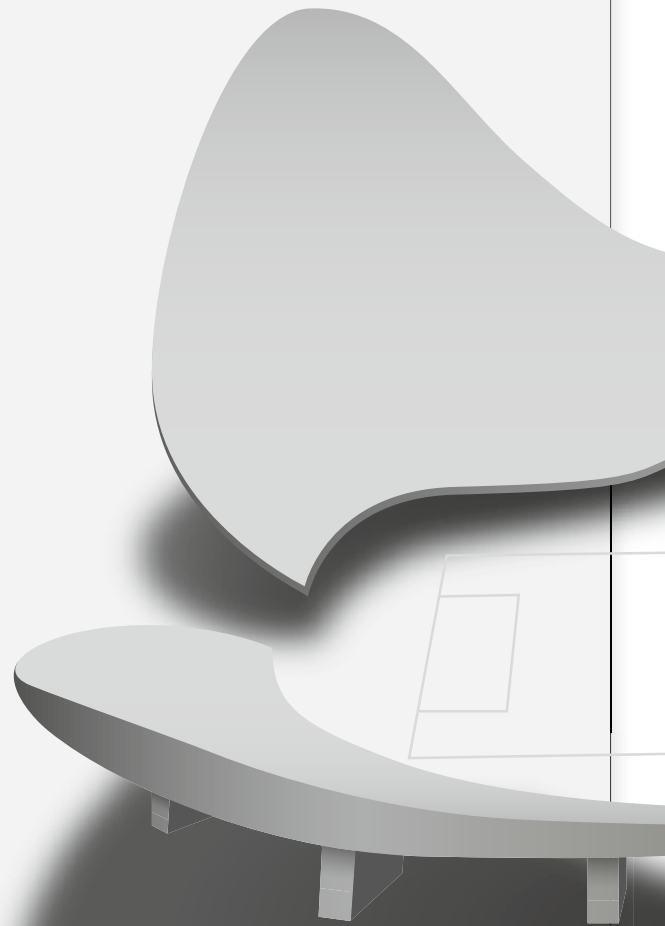# Parametric Computation

History and Future

John Frazer is a pioneer and leader in the field of generative design and evolutionary computation. In the 1970s he developed the world's first microcomputer-based design systems and invented tangible interfaces. Professor at the European Graduate School, he is the author of the seminal book *An Evolutionary Architecture* (1995). Here he traces the history of parametric architecture and discusses how, in its second state, redefined as Parametricism 2.0, Parametricism opens up the possibilities to become more than a matter of generational technique, scripting variational geometry, and a means to addressing wider social and environmental purpose.

Varying parameters, which respond to the iterations of an algorithm, are the basis of computation. This article briefly outlines the history of parametric architecture and shows how 'Parametricism 2.0' now proposes to return to addressing the environmental and social issues for which these powerful generative and evolutionary techniques were originally developed.

When in the mid-20th century computing absorbed the language of variables and parameters from mathematics, it adopted the terminology for programmable algorithms and procedures. The first documented computer programs were written by Ada Lovelace in 1843 for Charles Babbage's proposed analytical engine and were based on his algorithms. These algorithms were based on varying parameters in a series of loops that Ada called 'backing' but were in fact the first uses of loops and conditional jumps.[1] The pioneers of digital design, such as Ivan Sutherland with his 1963 Sketchpad system, developed an essentially parametric system for architectural design.[2] Computer-aided design went on in the 1970s to fully assimilate parametrics, which is thus described now by Mark Burry as the 'sine qua non' of design computation.[3]

Architettura Parametrica

When it came to parametric architecture, the concept and use of the term again predated the feasibility of using actual computational processes, and appears to have originated from the Italian architect Luigi Moretti in the 1940s when he coined the term *'Architettura Parametrica'*.[4] Moretti researched the relationship between architectural design and parametric equations under the banner of 'Architettura Parametrica' between 1940 and 1942,[5] initially without the benefits of computers. However, by 1960, with the aid of a 610 IBM computer, he was able to exhibit models of parametrically designed stadia – *Progetti di strutture per lo sport e lo spettacolo* – at the XII Triennale di Milano.

The earlier work of Antoni Gaudí is also essentially parametric. However, we know this not from his own writings, but due to the painstaking and insightful post-analysis work by Mark Burry that is currently assisting the reconstruction of the intended forms of the Spanish architect's uncompleted Sagrada Família Basilica in Barcelona (see Burry's article on pp 30–35 of this issue). The parametric computation here should perhaps then be credited to Burry rather than to Gaudí. Though there are even earlier examples of parametrically described three-dimensional forms, it would seem that Moretti was probably the first to create three-dimensional architectural form using a complex set of parametric relationships resolved by digital computation.[6]

Luigi Moretti

Model of parametrically designed sports stadium

XII Triennale di Milano

1960

Drawing after Luigi Moretti by CHK Design

Moretti worked on a parametric design process from 1940 onwards and appears to have originated the concept of parametric design as *'Architettura Parametrica'*, which he published before the development of computers. This series of *'Progetti di strutture per lo sport e lo spettacolo'* was realised later when he had access to the necessary computational power and was exhibited at the XII Triennale di Milano in 1960.

Parametric Design Now

Parametric design as now understood is not fundamentally different from the way Moretti described it in the 1940s, but the terminology has changed. A usefully loose definition by Wassim Jabi reads: 'Parametric Design: A process based on algorithmic thinking that enables the expression of parameters and rules that, together, define, encode and clarify the relationship between design intent and design response.'[7]
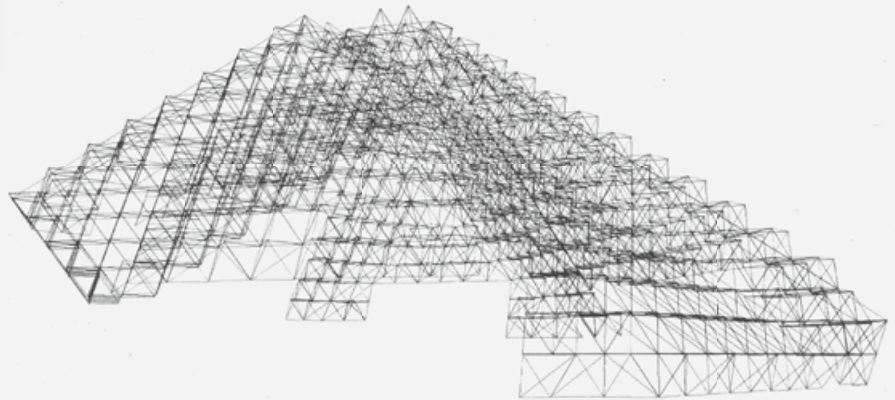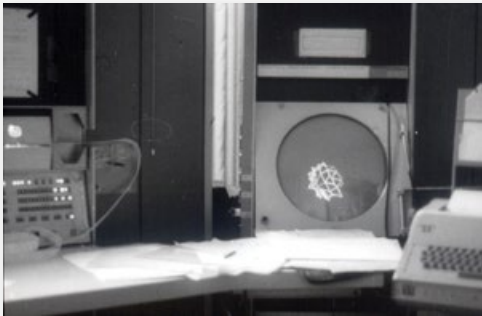
The parametric design process is dependent on a parametric model, and Patrick Janssen differentiates several kinds of parametric modelling techniques – object modelling, associative, dataflow and procedural – that mainly vary in their ability to support iteration.[8] He defines a parametric model as:

> an algorithm that generates models consisting of geometry and attributes (e.g. material definitions). This algorithm uses functions and variables, including both dependent and independent variables. Some of the

independent variables can be given a more prominent status, as the interface to the parametric model – these are referred to as the parameters of the model.[9]

The advantage of this definition is that it leads to an understanding of how different parametric systems can have very different styles, and indeed can be used to define those styles. Consider a classical column that has parameters that define the proportional relationships between the elements of, say, the base, capital and entablature, and the specific dimensions of an instance of the column for a particular application that is controlled by a variable, such as column height. All other dimensions, such as the diameter, are dependent variables and produced automatically from the proportioning rules controlled by the parameters.[10]

Just as changing the parameters of the proportioning rules changes the style of a classical column from Doric to Ionic, so too does the style of, say, a building by Zaha Hadid Architects depend on the parameters controlling the
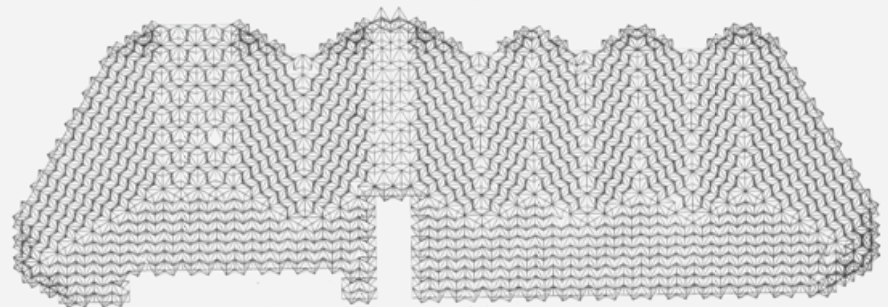

John Frazer

Parametric design program for the Reptile Structural System

Architectural Association (AA) and the University of Cambridge

1969

right (both): Frazer's concept-seeding technique used to develop complex enclosure structures parametrically from a minimal seed of structural units.

above: The parametric design program on-screen in the University of Cambridge Mathematical Laboratory in 1969. A parametrically controlled seed being interactively developed on-screen for the first time, in accordance with Frazer's rules.

relationships between the geometrical elements and the use of iterative generative procedures to control the variables of a specific instantiation. The parameters selected by an architect to define the style and its aesthetics are a very small subset of possible parameters that could be varied, and that selection is what gives that architectural style a particular appearance, perhaps a currently fashionable Baroque curvilinearity. But the selection and definition of a different set of parameters can just as easily lead to a minimalist rectilinear aesthetic, for example. In fact, the use of parametrics as such does not necessarily lead to any style at all, and is just an efficient way of flexibly describing geometry, which led Burry to remark in 2011 that non-parametric design was now inconceivable.[11]

In due course Patrik Schumacher coined the term 'Parametricism' to indicate a stylistic intentionality,[12] and then, more recently, 'Parametricism 2.0' to emphasise a second phase focused on addressing real-world social and environmental problems, which is what the originators of parametrics intended from the outset.
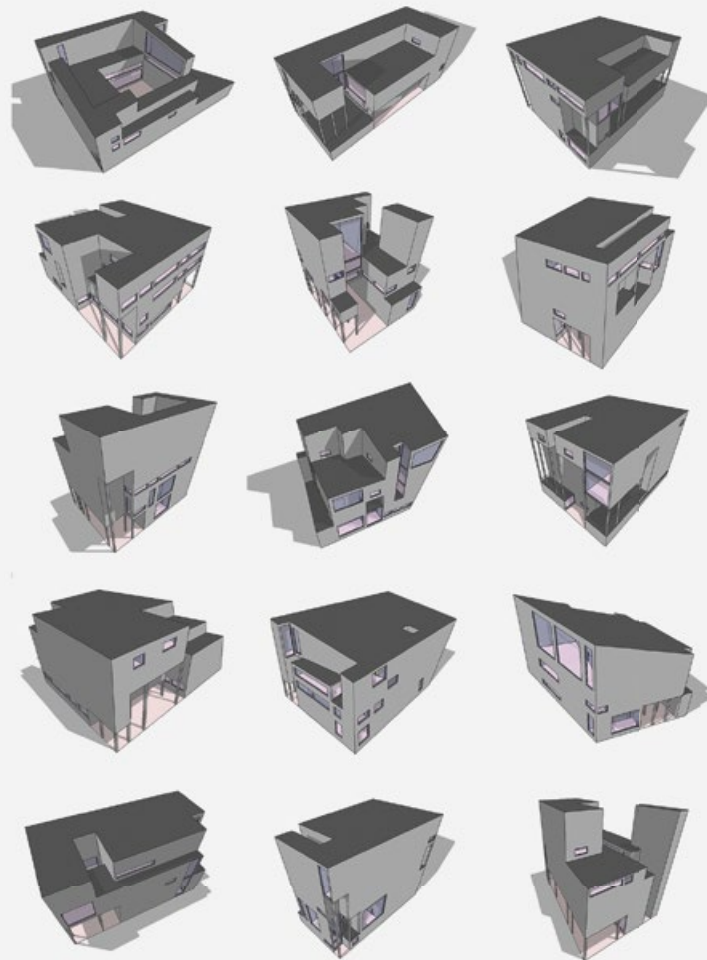
Parametricism

In describing, defining and positioning Parametricism, Schumacher's two volumes on *The Autopoiesis of Architecture*[13] reveal a significant ambivalence and duality of meaning. He describes it both as a style in the visual sense, or 'physiognomy' in his terminology, and also as a process-driven architecture in terms of a method. Firstly he establishes the goal as massively ambitious and all-embracing:

> Parametricism is the great new style after Modernism.[14]

> It is now gearing up to go mainstream to finally succeed Modernism in changing the physiognomy of the global built environment.[15]

He goes on to identify the new style by its visual characteristics:

> There is a strong, global convergence in recent avant-garde architecture that justifies the enunciation of

... the use of parametrics as such does not necessarily lead to any style at all, and is just an efficient way of flexibly describing geometry

A set of generative rules defines a parametric space that includes a wide variety of feasible designs, but at the same time excludes all non-feasible ones.

a new style: Parametricism. Its most conspicuous outward characteristic is a complex and dynamic curvilinearity accentuated by a swarm-like proliferation of continuously differentiated components.[16]

He then refers to the new methods:

Beyond such obvious surface features one can identify a series of new concepts and methods that are so different from the repertoire of both traditional and modern architecture that one is justified in speaking of the emergence of a new paradigm within architecture. New design tools play a crucial part in making this possible, establishing a whole new design process and methodology. … Parametricism is thus dependent on the adoption of sophisticated computational techniques. However as a style rather than as a mere panoply of new techniques, Parametricism is characterised by its new distinctive values and sensibilities that started to emerge even before the computational methods were ready to hand.[17]
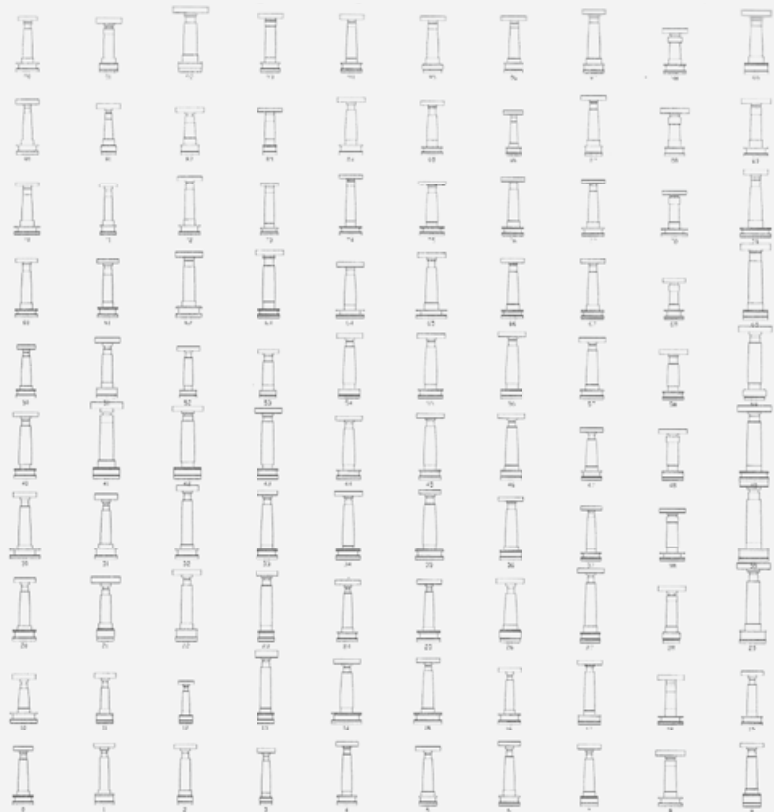
And finally he writes: 'An architectural style is a coherent and comprehensive (research) programme, complete with both a functional and a formal heuristic.'[18]

Schumacher's *Autopoiesis* books thus clearly embrace process and research as essential elements of a style in the visual sense of the word (although that meaning is strongly embraced too).

Adding Power to Parametrics

Parametric functions in software allow for variable geometries, but do not in themselves drive the generation of form. To build a morphogenetic generative system, further elements are required, which though frequently thought of as associated with parametrics, are not essentially part of it nor indeed usually encoded within the parametric graphics system. These are a generative engine, selection procedure, learning algorithm and a complete design system from inception to development, optimisation and resolution. Such a complete and mature system is typified by my 'Evolutionary Digital Design Method' and described in *An Evolutionary Architecture* (1995).[19]

But we have much further to go yet. Architecture does not address trivial problems, so a computer program of sufficient complexity to play an active role in building design needs to learn skills far beyond the knowledge and experience of the programmer. We are currently still using algorithmic procedures despite the fact that architectural design is obviously not an algorithmic process. This does not mean that algorithms are not useful, just that scripting is simply not enough to address anything more than variational geometry: 'If all we have achieved is to replace drawing with typing then we have achieved nothing!'.[20] However, I believe scripting is now finished and that entirely new environments and media for design will soon be available that employ far more powerful techniques than have yet been tried outside of the research lab.[21]

John Frazer and Peter Graham

Evolving a Tuscan column using the parametric rules of James Gibbs (1732) and genetic algorithms

Ulster University

Belfast

1990

A population of 100 columns at generation 6 in the evolution of the proportions of the column controlled by the rules of Gibbs with a genetic algorithm controlling the variations.
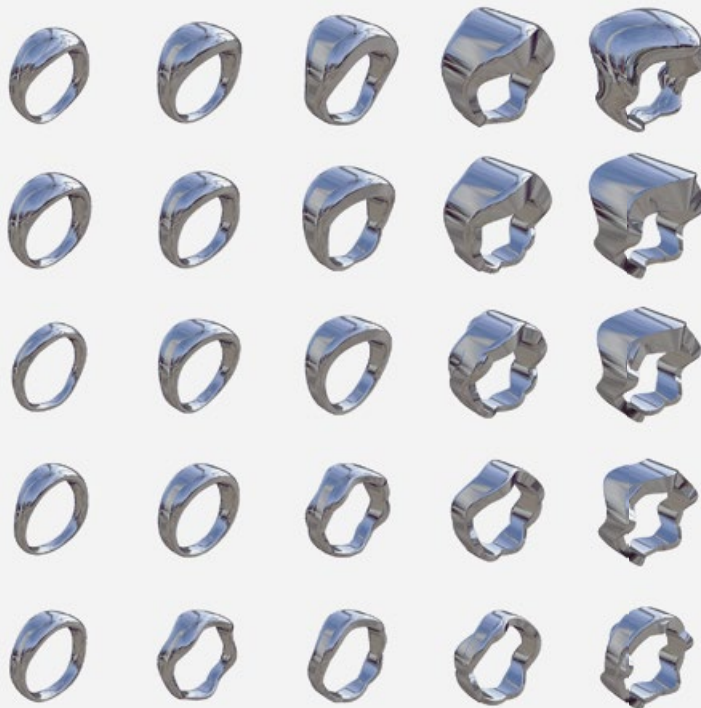
Parametricism Redefined

Parametricism is demonstrably moving to redefine itself as a process – a rapidly developing one that embraces new technologies and social and environmental purpose. Earlier works with a particular aesthetic will come to be understood as explorations and feasibility studies under the narrower definition of style, to achieve clarity of differentiation from other styles and approaches, and to test whether the computer techniques of the time were workable and contractors could cope with the new demands of working purely from a digital model. Thus Parametricism (1.0) will soon be re-described as the testing phase, and Parametricism 2.0 will move on to apply powerful computational techniques to real and pressing social and environmental problems.

Or in Moretti's words:

> In this way what I have long solicited and call 'parametric architecture' will be born. Its ineluctable geometric character, its rigorous concatenation of forms, the absolute freedom of fantasy that will spring up in places where equations cannot fix their own roots, will give it a crystalline splendour.[22]

Parametric architecture 'opens for future architecture a whole world of new and revolutionary forms; a new human behaviour of the highest dignity.'[23] △

Notes

1. Michelle Lane, 'Recovering Ada: Finding Our Way Home Through Sensuous Correspondence', unpublished Master's thesis, European Graduate School, 2015. See also Luigi Federico Menabrea, *Sketch of the Analytical Engine invented by Charles Babbage*, translated and appended with additional notes by Augusta Ada, Countess of Lovelace. Richard & John Taylor (London), 1843.
2. Robert Woodbury, *Elements of Parametric Design*, Routledge (London and New York), 2010.
3. Mark Burry, *Scripting Cultures*, John Wiley & Sons (Chichester), 2011, p 18.
4. Federico Bucci and Marco Mulazzani, *Luigi Moretti: Works and Writings*, Princeton Architectural Press (New York), 2002.
5. Luigi Moretti, 'Struttura come forma', *Spazio*, 3 (6), December 1951–April 1952.
6. Daniel Davis, 'A History of Parametric', 6 August 2013: www.danieldavis.com/a-history-of-parametric/.
7. Wassim Jabi, *Parametric Design for Architecture*, Laurence King (London), 2013, p 201.
8. Patrick Janssen and Rudi Stouffs, 'Types of Parametric Modelling', *Proceedings of the 20th International Conference of the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA)*, Daegu, South Korea, 2015, pp 157–66.
9. Patrick Janssen, personal communication to the author, 9 July 2015.
10. Peter Graham, 'The Application of Rule-based Techniques in Computer Aided Design', doctorate thesis supervised by John Frazer, University of Ulster, 1996.
11. Mark Burry, *op cit*, p 18.
12. Patrik Schumacher, 'Parametricism as Style – Parametricist Manifesto', presented and discussed at the Dark Side Club, 11th Architecture Biennale, Venice, 2008: www.patrikschumacher.com/Texts/Parametricism%20as%20Style.htm.
13. Patrik Schumacher, *The Autopoiesis of Architecture, Vol I: A New Framework for Architecture* and *Vol II: A New Agenda for Architecture*, John Wiley & Sons (Chichester), 2011 and 2012.
14. *Ibid*, Vol II, p 617.
15. *Ibid*, Vol II, p 619.
16. *Ibid*, Vol II, p 617.
17. *Ibid*, Vol II, p 617.
18. *Ibid*, Vol II, p 244.
19. John Frazer, 'Creative Design and the Generative Evolutionary Paradigm', in Peter J Bentley and David W Corne, *Creative Evolutionary Systems*, Morgan Kaufmann (San Francisco, CA), 2002, pp 253–74, and John Frazer, *An Evolutionary Architecture*, Architectural Association (London), 1995.
20. John Frazer, as quoted in Mark Burry, *op cit*, p 64.
21. For example the work of the John and Julia Frazer Foundation is developing new environments and media for architectural creativity.
22. Moretti, *op cit*.
23. Luigi Moretti, 'Ricerca matematica in architettura e urbabanisica', *Moebius: unità della cultura: architettura, urbanistica, arte*, IV, 1, 1971, pp 30–53.

Thomas Fischer and Christiane Herr

Parametric jewellery design and fabrication system

proposed demonstration for a future exhibition

2015

Computer renderings of ring shapes generated using the parametric jewellery design and fabrication system. Eighteen physical sliders in the exhibition would control the parameters to produce a wide variety of shapes while maintaining control of the design aesthetic.