Parametric Strategies in an Architectural Design Workshop

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Abstract. Digital instruments are among the means of production of architecture. This improved productivity and reduced errors and inaccuracies in architectural design; however, in the case of parametric design, there is the risk of mistaking tools that may improve the overall quality of architecture for an approach that, as intrinsically scientific, guarantees quality architecture. This misunderstanding may characterise students' first experience with parametric modelling. Therefore, a workshop has been developed as a seed to unfold the formal potentiality of parametric modelling with limited methodological bias and to inform on what to expect from parametric modelling. The workshop results show a preference for some parametric strategies over others. This tendency can be linked to those morphologies that, due to collective bias, are perceived as parametric; Consequently, the importance of working simultaneously on technical competence and cultural aspects of parametric architecture emerges as a necessity.

Keywords: Architecture, Architectural Design, Architectural Design Education, CAAD, Parametric Design

1 Introduction

Parametric architecture, in its contemporary conception, is based on the design of a "*field*" of architectural solutions. This field of solutions consists of branches of possible outputs obtainable from the execution of a procedure, which has historically taken the form of algorithms, programming codes, physical models, textual instructions and more. The use of these procedures has broadened the formal and methodological horizons of the architectural project, which today can absorb, through the parametric tools, the innovations of multiple disciplines. This paradigm shift is, therefore, a profound change in the tools of architectural design, as well as in its results.

An architect's approach to the tools of parametric architecture may present various difficulties on didactic levels (Celani & Verzola, 2012), especially concerning Information Technology skills. But it is also necessary to recognise how the ability of parametric architecture to produce iconic forms often overshadows, from a student's perspective, cultural aspects and methodological implications of its tools.

Aspects such as how parametric architecture tools are implemented in a complex design process (Cichocka et al., 2017) and a designer's actual expectations from these tools (Bradner et al., 2014) suggest the importance of possessing a solid cultural framework along with technical skills. For these reasons, a workshop has been proposed that, in its didactic construction, aims to build design skills that may be transferred to processes that are not parametric: concepts such as "*thinking with abstraction*", "*thinking mathematically*" and "*thinking algorithmically*", already defined by Robert Woodbury (2010, 30-34), are considered more important than instrumental skills given the limited time of the workshop. The latter ones are, in fact, effective only over a limited time horizon as the software for architecture is constantly evolving.

1.1 Digital Technologies in the Italian Culture of Architectural Design

The didactic construction of the workshop, being framed in the Italian academic context, was also an opportunity to reflect on the "*Italian measure*" of relating to the most modern digital technologies, in the didactic and design fields.

Franco Purini (2008, 79) already refers to the duality between the "*ancients*" and the "*moderns"* to outline two architecture's ways of relating with digital culture in the Italian context. For the *ancients,* digital tools do not update the eternal condition of architectural composition but merely decline it differently, adding new design themes and impoverishing others. The *ancients* show a detached interest in the digital world, which leads to reducing it to a project's instruments, or, in more radical positions, developing an aversion to the digital dimension. For the *moderns*, on the other hand, digital can be the place where architectural design's ideas arise; this can lead to total freedom of formal invention, in which Information Technology offers research tools capable of revealing new imaginaries for architecture. But these new aesthetic imaginaries have always been hounded by questions about their relationship with the constructive aspects of architectural form.

This duality can be framed in a more general spirit of distrust of Italian architecture towards innovations, which leads to a delay in absorbing the characters of these innovations. This delay, however, has often made it possible to observe the aftermath and grasp the essence of various transformations.

Furthermore, it emerges that the duality between *ancients* and *moderns* in Italian architecture appears as a cultural issue rather than a generational one.

Despite some brilliant intuitions, such as Luigi Moretti's (1960) ethical and scientific conception of *Parametric Architecture,* Italian architecture has therefore assumed the position of an attentive observer capable of distilling aesthetic, formal, and methodological themes starting from technique innovations offered by international and interdisciplinary research. Franco Purini (2008, 53) suggests how, in the *Italian measure*, we tend to recognise the technique as an instrument but not as a "*privileged theoretical and operational place*". This has led to a certain decline and marginalisation of the technical aspects in the Italian culture of architectural design. The consequences of this are the impoverishment of some frontiers of architectural research. Further, this impoverishment can also be recorded for digital culture if its technical dimension is recognised.

The research of possible didactic approaches to parametric design in condensed workshops discussed below confirms the fear of exaltation of the technique. These workshops intend to stem potential formal drifts through a consistent theoretical dimension and they identify in a design activity the synthesis of the interdisciplinary knowledge learned.

1.2 Examples of Didactic Approaches to Parametric Design

The first approach to parametric design may be driven by a naïve fascination with architectural form. To avoid that, the paradigm of "analogue computation" is proposed in several workshops. Analogue computation consists of associating a physical proto-model with digital procedural modelling. This type of didactic approach is attentive to form, which can be explored thanks to the physical proto-model, but also it leads to associate a clear tectonic dimension to the design. This follows the research and optimisation processes of shape-resistant architectures in which, for various authors, the "seed" of parametric architecture is contained (Canestrino, 2021a).

The series of workshops collected in *Parametrico Nostrano* (Corbellini & Morassi, 2013) shows different variations of the relationship between digital and analogue in the teaching of parametric design: *PaperFields* by Studio AION and *Infrastrutture Urbane Fibrose* by ecoLogicStudio search for complex forms starting from the concatenation of simple elementary operations guided by physical proto-models; *Data Playground* by Co-de-iT moves away from the analogue dimension, but operates an interesting didactic breakdown of the digital code, pushing to design in terms of genotype and phenotype; *Allucinosi Da Simulazione* by Disguincio&co introduces the theme of "partial control", in which the design process is deterministic, but at the same time it is also a black-box given its complexity.

These workshops also suggest a reflection of the teaching of parametric design in the Italian context: if it is "*at the centre of teaching in the major international schools and in the most advanced design practices*", in Italy it instead faces "*an opposed, viral, almost clandestine diffusion*" (Corbellini & Morassi, 2013).

A further didactic proposal, in which the role of the project is fundamental, is that of *How Virtual Becomes Real* by Alberto Pugnale (2021): the irreverent forms that can be generated by parametric design are here tamed by the introduction of compositional, constructive, and structural principles that guide the research of the architectural morphology. Also in this case, specific design and technical themes accompany the didactic introduction to parametric design.

2 Methods

The objectives of the workshop, its temporal characteristics, the topics covered, the expected project output, and how students were guided towards it are described below.

The workshop is an extra activity of the course “Architecture and Architectural Composition 3” (Architectural Design) at University of Calabria intended for students in “Building Engineering-Architecture” on their last architectural design experience before graduation. Due to their educational curriculum, these students have limited knowledge of computer programming, consistent with the typical training of an Italian Architect. For this reason, visual programming is identified as an accessible coding tool (Celani & Verzola, 2012) capable of being representative of the possibilities of the parametric approach without excessive effort towards the IT tools; the workshop is therefore based on the use of Grasshopper and Rhinoceros.

A total of 42 students divided into 16 groups took part in the workshop. The workshop is comprised of a total of 14 hours, spread over a week of courses, in which about half the time was dedicated to those already-mentioned theoretical and cultural aspects of the parametric approach.

2.1 Workshop’s Theme

The theme of the workshop seeks a balance between morphological, functional and IT complexity. Interesting topics, such as form-finding, space-syntax or shape grammar are not addressed as they require important theoretical insights to allow a student an architectural synthesis capable of conveying the cultural aspects of the parametric approach.

A design theme different from an entire building is therefore sought because it could not reach a mature level of synthesis in the time of the workshop. The architectural envelope is identified as an element of the architectural project capable of being representative of its formal, technical, and symbolic values, as well as a typical field of application of parametric design. To contain the aforementioned complexity, it is proposed to design a portion of the envelope measuring 3 meters by 1 meter. The dimensions of this portion, which for many groups has taken the name of “panel”, are the only constraint imposed: the orientation of the panel in space, its materials, its production and construction

technology, its morphological relationship with other panels and with the building have not been imposed. The design choices of those characteristics are left to the students also to develop a greater awareness of the relation between technology and architectural form.

The fascination of the architectural form is limited by some indications on the requirements of the portion of the envelope being designed. In addition to the traditional requirement framework for an architectural envelope, which refers to aspects such as the shielding of solar radiation, it was necessary to introduce new requirements related to the parametric approach. An example is the request to design a modelling strategy capable of allowing different levels of permeability to the solar light. This request has a strong didactic value, as it is representative of the paradigm shift from the design of a shape to the design of a field of shapes. The cultural references provided to the students to better understand this paradigm shift are those of the *objectile* as conceived by Gilles Deleuze and Bernard Cachè.

The request to outline a technological strategy for this portion of the architectural envelope also helps to link an innovative design method with construction's techniques. This allows a conscious exploration of the relationship between technology and architecture to expand the research areas of the latter, as already indicated by Sigfried Giedion (1941). To this end, in the theoretical part of the workshop, the relationship between architecture and some material innovations (e.g., high-performance cement such as ductal, i.active BIODYNAMIC, FibreC) and process innovation (e.g., digital fabrication, robotic construction) was briefly discussed. Cases in which parametric tools are associated with a more traditional constructive dimension, as in DOME by Studio AION, have also been shown.

2.2 Parametric Strategies

The workshop's teaching approach is based on the proposal of single parametric modelling strategies, leaving students with the task of combining them in their projects. The recomposition of the proposed strategies into a single system does not return the simple sum of its components, but, as already suggested by Christopher Alexander (1968), generates a system of interactions capable of showing emergent properties and containing multiple possible solutions to a single architectural problem. Some similarities may be traced with Alexander's (1977) patterns as parametric strategies may be combined to form a network of strategies; however, our parametric strategies are not tied to an architectural problem and do not offer solutions.

The strategies are chosen by seeking a balance between their ability to facilitate the learning of parametric software, their ease of coding (e.g., availability of educational resources, commands, and special plugins), and their effective possibility of being used in the design of an architectural envelope. A first selection of the possible strategies that can be used is offered by technical manuals (such as *Grasshopper Primer, Algorithmic Modelling with*

Grasshopper, and *Essential Mathematics for Computational Design*) which are characterised by a certain level of abstraction as they are not built specifically for architects. The workshop proposed by us, on the other hand, tries to link the act of modelling to a possible architectural design supported by a clear tectonic dimension. For this reason, a fundamental factor in the construction of the workshop lessons was the association of architectural projects with each modelling strategy shown. Each project was briefly analysed to bring out the compositional, technical and functional principles, in order to link the parametric design to a tectonic dimension, thus making it less abstract.

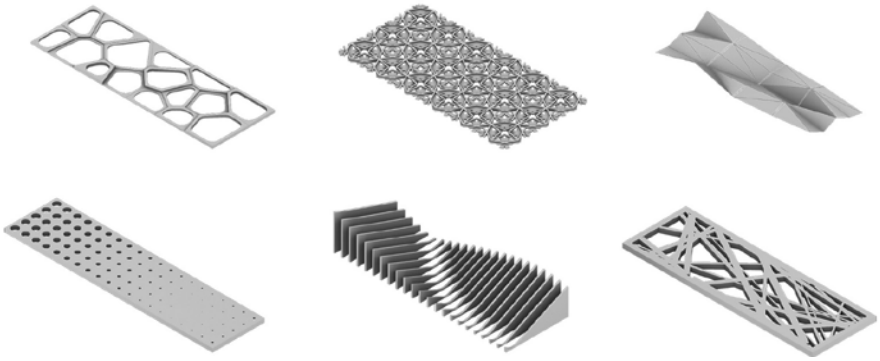

Figure 1. Examples of shown parametric strategies. Image by authors.

The strategies shown are geometric series, attractors, randomizations, symmetric aggregations, and tessellations.

Figure 2. Al Bahar Towers by Aedas. Photo by Inhabitat, CC BY-NC-ND 2.0.

Geometric series concern the repetition in three-dimensional space of elementary morphologies. They can be used to construct formal grids to be used as a guide to architectural composition, generating regular or more complex lattices, such as a tartan grid. In the parametric field, however, they are often used as ordering elements for subsequent complex transformations. During the workshop, the architectural envelope of the Al Bahars Towers was analysed.

Figure 3. Nanjing International Youth Cultural Centre by Zaha Hadid Architects. Photo by Leiem, CC BY-SA 4.0.

The attractors' strategy is based on modulating the intensity of a parametric procedure concerning the distance from a point, a curve, or a set of them. This strategy is typically associated with geometric transformations, such as rotations, scaling, and movements in space. It is necessary to acquire concepts such as *Domains* and *Remapping* for optimal management of the intensity of these transformations. Zaha Hadid Architects' Nanjing International Youth Cultural Centre was proposed as a case study.

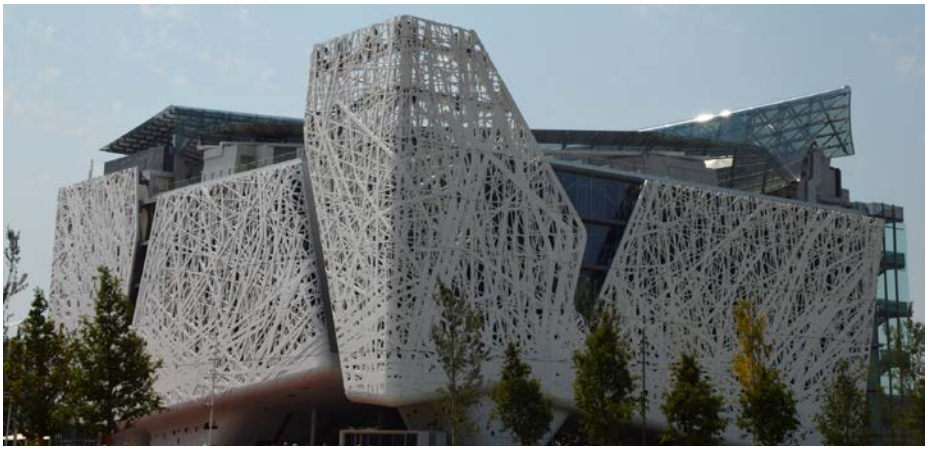

Figure 4. Padiglione Italia EXPO 2015 by NEMESI Studio. Photo by Emmanuel Bendiyan, CC BY-SA 3.0.

Randomization is the process of removing patterns or predictability in something initially defined as an ordered system. In parametric modelling, it is used to define a set or a list of random numbers, which become the input of subsequent procedures. Again, the IT concepts of *Domains* and *Remapping* are fundamental in defining the variability range of the numbers that can be generated. The 2015 Italian Expo pavilion by NEMESI studio was proposed as a case study.

Figure 5. Louvre Abu Dhabi by Ateliers Jean Nouvel. Photo by Eduard Marmet, CC BY-SA 2.0.

Modelling strategies for symmetrical aggregations are based on the combination of morphologies using procedures that refer to a limited number of rules, such as reflection, rotational, or translational symmetry. The composition of these rules allows obtaining patterns with high morphological complexity starting from simple geometries. During the workshop, the dome of the Louvre in Abu Dhabi by Jean Nouvel was analysed, also introducing the theme of the mashrabiyya.

Figure 6. Beijing National Aquatics Center by PTW Architects. Photo by Benny Wilaya, CC BY-NC-ND 2.0

Tesselations are methods to cover a plane with one or more geometric figures repeated endlessly without overlapping. These geometric figures, called tiles, can be regular or irregular and have curved sides. The operations necessary to perform a tessellation can be translated into algorithms as they always return the same result with the same input parameters. Designing an architectural envelope using a tessellation allows rationalizing complex shapes

by solving various production and construction problems. PTW Architects “WaterCube” in Beijing was shown as an example of Voronoi tessellation.

2.3 Limitations

Major limitations of the proposed workshop are linked to the difficult relationship between the learning curves of parametric design (Aish, Hanna, 2017) and the limited time available. This has led to the shifting of the didactic effort from the technical aspects towards the cultural ones. Possible parametric design’s research horizons, such as scripting, Design Space Exploration (DSE) or design optimisation have therefore been addressed only theoretically.

3 Results

All the groups involved in the workshop proposed a parametric design for a portion of the architectural envelope, almost always combining more modelling strategies. A quantitative analysis returns students’ preference to work with strategies such as geometric series, attractors, and randomizations.

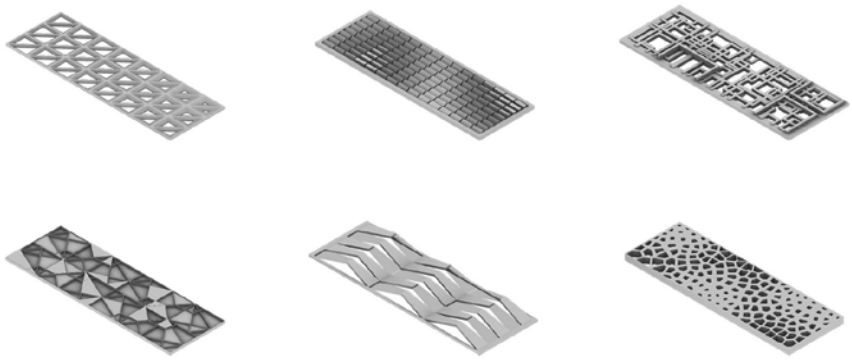

Figure 7. Examples of students’ design proposals. Image by authors.

A qualitative analysis, instead, returns students’ preference to work with what easily produces what is commonly perceived as parametric: the harmonic variation and articulation of morphologies that make up a larger architectural ensemble, which recalls the *Swarmism* of Patrik Schumacher (2018). In fact, in many of the students’ proposals, some architectural morphologies linked to traditional modelling processes and articulated by transformation dependent on attractors or randomizations can be identified. Although approaches such as Voronoi’s tesselations are relatively simple to code, they impose new design paradigms that significantly differs from traditional modelling. For this reason, they may have seen limited use in the workshop. The limited interest of students

in symmetrical aggregations can be traced not in the IT difficulties, but in the greater interest for more contemporary architectural languages.

Table 1. Parametric strategies reception in student's projects

Group	Geometrical Series	Attractor	Random	Symmetrical Aggregation	Tessellation
1	x		x		
2		x		x	
3		x		x	
4			x	x	
5	x		x		
6	x	x			
7	x	x			
8	x		x		x
9		x			x
10	x				
11	x				
12	x	x			
13	x	x	x		
14			x		
15			x		
16		x	x		x

4 Discussion

The didactic construction of the workshop allowed a reflection on the relationship between Italian architecture and technical innovations, with particular reference to digital culture. This led to the search for a balance between the acquisition of technical skills and the acquisition of broader cultural coordinates. The latter ones are certainly more useful in the long run since architectural software, despite being a favourite research field for many designers, are extremely changeable, not only in their operational aspects but also in the approach's paradigms to the architectural problem (McCullough, 2006). Sometimes, it is precisely the designers who push for the advancement of digital tools, as evidenced by the *Letters to Autodesk* (2020). It is therefore essential to lead students towards a critical and informed reading of innovative architectural design methods, even before they become fluent with their tools.

The workshop also posed the need to reflect not only on the nature of digital tools, essential for bold design intuitions to become an architectural form, but also on how these tools are approached by a student (Canestrino, 2021b). In the past, with particular reference to the period of drawing before CAD, how the mastery of drawing was acquired only marginally influenced the architectural design process. This was due to a certain ease in achieving full mastery of the technical drawing tools. However, already starting from *paper architectures,* technical virtuosity has become a research territory for architectural design, thus generating new aesthetics visions and new ways of designing. Digital technologies, with particular reference to the parametric ones covered by the workshop, today face an even greater complexification of the project tools, which require increasingly interdisciplinary skills to be governed. Soon, designers interested in identifying the digital as their favourite research territory will face increasingly steep learning curves to manage the most innovative tools and methods that information technology offers to the project.

The cultural training of an architect, also extended to the digital dimension, will therefore appear more fundamental than ever in order to continue identifying in the project his ability to synthesize complex knowledge.

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