MODELLING AND OPTIMISATION OF HOLISTIC BUILDING PERFORMANCE

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ABSTRACT

The complexity of modern buildings requires that a significant number of specialised teams are able to collaborate to ensure the success of a building's design. Furthermore, within teams, there is a need to be able to efficiently design aspects and components to conflicting requirements. By performing research within a practising engineering consultancy, the aim is to develop an understanding of how computational methods can be used more effectively to find optimised solutions to multi-objective problems in the early design stages. To explore this, prototype framework using Grasshopper for Rhino is outlined.

INTRODUCTION

Modern buildings are highly complicated structures. There are many often-conflicting constraints in their design, including cost, structural strength and durability, environmental footprint, and comfort. BIM exists in part to help manage the large amount of data, but the complexity and detail that BIM offers does not favour rapid exploration of ideas in the earlier stages of design. In industry, there remains a gap for early-design, multi-objective, multi-disciplinary optimisation tools and frameworks at the intra- and low-level inter-team levels.

This research is being led by an Engineering Doctorate student who is in the advantageous position of performing doctoral level research primarily in an engineering consultancy. The wider aim of this research is to use this experience to assemble the most beneficial of existing tools (Attiaa et al., 2013) and methodologies (Lapinskiene & Martinaitis, 2013) using a Systems-based approach, as discussed by Geyer (2012), into a general framework that will assist consultancies in generating a range of optimised solutions for a given design problem.

DISCUSSION

A prototype framework is being developed (Figure 1) that will allow geometry and construction properties to be defined parametrically, and for an optimisation loop to improve a user-specified range of these parameters. This loop currently supports multi-objective optimisation with scalarisation, and can be adapted to optimise based upon a Pareto analysis, but in order to fully balance the conflicting needs that occur in holistic design, a strategy such as MDO (Multi-Disciplinary Optimisation) is required, as summarised in (Ren et al., 2011). However, because of the requirement to ensure that any solution remains accessible and ultimately time-saving for end users, the focus for the immediate future shall be to employ the simpler system in Figure 1 on a number of projects and studies, and to use learning from this experience to drive the next stage of research.

Grasshopper studies

Grasshopper is a plugin for the Rhino NURBS modelling tool that provides an intuitive, visual way of parametrically defining geometry through graphical programming. It has a wide community developing third-party tools for analysis and creating geometry, including tools which link to existing analysis packages. These benefits have made Grasshopper a prime candidate for applying the framework above. An example of how Grasshopper has been used to optimise simple structures is shown in Figure 2. Arbitrary cost functions were applied to geometry and scalarised to solar gain, and the geometry was optimised to minimise the total cost. A key outcome of this was the challenge of concisely and rapidly defining geometry; a number of components were consequently developed to allow users to quickly define rooms and windows.

To further enhance geometry creation and analysis, a platform-independent geometry DLL has been written in-house at Buro Happold, and links are being made between this library and Grasshopper, and with Dynamo for Revit. The generic nature of this library means that it is relatively simple to create new analysis links with other external programs as required in the future. The components written for Grasshopper as a result of this development have been used on a number of projects, including panel analysis on a major development for

Singapore Changi Airport (Figure 2). These components can be used seamlessly with all other components available in Grasshopper, including the Galapagos optimisation component.

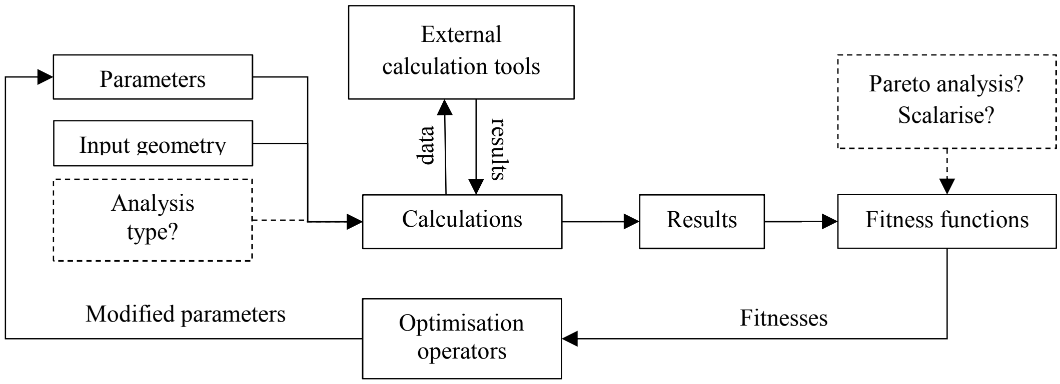

Figure 1A simple optimisation procedure to be used as the basis for current and future work

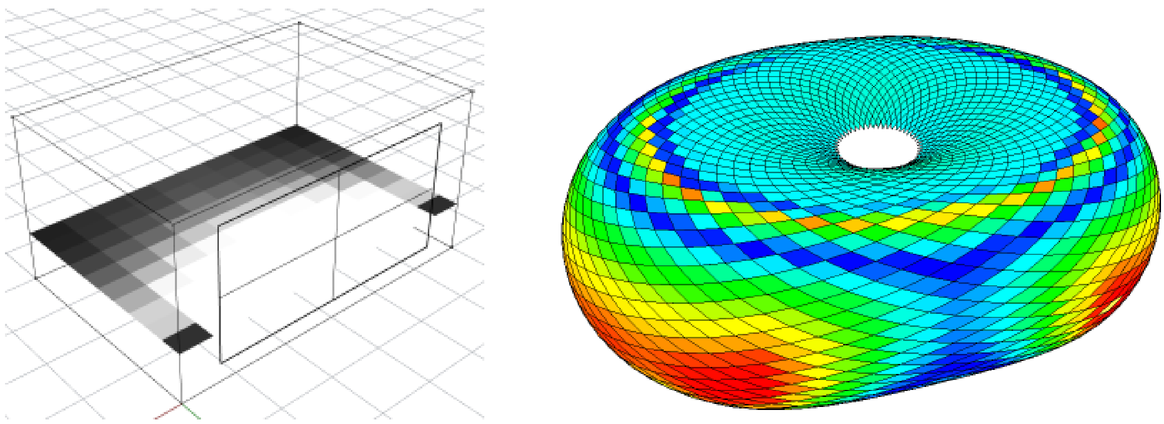

Figure 2 Analysis of parametically defined structures using DIVA daylighting analysis of a room with one window (left) and using in-house software to analyse the grid planarity on a real project (right)

CONCLUSION

A gap has been found in industry in using computational tools and frameworks to assist in the multi-disciplinary design process. An optimisation procedure has been demonstrated and implemented in Grasshopper, and the benefits of this are currently being explored. Future work will include exploring more sophisticated frameworks to handle the conflicting requirements that come with holistic design.

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