Meta-Parametric Design

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Parametric modelling software often maintains an explicit history of design development in the form of a graph. However, as the graph increases in complexity it quickly becomes inflexible and unsuitable for exploring a wide design space. By contrast, implicit low-level rule systems can offer wide design exploration due to their lack of structure, but often act as black boxes to human observers with only initial conditions and final designs cognisable. In response to these two extremes, the authors propose a new approach called Meta-Parametric Design, combining graph-based parametric modelling with genetic programming. The advantages of this approach are demonstrated using two real case-study projects that widen design exploration whilst maintaining the benefits of a graph representation.

Keywords: parametric design, conceptual design, design cognition, human–computer interaction, genetic programming

In Computer-Aided Architectural Design (CAAD), two distinct approaches have found favour in recent years. The first involves parametric modelling using an explicit visual dataflow program in the form of a graph. Design variations are explored by adjusting input parameters. The second approach concerns implicit methods inspired by complex systems, whereby the process of generation is irreducible to an explicit representation.

Although the latter approach can often offer wide design exploration (Bentley & Kumar, 1999), it is debatable whether implicit bottom-up methods are suitable at the conceptual design stage simply because natural systems develop form in this way. Instead, by acknowledging that humans must converse with machines and each other as part of a healthy digital design process, an alternative approach is proposed that offers wide design exploration whilst retaining an explicit representation of development for human cognition.

1 Parametric modelling

Parametric modelling is now a well-established tool in the computational design community. Software applications such as Generative Components (Bentley Systems), Dynamo (Autodesk) and Grasshopper (McNeel and

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Associates) allow complex ideas to be quickly explored, often beyond the reach of traditional techniques such as hand sketching, physical model making and CAD.

A subset of parametric modelling based on dataflow programming associates parameters and functions to form a Directed Acyclic Graph (DAG). As well as generating a design, the DAG acts as a *cognitive artifact* describing the history of design development and shifting the focus from final form to that of digital process (Oxman, 2006).

1.1 Parametric design exploration

The structure of the DAG governs the design space to be explored when parameters are adjusted (Aish & Woodbury, 2005). A combination of parametric modelling and performance analysis tools allow designs to be evaluated both quantitatively and qualitatively in real-time when adjusting parameters (Shea, Aish, & Gourtovaia, 2005). A typical DAG-based parametric schema is shown in Figure 1. Five numeric parameters (a) are passed through associated functions (b) that generate the design (c). Performance feedback from analysis (d) guides parameter adjustment, either manually or by setting an objective function and using a metaheuristic algorithm (e).

To date, the most popular metaheuristics used in parametric design are evolutionary algorithms, due to their ability to efficiently explore a wide and unknown solution space (Turrin, von Buelow, & Stouffs, 2011). Such tools are becoming increasingly mainstream as little or no programming experience is required to use them. For example, the introduction of the Galapagos Evolutionary Solver for Grasshopper (Rutten, 2013) has increased their popularity in architectural design (Ercan & Elias-Ozkan, 2015).

1.2 Limitations at the concept stage

The conceptual design stage is when the most important decisions are made that will shape the future of a project. It is also the time when least is known about the design constraints and objectives that will co-evolve during design development (Menges, 2012). Even if consistent quantitative design drivers can be identified, there often exist qualitative criteria that cannot be easily defined.

Although a DAG-based parametric model keeps a record of how the building geometry is created, displaying this explicitly comes at a price. As Aish and Woodbury (2005, p. 11) state: 'nothing can be created in a parametric system for which a designer has not explicitly externalised. This runs counter to the often-deliberate cultivation of ambiguity that appears to be part of the healthy design process'. As the DAG becomes ever more complicated, so its flexibility reduces. The graph can quickly resemble a tangle of spaghetti, making it hard to

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