Organising complexity: a reflection on parametric design

Ángel J. Fernández-Álvarez

Departamento de Expresión Gráfica Arquitectónica, Universidad de A Coruña, Galicia, Spain.
angel.fernandez.alvarez@udc.es

Abstract. This paper reflects on the role of parametric design in architecture carried out with digital tools.
The digital revolution has profoundly altered the architectural discourse by introducing debates on theory and design that are based on ideas arising from the intersection between art, science and technology.
Parametric design has become a powerful tool for organising complexity and this creates the need for critical reflection on its current and future influence on architectural projects.
The mechanisms for bringing together the information processing power of computers and the intuitive skills of designers poses new challenges that require the inclusion of computational thinking in the training of future professionals.
A redefinition of the relationships between architecture, the digital technologies and production and manufacturing techniques is needed so that we can have intelligent design thinking that allows us to properly organise the complexity of the activity involved in the architectural project.

Keywords: Digital architecture, Parametric design, Complexity.

1 Introduction

Architectural discourse has been profoundly altered by the so-called "digital revolution" and simultaneously we are seeing new debates arising in relation to theory and design that are based on ideas coming from the intersection between art, science and technology.

The success and growth of parametric and algorithmic design techniques and strategies (Terzidis, 2006; Sakamoto and Ferré, 2008; Jabi, 2013; Aiello, 2014) has led to an identity crisis for the discipline and new considerations regarding the authorship of architectural works.

This situation provokes the need for critical reflection on the role of parametric design in the practice of architecture carried out with digital tools.

2 Towards generative and relational design

As a design tool or strategy, parametricism defines relationships between elements by assigning values in order to organise and control complexity, so its underlying principles are connectivity and interrelation (Dunn, 2012). It is a relational design methodology based on the consideration of systems instead of objects. The designer in some way becomes an "editor" of relations between the different elements and later selects the results obtained based on different criteria that can be linked to aesthetics, functionality, finance, interaction, etc.

The parametric approach was one of the first operational concepts in the field of computer-aided design. In 1963, Ivan Sutherland proposed the first graphic user interface in his famous doctoral thesis: Sketchpad: A Man-machine Graphical Communications System. This system allowed him to draw with the computer and, at the same time, apply changes to the design parametrically. Sutherland himself pointed out the possibility of establishing a kind of "conversation" between the user and the computer through the use of graphic information, as opposed to communication through written instructions as had been carried out previously.

The use of code languages and scripting techniques (Reas et al., 2010) has become a very important project tool that uses construction modelling, geometric programming, structural optimisation, environmental simulation, genetic algorithms and digital manufacturing techniques (García Alvarado, 2013). The potential of software and the power of hardware make it possible to explore design alternatives very rapidly, while progress in digital manufacturing tools allow us to switch from conventional artisanal and industrial models to a new digital model in which variations can be made at no extra cost.

What Patrik Schumacher in his 2008 manifesto calls a "sense of organised complexity" is in addition to the strong emphasis on differentiation. The complexity of the project is addressed in a similar way to the strategies developed by natural systems, the final form being the result of the interaction between forces according to pre-established laws (Schumacher, 2008). So, in contrast to the modern mechanistic concept of space, parametricism considers the notion of "field" with the dynamic vision of a changing reality based on trends, flows and gradients in which variation and deformation are regarded as organised information structures.

The multidisciplinary nature inherent to parametric design adds great flexibility to the design process and transforms it into a collective and collaborative task that calls into question the role of authorship in the architectural design process. The designer goes from being the creator/generator of the form to becoming the editor/programmer of the processes and systems, with the task of defining some initial starting conditions and creatively selecting an appropriate end result (Fernández-Álvarez, 2014).

One key aspect is precisely the need to define existing relationships through the use of formal notations that require the designer to have some experience, but that also offer the advantage of quickly being able to explore new solutions with great freedom and a certain amount of randomness.

In this context, the parametric tool may be seen more as a production system than a representational construct and, although some consider it to be a true style (Schumacher, 2009), others consider it simply to be a design methodology. In reality, Schumacher provides a style idea as a "design and research program" following methodological criteria taken from Imre Lakatos' theories of the philosophy of science and also strongly taking into account the communicative dimension of architecture.

In contrast to the widespread idea of programmed automation, parametric design implies an intentionality, a user-defined logic that transforms into a conscious digital design. This logic lies in the ability to achieve a suitable definition of the problem through an abstract diagram and its correct mathematical description. The resolution of complex projects is where the parametric tool allows the integration of multiple variables and the realisation of successive iterations that allow us to obtain versions that evolve towards the most suitable solution, in a shorter time and without losing the previous modifications.

In contrast to the primacy of visualisation in conventional design methods, parametricism involves the proper definition of a system of relations, the parametric software being responsible for the graphic results of each proposal. This situation, in which the planner becomes the designer of systems and processes, had already been foreseen in the era of the pioneers of digital in architecture, such as Gordon Pask when he proposed the idea that "design is control of control" (Pask, 1969).

Finally, we must also consider the capacity offered by the new tools to mediate with the tectonic, establishing a link between information and matter. The processes involved in searching for form are structured around three principles (Oxman and Oxman, 2014): the differentiation processes characteristic of natural systems, [in]formed or integrated tectonics and continuity from the design phase through to the production phase by including the logic of the material in the parametric approach.

3 Towards design intelligence

The possibility of reusing code modules, the concept of "open work" that allows for collective and participatory knowledge strategies, a conceptual change from the object to the process and the exploration of the unexpected, caused by the introduction of randomness, make parametric design a powerful tool for organising complexity with a huge current and future influence on architecture projects and the configuration of an intelligent design thinking.

Immersed in what some call a "post-digital" era or what Mario Carpo has described as the "Second Digital Turn", there is a need for critical reflection on the phenomenon that goes beyond the mere academic review of technological tools, always in continuous evolution. These have become true tools for "thinking" rather than tools for "making" (Carpo, 2017).

From the viewpoint of theoretical criticism, it is also necessary to highlight the importance of cultural approaches to the problem from a cross-cutting and multidisciplinary perspective in order to take into consideration the social, ethical, political and philosophical implications that any technology involves. The popularisation of parametric generative systems (Agkathidis, 2016) allows us to contemplate digital design, process and production technologies not only as tools but also as ways of thinking. Computational thinking (Wing, 2006), intelligent digital design or design intelligence become emerging ideas, offering new ways of seeing, thinking and doing architecture.

In terms of existing examples, we can think about the introduction of cybernetic theory into architecture during the 1960s and 1970s, when we had the curious situation of advanced digital thinking but without the technological infrastructure required to implement it, proving once again that ideas are what are truly innovative and disruptive, rather than technologies.

The dissemination and democratisation of parametric design and BIM methodologies have contributed to the development of a growing trend towards the consideration of what is known as "computational design", consisting of the development of a certain mental model that allows us to organise thinking in architectural design processes developed with digital tools. According to the definition by Jeannette Wing (2011), "computational thinking" consists of "the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent".

This involves developing skills that allow us to harness the power of computing for the study, analysis and resolution of complex problems. To do this, it is necessary to rely on the profound knowledge of the underlying principles behind the different tools rather than on practical training in the use of the different commands for the software programs. As stated by Senske (2011), the transfer of knowledge is one of the hallmarks of this type of approach to design problems, as it promotes the application of that knowledge outside of its own learning contexts.

Senske deems it a priority to consider this transfer as an objective in the educational programmes of schools of architecture and for this he suggests three basic conditions in the digital training of future professionals: taking different contexts of using software into consideration, promoting self-discovery (perfectly compatible with the well-known phenomenon of self-learning linked to these technologies) and introducing meta-cognitive approaches that allow for an active learning experience. This is intended to highlight the computational aspects of design so that students understand the internal processes that underlie the creation of forms through parametric strategies. To do this, the writing of code is enhanced through scripting languages such as Processing or Python and the generation of compositional rules following the logic of algorithmic design. Programming skills allow designers to interact with other media, thereby expanding the repertoire of operational tools that can be used in a project.

The ultimate goal is to achieve a conscious and flexible use of digital design, overcoming the limitations of simply giving training in the routine use of different programs. The aim is to ensure that the concepts of computational thinking can be applied to any type of software and their different technological evolutions and new versions. This same issue had already been raised by Stan Allen (2005) when he advocated "a relaxed, pragmatic, inventive and direct approach" to digital technologies, emphasising the need to promote the user's digital "astuteness" that, when "moving beyond the logics of visualisation", would allow new design potentials to be found.

4 Towards a new concept of authorship

The simplifying term "digital revolution" is now referred to as more of a "digital turn", an expression that suggests the idea of introducing digital technology into architectural design processes that began at the beginning of the 1990s and still continues today. In the initial phase, which we can call the phase of the "pioneers", the possibility of an electronic space as an alternative to the physical space was even considered, in which bits would take the place of the traditional materials with which, until that time, architecture had been built (bits not bricks).

As outlined above, the emergence of a new generation of 3D modelling software along with the progressive evolution of hardware power has led to significant changes in the way we use computer tools to design and produce architecture. For Dunn (2012), the role of the computer branches off in two directions. First, it has the function of improving productivity by becoming an advanced tool for designing complex forms and a powerful interface for the proper visualisation of the design processes. Second, it offers the chance to manipulate and work in the very core of the act of devising through programming using scripts and algorithms.

Terzidis (2006) distinguishes between "computerization" (which relates to the first option) and "computation" (more linked to the second). It is in this second area where we see more than the mere digital interpretation of the ideas in the planner's mind, by transferring the designer's intentions to the algorithmic process but taking advantage of the machine's capabilities to explore and offer a set of alternative new solutions.

It should be noted that the key lies in obtaining a generic, open and parametric notation that faithfully reflects the conditions of the process. However, this working method raises the possibility that ownership may be shared by the different agents participating in the design process: architects, owners, builders, manufacturers, users, etc. To this we need to add the potential possibilities for the materialisation of the design provided by the new 3D manufacturing technologies, together with the introduction of concepts taken from the theory of systems and the sciences of complexity (energy considerations, fractals, indetermination, chaos theory, fuzzy logic, emergency, non-linearity, etc.), which adapt perfectly to the way computers work.

It is also worth highlighting the impact of what could be called a symbolised "participatory turn" on the advances of Web 2.0 and 3.0 (semantic web), which allows us to go beyond the limited zoning of traditional spaces. The new technological developments facilitate hybridisations and interactions between physical and virtual spaces with user participation in the configuration of "augmented" spaces. These open up the possibility of introducing human experience and communication into a real-time performative design process.

The philosophy of free software and the possibilities of collaborative working offered by the Internet also open up the path towards a hypothetical open source architecture, with designs that can be freely downloaded and edited. This basic idea is reflected in Alastair Parvin's WikiHouse project, whose objective is the democratisation of building at the same time as, through simplification, also pursuing sustainability principles.

The utopian idea of architecture with a Creative Commons licence is based on the creation of libraries of digital models that can be downloaded, manufactured and assembled in a simple and low-cost way, adapting to the needs of the users. This concept of "participatory authorship", somehow implicit in the development of the BIM methodology and in the implementation of parametric strategies, calls into question the authorship model that has been a feature of the discipline since the Renaissance era. This is at a time when the dominant trend is moving towards the adoption of collaborative strategies.

As stated by Carpo, we are entering a "post-digital" or a "second digital turn" phase characterised by the consolidation of the use of digital tools in design practice, by a moving of the boundaries between previously very clearly defined disciplines and that now see their boundaries becoming more blurred, promoting multidisciplinary hybridisations and actions that become characteristic elements of the new situation.

In these trends we can see the influence of what is happening in the field of artistic experimentation, with a much more dynamic and innovative model of reflection and research that provides innovative and disruptive ideas and cutting-edge architectural concepts. Concepts therefore emerge that characterise post-digital aesthetics such as, for example, the "bastardisation" of technology advocated by John Richards, researcher in digital electronic music. This consists of "forcing a system in to a state in which it was never intended, or appropriating something for a use other than what it was initially designed for" (Richards, 2006).

Along with experience from the world of art, it is worth highlighting the influence of the DIY (Do It Yourself) postulates that characterise the most advanced and experimental architecture and that support a relaxed and free use of software based on the reuse of code and also of physical objects in a contemporary recovery of the concept of "ready-made".

It is this notion of "digital DIY", linked to the idea of heterogeneity, which in some way characterises the "post-digital" concept. Permanence, change, integration and separation coexist simultaneously with the valuing of uncertainty, indeterminacy and ambiguity, aspects that can only be properly described with the communicative metaphors from the abstract logic underlying the digital world. This gives rise to such interesting suggestions as experimentation with a so-called "aesthetics of error". This takes advantage of technological failures which it uses as inputs for exploring new design possibilities, freely and without prejudice expanding the conventional functions and uses of the software (Cascone, 2000).

The concept of authorship becomes a key aspect in the theoretical reflection on digital architecture. Mass customisation, which contrasts with the standardisation advocated by modernity, and digital variability at no extra cost link the current situation to the artisanal model that existed prior to the Industrial Revolution, suggesting a new paradigm of "digital craftsmanship". This links to the ideas of the Maker Movement based on the participation and democratisation of production and design (Anderson, 2012). This situation may lead to resistance in the discipline of architecture, characterised as it is by a "strong" authorship concept and with a strict sense of control of the processes. Distributed authorship, made possible by the new design tools and strategies, represents a break from the tradition of separating the design and the material realisation of the project, and therefore with the concept of individual authorship developed in the era of Renaissance humanism (Carpo, 2011).

For Carpo, a new type of "authorship" is created which he classifies as "generic" (Carpo, 2009). This connects, for example, with the way of working in the great works of medieval Gothic architecture. However, this apparent pre-modern optimism is marred by a negative vision of the resistance that may appear to these new forms of "diffuse" authorship, calling into question the very definition of the discipline's professional framework that has existed since it first appeared in the 15th century.

5 Conclusions

All of the foregoing means that we are seeing a disciplinary crisis of unpredictable consequences as a result of the idea, frightening from the perspective of the humanist paradigm, that the end product of the design process is no longer preconceived in the mind of the designer but is instead obtained through a complex collaboration mechanism involving the information processing power of computers and the naive and intuitive skill of the designer.

This threat to the traditional idea of authorship leaves us in a difficult place, halfway between disruption and nostalgia (Picon, 2017), which requires urgent theoretical and critical reflection and new approaches to the design of academic courses so that they include computational thinking in the training of designers.

The new teaching plans should introduce strategies and principles from computer science in order to consciously apply them to the analysis and resolution of complex design problems while promoting the transfer of knowledge between various contexts (Senske, 2011).

Together with parametric and generative design, the constant advances and developments in the fields of Artificial Intelligence, Machine Learning and Big Data, and the consequent emergence of applications linked to architectural design, will lead to new and exciting challenges that must be faced with realism and determination. The final objective is an ambitious redefinition of the relationship existing between architecture, the digital technologies and production and manufacturing techniques. This is required in order to create intelligent design thinking that allows us to properly organise the complexity of the activity involved in the architectural project.

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Author Biography

Ángel J. Fernández-Álvarez. He is a graduate in Building Engineering and has a Bachelor of Humanities and a Doctorate from the University of A Coruña (Theory and Representation of Architecture). He is a faculty member of the Department of Architectural Graphic Expression at the UDC and coordinator and lecturer for the courses "Descriptive Geometry" and "Technical Projects" in the Degree in Technical Architecture and for the courses "Advanced Technologies in Graphic Representation in Building", "Advanced Information Management in Building: SIG and BIM" and "Smart Cities. Emerging technologies for sustainable cities" in the programme for the Master in Sustainable Building at the UDC. His areas of research include the analysis of the influence of the ICTs on the representation of architecture and the design of space, as well as the relationships and hybridisations between art, science, technology and architecture. He has specialised in the critical study of Digital Architecture. He has written several articles and presented papers at conferences on Architectural Graphic Expression and the ICTs.