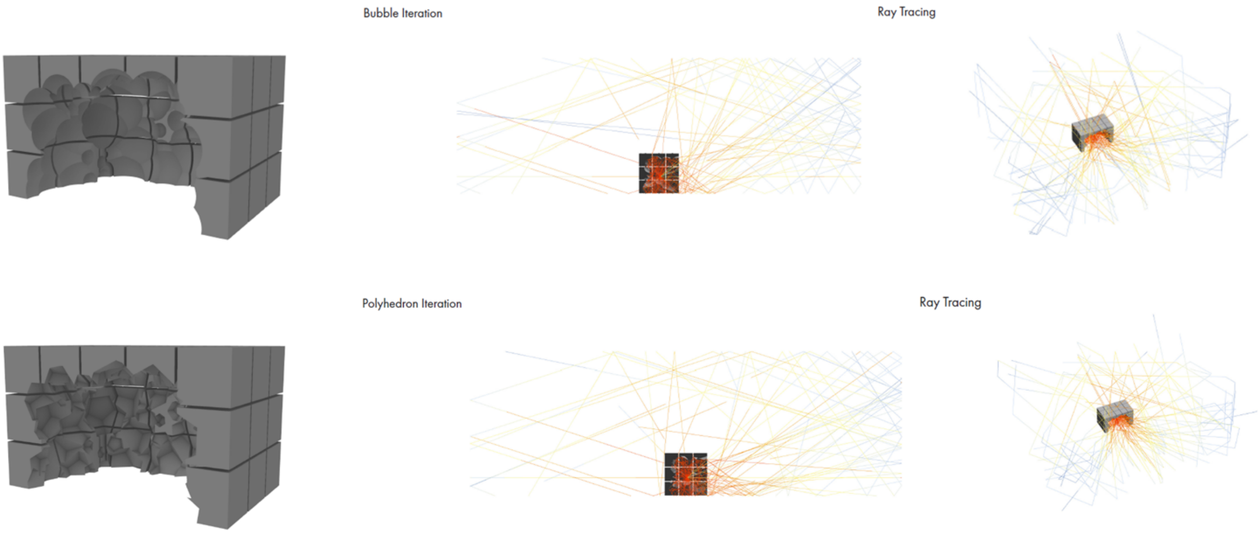

Figure 2 – Ray Tracing in 3D model iterations (Image courtesy of Billy Park

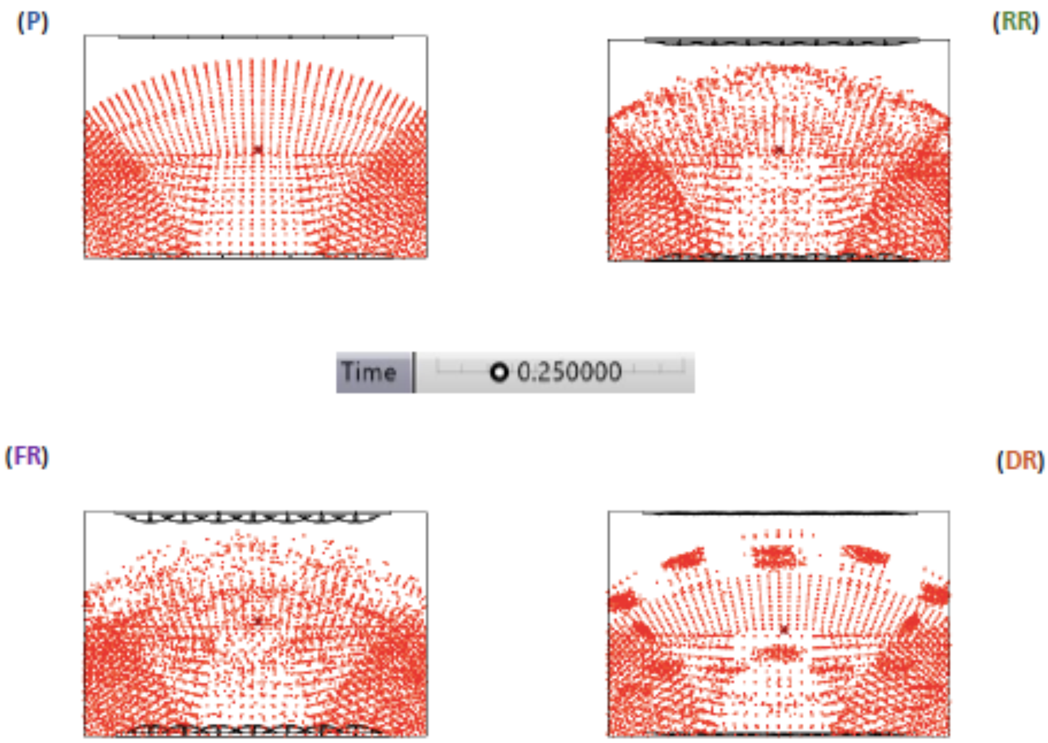

Figure 3 – Sound source propagation simulations for 4 iterations (Image courtesy of Eddie Azzi)

In 2019 researchers Milo and Reiss [11] reviewed the technical features of a range of acoustic simulation tools, including expensive, specialist, and typology-specific software such as ODEON, to more recently released and accessible options geared towards creative exploration such as the RAVEN plugin for SketchUp. Milo [10] notes that Pachyderm developed by Arthur van der Harten in 2013 while at Foster + Posters remains the only open-source acoustic simulation plugin for use in the Rhinocerous/Grasshopper 3D modelling environment. The following sections of this paper describe the use of Pachyderm in a 3rd year Digital Collaboration design studio.

4 Digital Collaboration Studio

The Digital Collaboration Studio is one of the penultimate 3rd year courses in the School of Built Environment, Faculty of Arts, Design, and Architecture, at the University of New South Wales, Sydney, Australia. It is a course that interprets the notion of 'digital collaboration' from two key perspectives. Firstly, it conceptualises 'digital collaboration' as an ecological design method that brings into relationship allied computational methods and digital technologies to frame design problems and iteratively work towards their resolution. Secondly, it involves students working collaboratively to assemble computational workflows to simulate, analyse and evaluate multiple design iterations, and create a design prototype. In 2020 course students were tasked with designing a small music performance pavilion to be situated on the Sydney Opera House forecourt. The design brief called for an adaptive pavilion in dialog with a range of environmental phenomena. As such, design teams were required to facilitate and demonstrate this dialog by constructing computational workflows and using environmental simulator plugins for Grasshopper such as Ladybug, Honeybee, DragonFly, Butterfly, and Pachyderm, as well as structural analysis using Karamba, to test and calibrate the design model geometry. In 2021, and based on the experiences of the previous year, the design brief was revised in scale and scope. In 2021 the focus shifted to the design of kinetic acoustic panels for an office environment that could be rescaled using soft robotics techniques to accommodate different functions, such as small meeting, lecture/presentation, and quiet work.

As 3rd students enrolled in a Bachelor of Computational Design each class came to the Digital Collaboration design studio with significant experience using the visual programming language interface Grasshopper within the Rhinocerous 3D modelling environment, as well as text-based programming such as Python. In the 2020 class, where teams explored a wide range of environmental phenomena most of the students had prior experience using climate data plugins such as Ladybug, but limited experience with wind analysis. Across each year group none of the students had prior experience with Pachyderm and few were familiar with the principles of architectural acoustics. Overall, in 2020 the students successfully conducted a range of environmental simulations for their site and design (Figure 4). The wind analysis required some debugging and technical wizardry, but the acoustic analysis proved most challenging for the 2020 class who were expected to optimise their designs based on multiple parameters. The open sided-sided nature of the pavilion designs presented further challenges for the 2020 class who soon realised the Pachyderm simulation required a closed geometry or bounding box. For the 2021 class the design site was an internal office and thus inherently more aligned for use within the acoustic plugin tool.

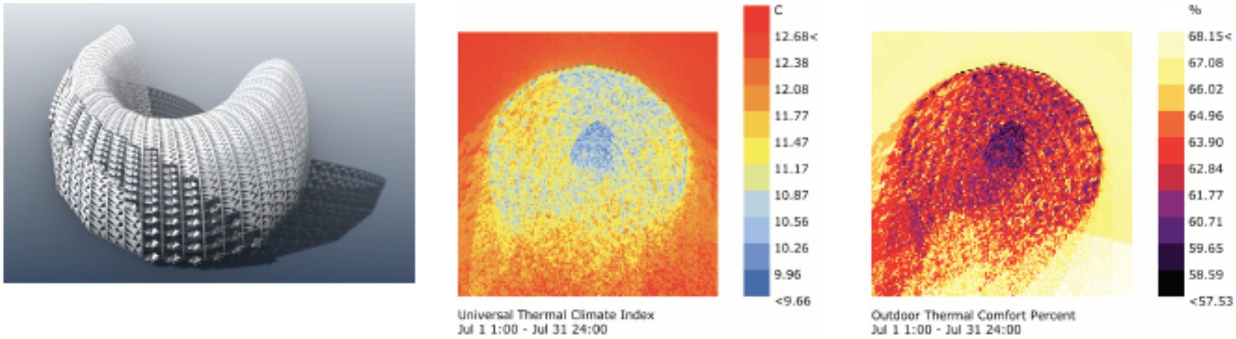

Figure 4 – Pavilion Solar Analysis 2020 (Image courtesy of Monica Ooi, 2020)

In attempting to undertake acoustic analysis, students across both years encountered a combination of technical and hermeneutic challenges. This included software version compatibility, interoperability, model preparation issues, and output interpretation issues. In terms of the technical issues, for analysis to run, the Rhino model had to be prepared as rhino baked objects in layers, in the correct scale (metres) and with specified materials and absorbency. In 2021, students were specifically exploring soft robotics and silicone as a material for acoustic panels and were not necessarily able to assign this material from the options provided in the plugin. In general, students felt that the material options in the plugin were limited. Additionally, some students reported difficulties in running simulations depending on computing power and the complexity of the design. The excessive drain on computer processing power meant long run-times, including one student reporting more than 1 hour to render a ray tracing. For some students, these technical challenges made the exploration of multiple design iterations unfeasible.

Beyond the aforementioned technical demands, and although students were equipped with a basic introduction to the principles of architectural acoustics and resources, they confronted a hermeneutical gap. The time spent setting up the simulations meant that while captivating visualisations of sound energy propagation were produced, less time was spent on interrogating their significance. The simulations in this way became seen as an end goal, rather than the production of data to be analysed to reinform further design iterations. Overall, the short teaching term length of 10 weeks placed limits on the opportunity for iterative cycles of simulation, feedback into design and further simulation (Figure 5).

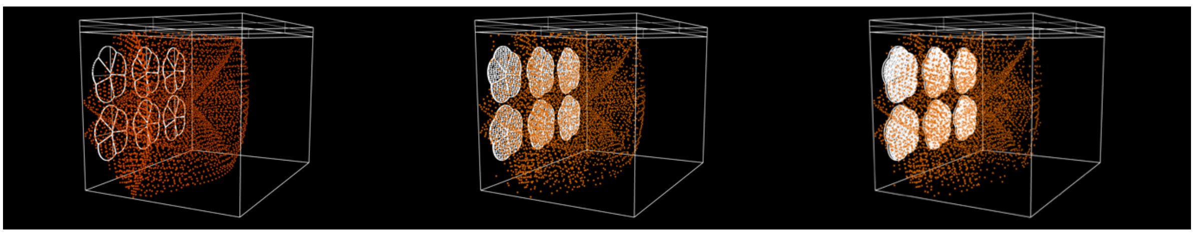

Figure 5. Sound energy distribution simulation comparing 3 different panel designs, in states of deflation and inflation (Images courtesy of Nicole Hua, 2021).

5 Discussion

It would be tempting to dismiss the technical issues related to computer processing power encountered by the students during the Digital Collaboration Studio as trivial, as the individual's responsibility, or not within the scope of the developer. But these issues are entirely relevant when the problem in question concerns encouraging more designers and design students to purposefully engage with the phenomena of sound as a design parameter. Systems and tools that necessitate an excessive drain on computer processing power and feature complex user interfaces can rapidly deter the wider uptake and diffusion of digital tools and undermine their value. In the Digital Collaboration Studio, working in teams offered a short-term workaround to computer processing power issues, as students had a range of laptop specs. Following Moore's Law, it could be optimistically assumed that the continued increased in the speed and capability of computers will simply remove this issue, but equally, designing open-source tools that require high-end computer processing power is an incongruous approach.

The challenges identified and discussed briefly here are situated, shaped by the design project, teaching conditions, computer power, internet speeds, and a pandemic that meant students and staff were in lockdown and collaborated online. But equally the challenges and opportunities faced echo wider issues in digital and computational research more generally. Much architectural computing research has focused on testing and validating the technical feasibility of digital tools and their potential applications, but few studies have explored the challenges of practical implementation, user experience, and broader adoption issues in industry. The consequences of this as Zboinska [12] argues, are that many designers are put off by the tools proposed by academic research contexts that they perceive to be too abstract and tedious to use. And for many designers who do take up the tools, as Bernal et al [1] highlights, there can be a "significant cognitive cost" as they "…spend a considerable amount of time attempting to interface their work rather than focusing on the design itself" (p.165). But most digital and computational tools demand more upfront time to run simulations and analysis. In the context of acoustic design, for established and advanced non-integrated acoustic engineering simulation software based on geometric acoustic (GA) principles and algorithms, 3D models must be simplified for translation. Other acoustic analysis software requires a re-organisation of 3D geometry data (architectural models) layer-separated by material [7]. This onerous preparation work to 'clean' and duplicate 3D models is one of numerous identified problems that spurred Pachyderm developer Arthur van der Harten to create and release an open-source and integrated acoustic simulator to begin with [14]. But preparation time to set up these valuable tools needs to also be understood as part of new ways that humans and machines can design together. It is, more broadly, necessary for designers and educators to appreciate this shift and for clients to understand that 'time-taken' in the short-term is always far easy to measure than 'time-saved' in the longer-term that will likely render more extensible value. Equally, while data exchange issues and wrangling model files into compatible formats can be difficult tasks for first time users this becomes less arduous with continued use.

Significantly, the notion of 'interfacing the work' as merely a cognitive cost is misleading and overlooks the value of the knowledge that is generated through human-machine interaction. Setting up a software system to run a simulation to extend a designer's exploration of the design space is not apart from the design process, it is rather now firmly rooted in it. In the Digital Collaboration Studio student learning was activated *through* their interfacing with the technology. The necessity to rigorously organise their 3D models to run simulations forced students to connect between 3D spatial configurations, material choices, acoustic principles, and sound quality indexes. In short, their awareness and knowledge of architectural acoustics was shaped by and mediated through Pachyderm. Nonetheless, going forward, the Digital Collaboration studio must also find ways to bridge the hermeneutic gap between data and interpretation. More time could be allocated for students to research and find precedents for sound quality to inform their design goals and then evaluate their simulations against. This could be informed by connecting embodied experience to indices and data in the form of "aural awareness" as described by Milo [10]. Involving 'listening experiences' in design education could bridge between experience and abstract representations of sound and complex sound quality indices and data. The aim here would be to develop a similar level of intuitive connection that students may have for other environmental phenomena such as thermal comfort and temperature. Put another way, such methods could facilitate a more intuitive understanding of the implications of an office environment registering loudness at 50dB or a classroom environment with 0.5sec reverberation time (RT). Milo writes that future designers could develop a "sound-based vocabulary" from listening and documenting "sonic environments in combination with design tasks [10] [p.105]. Equally, and from a computational design perspective, collecting sound data in environments could be used to add additional machine learning features to plugins such as Pachyderm. For example, using historic sound data measured by acoustic engineers from existing buildings as a training set in combination with spatial data, could provide opportunities for transfer learning to generate faster, yet less computationally heavy acoustic simulations.

6 Conclusion

Open-source computational design tools afford distinctly new, adaptable, and integrated ways to augment design intelligence and make codifiable, specialist knowledge and analysis methods more accessible to designers at all stages of the design process. In the context of architectural acoustics, more accessible computational tools such as Pachyderm offer ways for designers and students to explore sound as a design driver rather than a condition to be mitigated during late-stage design development, or worse, remediated during construction or post-occupancy. That the phenomenon of sound should be afforded as much consideration in early-stage design as other measurable environmental conditions, is a position that has underpinned the design studio experiences discussed in this paper. Computational design thinking and methods offer significant opportunities to further support design students and professionals alike in the design of environments *for* sound. But to navigate the hermeneutic gap between data and interpretation, computational acoustic analysis and simulation tools should develop approaches to connect between the embodied experience of sound and its abstraction as particle propagation and ray tracing visualisations, and sound quality indices and data.

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