Parametric Design

The solution for designing optimal energy-efficient buildings?

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1 Background

During the last three decades, Enerdata, declared that between 1990 and 2017, primary global energy consumption has grown by 38% (Fig.1) and CO2 emissions by 39% (Enerdata, 2018).

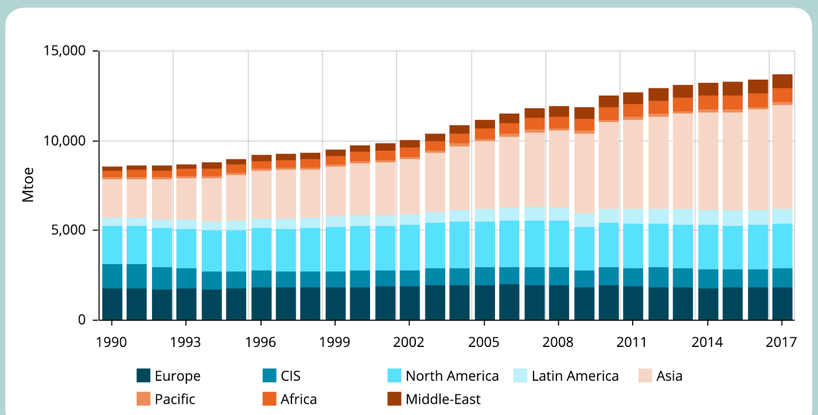

Figure 1. *Total world energy consumption. (Enerdata, 2018)*

In the EU, building energy consumption accounts for over 37% of final energy, bigger than industry (28%) and transport (32%) (Pérez-Lombard, Ortiz and Pout, 2008) and contributes enormously towards the threat of climate change.

Thus, it is paramount to analyse the issues and opportunities in building design methods to reduce this impact and an urgent need for research into integrated performance-oriented methods to assist the designer.

Parametric design has presented itself as a valuable optimisation method for architects in building design. Rather than working on a composition, containing individual objects with no pre-defined relationships, designers can create a computational parametric model based on an articulated internal associative logic (Peters, Peters and Kolsrevic, 2013).

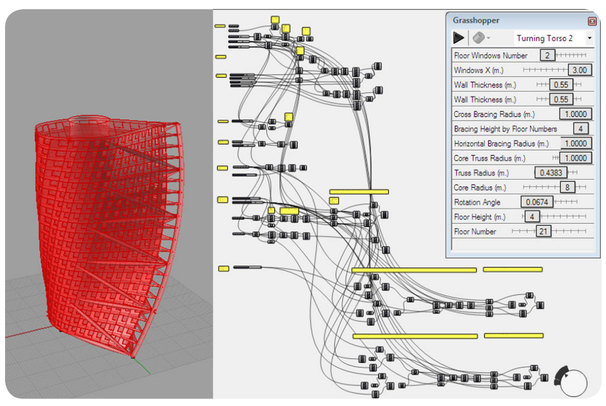

Figure 2. *A Complex Parametric Model, in Grasshopper (Bunteongjit, 2009)*

The parameters of the model are shown on the right of the image. Grasshopper is a popular parametric modelling software.

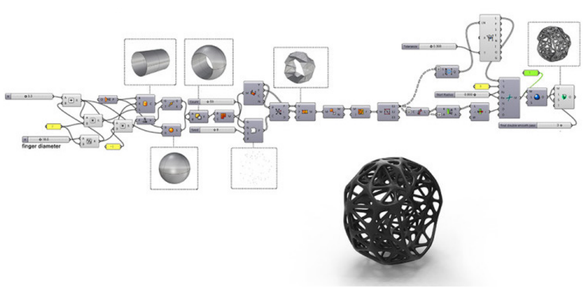

Figure 3. *Evolution of a Parametric Model Shown in the Visual Programming Interface of Grasshopper. (Responsive Design Studio, n.d.)*

Each parameter and shape command is a visual representation of a specific code command.

2 Methodology

The research primarily takes a critical literature-based approach. The critical literature review primarily aims to provide a critical evaluation and interpretive analysis of parametric design literature, intending to reveal strengths and weaknesses in the method and any important issues.

Case studies are integrated into the research to provide a demonstration of what techniques and processes that are discussed in the critical literature review. Two different case studies were chosen, the first one having used parametric design methods; the Al Bahr Towers, located in Abu Dhabi (Fig.4,5,6), the second not; The Terry Thomas building, located in Seattle. The case studies were chosen on the basis that shading was used on the façade to prevent solar gain, the shading devices were dynamic (movable) and that both were LEED (Leadership in Energy and Environmental Design) rated. The chosen parametric case study is the Al Bahr Towers, located in Abu Dhabi.

The aim of the research was to investigate the potential of parametric design for designing more energy-efficient buildings. This was explored through two principle research questions:

- *What are the benefits and limitations of parametric design methods in performance-based design in comparison to conventional methods?*
- *How can parametric design methods aid decision-making in architectural design?*

Literature Cited

Enerdata (2018) World Energy Consumption Statistics. Available at: https://yearbook.enerdata.net/total-energy/world-consumption-statistics.html (Accessed: 21 October 2018).

Pérez-Lombard, L., Ortiz, J. and Pout, C. (2008) 'A review on buildings energy consumption information', Energy and Buildings. Elsevier, 40(3), pp. 394–398. doi: 10.1016/j.enbuild.2007.03.007.

Peters, B., Peters, T. and Kolsrevic, B. (2013) Inside SmartGeometry. 1st edn. Edited by B. Peters and T. Peters. Chichester: John Wiley & Sons Ltd.

3 Results

What are the benefits and limitations of parametric design methods in performance-based design in comparison to conventional methods?

Topological Functionality

One of the key benefits of using parametric design methods that surfaced was its topological functionality to aid in more efficient iterations and faster alternatives with the use of the parameters (Fig.2), without the requirement for extensive low-level modifications needed for a non-parametric model.

Geometrically and Financially Well Defined

The pre-rationalisation parametric approach enables designers to design building components, such as shading panels and curtain wall glass panes, in a coherent and uniform manner. This optimisation process allows the elimination of bespoke manufacturing sizes and thus decreasing costs and construction waste.

Algorithmic Framework

Generative systems (GS), such as evolutionary optimisation algorithms, use the algorithmic control of the topological associative framework of parametric models to manipulate the geometry to create many variants and provide feedback and comparison of design performances to the architect. Designers can consider a much large number of iterations using a GS than a manual conventional method.

Specialist

Parametric computation is more difficult to learn than conventional modelling software and requires more knowledge in software and mathematics than conventional architects may have. Specialist modelling teams are usually present in heavily used parametric modelling firms. This poses a challenge of the difficulty of wide implementation and uptake in standard industry practice.

Greater Complexity

A parametric model largely takes longer and can be more difficult to build than a traditional non-parametric model and may not be necessary for certain projects, particularly smaller ones or types of projects that may not go through many iterations to achieve energy goals.

Figure 4. *The Al Bahr Towers (AHR Global, 2012)*

Figure 5. *Parametrically designed facade (AHR Global, 2012)*

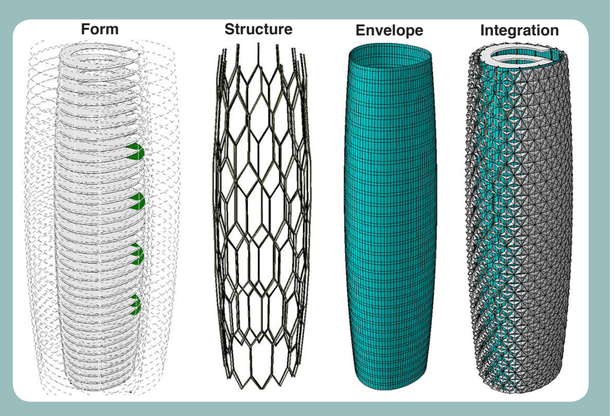

Figure 6. *The Parametric Components of the Towers. (AHR Global, 2012)*

How can parametric design methods aid decision-making in architectural design?

Design exploration

The topological structure of a parametric model, which can be theoretically geometrically manifested in an infinite number of forms, strongly emphasised its potential for performance-based design, as a greater area of the design space could be explored for an optimal solution.

In Depth Understanding

Constructing a parametric model requires breaking down a design problem to its functions, dependencies and object criteria. This emerged as requiring the designer to have a more profound and novel understanding of the overall design goals and its anticipated outcome, which can aid the designer to make better informed decisions.

Communication

Parametric master models, which are used as a simplified base reference model, to coordinate between the architects, consultants and contractors (Fig.6), provides a valuable tool for communication, coordination and allowing decisions between disciplines to become more understood, faster and synchronised.

Workflows and Integration

A significant capability of parametric modelling surfaced as the ability to link its platform with building simulation software, an integration called a *workflow*. A workflow integration of different software to communicate with each other allows the designer to create multiple design instances that can be tested quickly, and more comprehensively compare results to create a more cohesive and effective design process.

4 Conclusion

The key conclusions and benefits of parametric methods found in the research included:

- The topological nature of a parametric model enabled the ease of efficient iterations in the designer process and a valuable tool for rapid testing and feedback
- The computation methodology aided the designer to customise models and create workflows that could also incorporate generative optimisation algorithms
- Using parametric design to optimise façade design was seen as an effective approach to achieve greater energy efficiency
- The method showed a large capacity for design exploration for the designer, allowing a larger number of alternatives to be considered
- The method requires the designer to procure a deeper understanding of the design problem, enabling them to tackle the design problem more comprehensively
- Parametric master models were seen as a valuable aid in communication, coordination and sharing information, assisting in decision-making and bringing closer different disciplines in the design process

Limitations of parametric modelling found included:

- Difficulty of complexity with parametric models
- Potential to sometimes constrain the designer's creativity
- More difficult to implement as greater specialist modelling knowledge may be required

Overall, there is much potential in parametric design modelling methods for designing more energy-efficient buildings. Recommended future research is the focus on developing the usability of parametric software for a quicker and easier implementation in architectural practice.

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