OVER CONSTRAINED

Integrating Parametric Design as an Academic Tool

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Abstract. Parametric software has fundamentally changed the way in which architecture is conceptualized, developed and even constructed. The ability to assign parameters or numeric variables to specific portions of a project has allowed designers the potential to test variations of their design. Small changes to a single parameter can have an exponential effect on the designed object and alter its appearance beyond original preconceptions. The introduction of parametric design methodologies into an architectural pedagogy re-establishes architectural praxis in an academic setting. Students are taught to design based on creating relationships to parametric conditions; just as they would do in a professional architectural practice. This paper outlines how Digital Project, a parametric based software, was introduced into an academic setting in an attempt to reconnect the ideologies of academia with the practicalities of professional practice.

1. Thinking parametrically

The technological achievements within the architectural institution during the 21st century serve as an indicator of the ever increasing potential for new advanced digital methodologies to become applicable tools within the academic setting. As computer technologies ripple across the world, and continue to influence the field of architecture, academia inherits an obligation to question how to best tap these new tools to inform curricular objectives. This obligation further suggests that the pedagogical relationship relationship between what is taught and technological advancements in the field constantly strive to establish a real-time connection – one that keeps academia in line with, if not ahead of the profession. As a result, this allows the application of the most relevant technologies to influence the fundamental structure of architectural discourse. Parametric modelling, a current digital design methodology, has changed computational design from a tool that illustrates explicit geometrical notations to one that embodies instrumental geometric relationships embedded within the digital model (Mengis 2006, p. 46).

While it can be universally agreed upon that the philosophical underpinning of the parametric modelling process, the parameters themselves, branch back to the earliest developments of architecture, what is most profound is the emergence and application of the term within the digital environment. Loosely written, parameters can be described as either newly defined or pre-determined variable inputs used in order to intentionally direct the outcome of a previously undeterminable condition. This ideology has been injected into digital software, thus allowing architects to be able to compose projects that respond to designed variables, expressions, and conditions. Defining these types of potentially complex data within software applications grants the architect the ability to control information in the modelling process more precisely and alter or creatively experiment with data in a more absolute manner. After all, as the building industry shifts to incorporate technological processes that have helped mould the automotive and aerospace industries, it does so with the idea that our understanding of making becomes reinvigorated with creative options that lead to new qualities, without compromising the process through a streamlined train of thought (Ottchen 2009, p. 27).

In parametric design methodologies, there are typically two general categories within which most work can be classified: parameters driven automatically through computer code or scripting or parameters controlled manually, in discrete, incremental steps. In either case, when specific values are assigned to parameters, particular instances or moments are created from a potentially infinite range of possibilities (Kolarevic 2008, p.121). Furthermore, by utilizing parametric modelling tools, equations are established to describe geometric relationships, thus associative data emerges that allows for previously unexplored conditions to be revealed. This way, interdependencies between objects are established, and objects' behavior under controlled transformations becomes definitive. This provides an intended structuring principle for the generation and transformation of the digital model. As a result, the organization and reconfiguration of these interdependencies rely, to a considerable extent, on the capacity of the designer's perceptual abilities to interpret and manipulate a parametric construct in a complex design process.

2. Decoding Arc 465

In order to investigate the academic potential of Digital Project as a parameter based software, a project that creates cellular, flexible geometries was devised. Produced over one semester, the project set out to find ways of controlling designed geometry through programmed parameters that allowed the initial cell to be instantiated or replicated into a wall condition: maintaining a unified whole of discrete components. The project became reflexive in its nature be relying on visual feedback of non-particular geometrical outcomes of parametric procedures. Initial designs were intentionally crafted to understand the "threshold" or geometrical extents and characteristics of individual cells. Manipulating the parametric data to the breaking point, the moment when topological error is introduced, provided a condition to understand the software's potential for exploration as well as ways to reconstruct the initial proposal to achieve better performance. "The designer simultaneously interprets and manipulates a parametric computational construct in a complex design process that is continuously reconstituting itself" (Kolarevic 2008, p.122).

In order to structure the exercise effectively, a framework was developed based on the key features of the software. Set up in order to phase the exercise into manageable categories, the exercise could be subdivided into the following basic parts:

_Attributing.A
_Associating
_Attributing.B
_Instantiating

Each part is a critical component necessary to help the designer understand ways to effectively sequence information within the software and develop an understanding of digital parametric modelling. Designing through this specific approach allows one to thoroughly investigate the choices made in a design solution through immediate visual feedback from the software.

2.1. ATTRIBUTING.A

The first step focused on establishing data that would function as the basic driver for the anatomy of the cell. This driver data defined the intrinsic qualities of the project: the extents of the model, and the appropriate level of modelling detail. In the context of this project, a cellular element would be designed based on a simple cuboid wire frame (Figure 1). This allowed the cell to be defined with simple length, depth, and height parameters. This boundary acted as a flexible framework around which all remaining data would share a designed relationship; as intended this geometry established itself as the parent or driving feature for the cell. Any geometry subsequently added to this model became "children", which inherited characteristics of the parent. To help support this hierarchical structure, a new origin system was developed tying the geometrical origin of the cell to the parent. This origin, two groups of three planes, was located on opposite diagonal corners of the cuboid shape to easily define all six sides of the object.

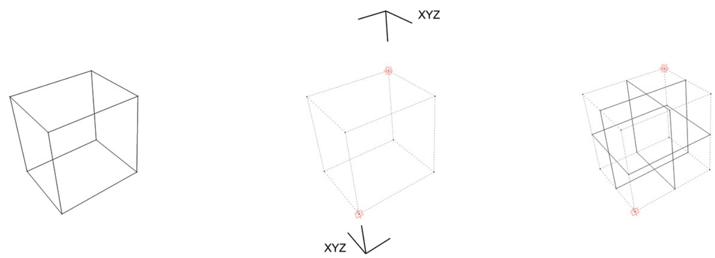

Figure 1. Initial Cuboid Structure

2.2. ASSOCIATING

The next step of the exercise required the visualization of the individual cell within the context of a larger field of cells. This field was studied to generate a simple wall condition. It became important to be able to zoom out and observe the potential relationships that could be designed between adjacent cells in horizontal and vertical directions. As a result adjacent faces, lines and vertices set up connections that permit the simultaneous development of the micro scale of the individual cell and the macro scale of a field of cells or wall. Considering that six faces of an individual cell would each share four identical edges and vertices with another cell in any direction, these faces would now serve as ‘planes’ to support the construction of the next layer of information– a Digital Project term called sketch geometry. The sketch relies on some pre-existing planar condition, in this case, one of the six planes that defined the local origins of the cuboid. The four edges of one face, when intersected with the sketch, would serve as the local dimensions for the construction of two-dimensional geometry that constrained itself within these edges (Figure 2). One vertex on each of the six surfaces would describe the local origin of the associated sketch geometry, thus acting as an anchor for the geometry within the sketch to be constrained. “Constraints, in general, allow for geometry to contain an extended database of mathematically defined relationships that help to define the geometrical and dimensional characteristics of a model” (Schodek, et. al., 2005, p.205). A constraint is a relation that prescribes the behaviour of an entity or a group of entities based on specific relationships such as, parallel/perpendicular/collinear, a line constrained to be tangent to a circle, or a dimension constrained to be less than/greater than a particular magnitude.

Constraints help to define the tolerance or degree of freedom present within a particular model structure. Although the primary focus is on capturing design intent, constraining geometry allows the user to go through a series of iterations focused on controlling geometry in a specific manner. With this layer of complex variables and relationships, models can be conceptualized as much more than simple, static geometrical representations – they begin to act and react to programmed conditions. However, ensuring that these relationships function properly solely depends on the ability of the designer to craft the structure of the model precisely. A high level of awareness is critical to ensure that geometry does not become over-constrained based on geometrical contradictions. For example, if two lines are constrained by an offset dimension, an angle constraint cannot be used to define their relationship. This is a geometrical contradiction since the offset created a parallel dimension constraint between the two lines thus ruling out the ability for an angle to be introduced. Understanding these concepts at the fundamental stages of individual sketch creation allowed the process to be developed in a more three-dimensional manner.

Sketches were used to create parallel and perpendicular, formal, relationships within faces of the cuboid cell. Sketch geometry allowed for the creation of curve or line based wire frames to begin to create volumetric geometry within the initial cuboid cell. While three-dimensional geometry began to take form, declaring the specific physical characteristics became secondary in relation to establishing the parameters to control the form. With parameters defined, it became important to ensure that specific dimensional relationships be constructed to minimize geometry failure by creating ratios or user defined parameters between the internal geometry of the cell and the initial cuboid frame.

These ratios were set up as formulas to create specific relationships between key dimensions of the internal cell geometry and either the overall width, depth, or height of the initial cuboid frame (Figure 2). Editing ratios that affect key dimensions is possible at any point, and parent-child relationships between geometry let changes affect dependent geometry. As long as no logical errors are detected, the model rebuilds according to the rules and relations set forth in the links between features. Parent features drive and determine the nature of their dependent children features.

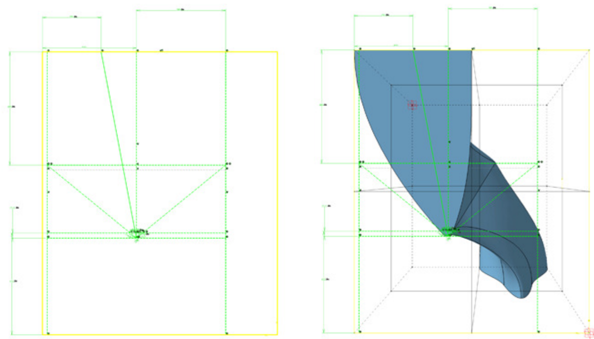

Figure 2. Sketch Workbench: Association-Based Formula

2.3. ATTRIBUTING.B

The organization and identification of the programmed information became a critical aspect of controlling the design. It was important to develop a classification system which would allow the parameters to be modified easily through the use of a specifically designed vocabulary set up by the user. Understanding the orientation of the cell in relationship to the primary sketches on any of the six faces resulted in the application of an ordering system. Therefore, the cell might be broken down into sets of faces; two horizontal faces that share sketch relationships could make one set. A set might be labeled as ‘A’ with two subsets, faces of the initial cuboid frame, as A1 and A2. Furthermore, each subset could have its own set of subsets defining horizontal or vertical relationships specific to that face. This would become increasingly important when the cell is instantiated into a wall condition, thus creating multiple similar cells with similar set of parameters. Distinctions would need to be made that would allow for the data to be read in spread sheet format.

This system would further come into play with the introduction of design tables into the project. Once all parameters were properly identified, they could be output into a Microsoft Excel document which would carry the the name and numeric value of all selected parameters. New columns could then be created within the spread sheet that would allow different combinations of numeric values to be input. As a result, these columns are re-linked to the digital file and offer the user to potentially activate any desired configuration of data. The continuous feedback loop of data between the design table and digital model actively engage the designer’s thinking process by having the ability to quickly observe the visual results of the cell geometry based on an infinite combination of numerical inputs. Engaging in this act allows the process to be evaluated based on the outcome of different variations and allow the designer to stretch the limits of the designed relationships and, if necessary, make adjustments accordingly.

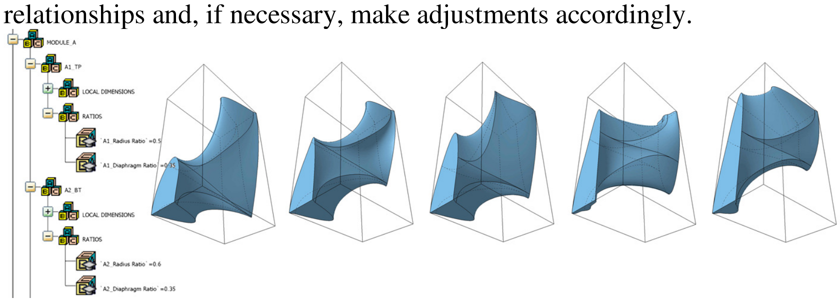

Figure 3. Cell Variations

2.4. INSTANTIATING

The first step of the final phase of the exercise requires the cell geometry to be prepared for instantiation or converted into what Digital Project labels a power copy. In order to set up a file properly, all geometry must be classified as input and output geometry; inputs being the parent or primary driver geometry, which allows for the creation of the output geometry. In the case of the cell file, the eight vertices that define the initial cuboid frame are the input geometry. The power copy allows the cell data, both geometrical and user defined parameters, to be packaged in such a way that in can be automatically generated based on the initial inputs identified (Figure 4). In other words, if a separate file is set up containing eight vertices that define an enclosed cuboid volume, regardless of the dimensions, the power copy can be instantiated by selecting these eight vertices. As a result, the steps recorded within the power copy are regenerated and inserted into this file.

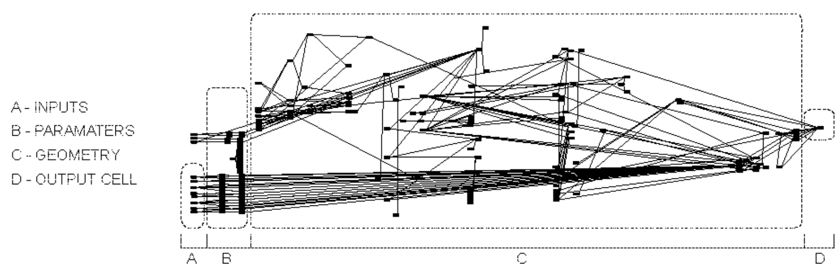

Figure 4. Power Copy Tree Structure Diagram

Using Digital Project's "product-file" and "part-file" structure – a system that allows smaller part files to be referenced into an organizing product file

– a base file is created which contains the basic structure of the wall. This file contains vertices which describe the boundaries of the wall and its potential cell quantities. Rows and columns are simply defined by vertices, which are based on width, depth, and height parameters. This geometry is then output in such a way that it is accessible by multiple files, which will contain all cell geometry. An individual cell would then become instantiated, instantiated, through the generation of a power copy, in such a way that a relationship is created between the cell geometry and the parent wall vertices. Modifications to the form of the wall would propagate down Digital Project's hierarchical tree structure, allowing all affected cell geometry to be updated.

Setting up the wall with a minimum of eight cells in the horizontal and vertical direction allowed for a large enough field to gauge the visual impact of various numerical inputs (Figure 5). In addition, as an aggregated element, the surface continuity from one cell to the next reinforces the conceptual framework of Digital Project, within this exercise, as a software predicated on challenging one's ability and foresight to control the flexibility of a project through the seamless integration of relationships and geometrical interdependencies.

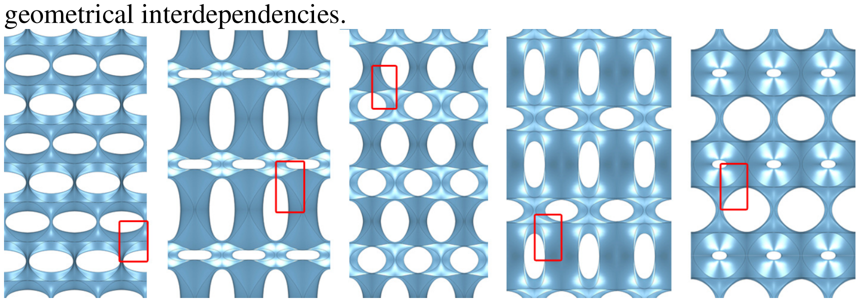

Figure 5. Instantiated cell variations with original module outlined in red.

3. Conclusion

The user defined parameters of the project were extremely simple yet wielded very complex and varied outputs. Students were expected to carefully define these parameters and then monitor the end results of altering their constructions throughout the course of the project. By monitoring the results, students were able to adjust the module and the wall in order to fulfil a design intent. This may have been to make the wall structurally sound, more or less opaque, or even more aesthetically pleasing. Students quickly learned the potential of their defined parameters to create unexpected and often positive results by visually tracking changes as they were being made – essentially testing their complex creations through the alteration of simplified attributes assigned to their object.

Through this exercise, students were challenged to look beyond their preconceived notions of digital modelling as a design tool. Understanding the ability for parametric modelling software to capture precise, intent specific data through complex organizational and constructional techniques, reinforces the software's relationships to the complexities present in architectural design and practice. This process corresponds with design at its most fundamental, by effectively representing design decisions, or more precisely, a model that allows a sequence of alternative decisions to be constructed and evaluated. The time has passed when it was sufficient for digital tools to simply capture static representations of a design. In parametric design, the conceptual emphasis shifts from declaring particular forms of geometry to specific relationships that potentially exist within the context of a project.

Although the process requires a substantial amount of experience and dexterity, it is an academic obligation to project forward and disseminate effective means by which this technology and future advancements can open the doors to new frontiers in investigating methods of architectural design. "After all, there must be an explicit recognition that the admittance of risk – the unpredictable and unexpected – paves the way to poetic invention and creative discovery" (Kolarevic 2008, p.122).

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