TOPOLOGICAL AND PARAMETRIC TEMPERATURES IN ARCHITECTURAL ACADEMIA

ALFREDO ANDIA
Florida International University

THOMAS SPIEGELHALTER
Florida International University

PARAMETRICS

Parametric in architecture contains a geometric model associated to knowledge structures, information, performance properties, and automatic procedures that can aid the designer to construct quick scenarios during the design process. These models can be updated and further breed its associations overtime.

Parametric Ideas in CAD History

Parametric ideas in design are not new. In fact, they were an essential feature of the first CAD program, "Sketchpad," developed by Ivan Sutherland in 1962. They were also part of the pioneering CAD systems in the early 1970s. A significant number of pioneering 3D software such as SSHA (developed at Edinburgh for the Scottish Special Housing Association), CEDAR (Property Services Agency), HARNESS (Department of Heath and Social Security) and OXSYS (Oxford Area Health Board) had parametric features and were associated to a particular type of knowledge as they were designed as specialized systems to serve particular organizations and building types (McCullough & Mitchell, 1990).

OXSYS was the precursor of BDS (Building Design System) and RUCAPS (Really Usable Computer-Aided Production System) which became available commercially in the UK in the 1970s and surfaced with concepts very similar to today's BIM systems.

All these systems had a common vision: to construct virtually a 3D building by modeling all their building elements and assemblies. They allowed multi-users to manipulate a single parametric 3D model. Graphic reports and 2D drawings were mere derivatives created automatically from the main 3D model. By the mid 1980s a second wave of 3D parametrically based software such as SONATA, Reflex, CHEOPS, GDS, CATIA, GE/CALMA, and Pro/Engineer achieved commercial presence. In fact, RUCAPS became SONATA in the 1990s and engineers from SONATA created the company that launched the software REVIT which was later acquired by AutoDesk.

Historical Divide: Parametrics vs. CAD

Many of these pioneering parametric programs in the 1980s, became standard in industries such as electronics, infrastructures, aerospace, and car manufacturing. In these industries there were significant rewards in accurately defining models whose performance could be analyzed, simulated, and fabricated. The elevated cost of hardware & software and the inherently segmented workflow in the Architecture, Engineering and Construction (AEC) industry proved to be significant barriers for the implementation of the parametric metaphor in the AEC sector during the 1980s and most practices choose to automate only their 2D drafting capabilities by massively buying CAD drafting software in Personal Computers (PC). It took close to two decades for the 3D parametric model to make a significant comeback in the AEC industry.

Technology and Organizational Implementation

It is important to observe that the implementation of information technology in industries is impossible if it is not shepherd with significant organizational change. One of the earliest cases of 3D parametric CAD/CAM software implementation in a large design environment was in the production of the Boeing 777 airplane. The story has been highly referenced in the literature but what is never told is that Boeing had to change its whole organization and business processes to introduce the parametric software CATIA.

When Boeing Co. began the 777 project in 1988 abandoned its 8 years old TIGER 3D in house project and selected CATIA for the design of their new 777, creating a $1 billion dollar in revenue for IBM-Dassault. To develop the plane, Boeing linked together 1,400 IBM workstations. Boeing's Seattle offices were also linked to its preassembly plants in Japan and Kansas where digital schematics were sent instead of paper. Boeing also linked all of its suppliers to enable them to have access to detailed renderings of parts of the 777 (Andia 1998).

Philip Condit was in charge of the 777 project and quickly realized that despite the large investment in technology engineers were not willing to share information. Condit explains, that in response management put up big signs on computer stations exhorting employees to "release early and release often." "It did not work," says Condit. Five design cycles went by before management began seeing collaboration and concurrences in the design-build process. Boeing began to understand that changing the design-manufacturing process involved more than acquiring a very sophisticated computer network. The task required a whole new way of thinking about their design process, the organizational structure and the culture of the firm. Up to this point, Boeing had a very linear design-to-manufacturing process and a very functional organization.

Changing how people work was also a major undertaking. To make the new system work, engineers at Boeing had to learn how to develop products as a team and to reward team work. Boeing learned how to move away from its functional organization and organize around a number of core design-build teams of 15 or 16 people with members from different disciplines. The company ended up with much smaller organizational entities and spent a lot more time talking about processes, investigating how good design-build team works, and looking much more closely at how people interact at work.

PARAMETRICS IN ACADEMIA

Parametric has also entered into the radar of contemporary architectural education. But most of these efforts have been reduced to support the digital metaphor promoted by the largest software companies in the world or formal exploration that support the careers of a few number of avant-garde designers.

But organizationally Architectural Education has not changed dramatically for many decades. Architectural professors in each school still divide their teaching assignment according to the different specialties the curriculum requires. In general, teaching collaboration is sporadic. Architectural students today follow a similar pattern of architectural education they did many decades ago. The wheel is reinvented with each architectural student. Each student began his or her path into architecture by acquiring drafting skills and slowly moves into different design cultures, while acquiring some technical proficiency on the way. But the knowledge is scattered and good design continues to be considered a black box protected by a cult to the genius-architect.

There has been very little possibility in advancing the knowledge base of Architecture or Architectural education. Design studios are at the core of the curriculum in architectural teaching. Architectural studios do not only attempt to simulate the real time experience of an architectural design project but also offers very intense interpersonal environment for students to learn from each other as they search for design solutions. But the search follows always a very obscure path. Knowledge, solution strategies, and design culture are transmitted by what Donald Schön called a process of "tacit learning" (Schön 1984). Schön explains that "tacit learning" cannot be fully explained or fully structured. It is transmitted by examples, gestures, acts, and developed by the investigation of problems as they arise. In this paper we will argue that a more collaborative environment among architectural professors and architectural schools can began to implement collaborative parametric thinking that could speed the design scenarios in which students are involved in their educational years. There are at least different narratives how parametric design is emerging in architecture today.

Parametric Formalism: the digital avant-garde

Parametric modeling and scripting has been used to find intricate utopian/dystopian formal visions in studios usually led by professors that are closely linked to the paperless studio digital avant-garde that emerged in the 90s and 00s. Parametric techniques substitute the sculptural or figurative designer and allowing much more complex spatial formation.

In the past few years Patrik Schumacher, partner at Zaha Hadid's office and head of the "parametric urbanism" program at the Architectural Association in London has acquired a leading voice. Schumacher argues that there has been a solid trend in the architectural avant-garde in the past 15 years in rooting their processes in digital animation technique. He observes that it is impossible to compete in the avant-garde scene today without using computational techniques such as scripting and parametric modeling. He goes further to argue that: "Avant-garde styles can be interpreted and evaluated analogously to new scientific paradigms," making a clear call for opening that traditionally closed black box that has traditionally permeated the avant-garde design culture (Schumacher 2009).

Schumacher call parametricism a style. He, as most digital avant-garde designers, is developing these techniques to differentiate in a design environment infatuated with shape generation possibilities. Precise families of forms and software tricks that bounce in blogs across the oceans and between architectural schools have emerged and soon it has become difficult to distinguish their authors. However, these scripting libraries are the first sign that architectural design can began to get disengaged of individual authorship. This contemporary generation of scripting techniques is the result of the obsession architecture has had almost exclusively with complex, aesthetically driven geometry, shapes, and form. In this theoretical paradigm, most courses and research that bear names such as topology and/or performance usually are limited only to advance geometrical aspirations. A more advanced narrative will emerge when this version of generative form making is coupled with algorithms that associate all different types of data and performative aspects with the digital model.

Parametric Topology: Associative Design at the Berlage Institute

An initial number Architects have observed that the scripting capabilities of parametric modeling will inevitably guide designers to enter into coding design thinking. This means the development of computing frameworks that associate 3D models with other parametric factors such as: land cost, density, codes, regulations, structural parameters, acoustics, automated parking layouts, sunlight, climatic evaluations, etc. We are not taking here about generic software, but scripts that are tailored to precise design thinking related to a particular architectural program, site, and cultural context. The architect in this milieu becomes a topological operator and the 3D design model turns into a dynamic mock-up model full of parallel intelligent scaffolds that can quickly test multiple scenarios.

One of the most remarkable prototypes of coding design intelligence can be found in the "Associative Design" Studios led by Peter Trummer at the Berlage Institute, in the Netherlands in 2007. In essence, the studio uses software devised for manufacturing industry and adapts it to generate complex parametric models for a large housing project in China.

Today the most efficient mass housing solutions in China are large mid to high-rise building blocks that repeat ad nauseam because it is very difficult for architects and developers to conceptualize the problem in a different manner given the time and constructability constrains. China is urbanizing 500 million people in a decade and contemporary architecture is too slow. Thus, most contemporary architecture in Chinese cities has defaulted to a copy and paste mode.

The studio was divided into research teams that studied issues such FAR, circulation, internal room organization, land value strategies, sun trajectories, parking requirements, Chinese national code, traditional construction techniques, and the traditional vernacular Chinese housing. The studio discovered that each one of the issues studied had a clear morphogenetic intelligence. These observations were coded into the manufacturing software achieving parametric and associative values.

The self-generative 3D routine automatically develops the internal layout of each apartment. For example, when the perimeter of the housing project has to change, the software interactively updates the design of the entire apartments, windows, and egress following the coded criteria. The routine calculates the spaces based on the studies of traditional use of courtyard, population densities, family structures, circulation requirements, egress, national sunlight and ventilation regulations, and different configuration for diverse income groups.

The associative model allows the designer to consider many domains which are impossible to consider in a manual drawing process or a traditional CAD system. The parametric model also considers more sophisticated issues and automatically calculates the insulation properties and solar gain for each wall in the project. The morphological 3D model automatically generates parking, public spaces, water systems, street corners, and land value maps to insure that the neighborhoods are not segregated by income. The process is self-organized and performed so the relationships of courtyards and street are maintained but making sure that we can never encounter an exact repetition.

Finally, the students can test in 3D flight through and renders the configuration and environmental performance of each interior space, wall, and public space. Every space is treated differently based on the performance criteria set in the parametric system moving the design morphology of the project closely to the vernacular experience found in the traditional Chinese cities.

Meta-heuristic Parametric: Aedas R&D and AEC Integration Laboratory, Georgia Institute of Technology

The R&D group inside Aedas Architecture is a team inside one of the largest firms in the world. The group is project-driven, it works aiding the firms architects explore generative and analytical computational processes in design. The group has worked in a variety of projects: from façade systems, performance analysis, digital layout, to large urban design proposals. The objective is to develop methods for design that explore the spatial and performative conditions of design more than just specific geometrical solutions for a project. Their work is closely related to academic ambitions explored in schools such as at the University of East London, University of Central London and lead by among others by Paul Coates (Coates, 2010).

In developing their tools and processes the group has developed meta-heuristic techniques to augment the traditional rules of thumbs used by the design teams in the firm. In computer science, meta-heuristic is a computational method that searches for a large number of candidate solutions. Meta-heuristic is an iterative process that can search quickly a large number of candidate solution but that can not assure that an optimal solution can ever be found. Among the many computational methods that they have developed are the following:

> *Adjacencies and layout:* The Computational Design team has developed several 3D tools to help designers understand adjacencies diagrams and program layouts. These tools are semi-automatic, not fixed, and the user can move bubbles and/or volumetric rooms while the adjacencies among functions are maintained. As the user moves the volumetric rooms they behave like 3D Jell-O boxes that attract or repel different configurations based on their topological configuration. These tools are intended to intensify the reflective period design teams have with the program layouts rather than provide fully optimized solutions (Derix 2010).
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> *Digital master planning tools:* The Computational Design Team at Aedas also has developed parametric methods such as massing, accessibility and movement, strategic planning, investment appraisals, and others that have been implemented at the urban scale. Two critical issues have emerged in the creation of these digitally assisted methods. The first is that users always continue to ask for more features to be added to the computer model. This creates a major visualization problem because these systems can became overwhelmed with information and the clarity and simplicity of the information can easily be lost. The second theme emerges with the potential temptation to develop optimization procedures. These systems are developed using a multi-criteria development and often there is no clear way to offer a family of optimized solutions. So an option is for the methodology not to provide any solutions and focus in usability and engagement criteria with the user. The observations in usability became important and it usually critical to understand the type of supervision

> these tool requires. Sometimes computers run too fast, and it is better for the user to see how it struggles for a solution. At that moment the users can see potential candidate solutions and by accident help move along different scenarios in the discussions that accompany a typical planning process.

A parallel example of Meta-heuristic parametric can be found at the AEC Integration Laboratory at the College of Architecture led by Charles Eastman at the Georgia Institute of Technology in the work commissioned the U.S. federal Government's General Service Administration (GSA). The GSA commissioned to automate the "design guidelines for all U.S. Courthouses in such a way that preliminary designs of architects could be assessed and checked against specific criteria" (Eastman 2009). The AEC Integration lab defined a set of digital design practices that follow the US Courts Design Guide, which defines factors such as spatial, security, communications and environmental in court design.

The design model provided by the architects has to be exported in IFC format for the assessments of criteria such as: 1) Spatial layout validation; 2) Circulation analysis; 3) Preliminary energy assessment (using Energy-Plus); 4) Preliminary cost estimate (using PACES). Eastman reported in 2009 that modules "for the space program review and the circulation and security review are operational and provide reports in little more than a minute for a five-storey courthouse….the preliminary energy analysis module has been successfully integrated with the EnergyPlus simulation engine" and that the Georgia Tech team had began the integration of the model into the PACES database. It is reported that "Once completed this will require minimal or no input form the user to produce cost estimations representative of the analyzed design phase."

As Eastman points out, the objective is not to obstruct the creativity in developing architecture at the early stage of design, but instead allow designers to be better informed and promote discussion. He concludes: "such tools are also expected to allow young designers to gain invaluable experience more quickly using virtual architecture assessments, and to facilitate the more rapid emergence of new ideas in practice" (Eastman 2009).

MORE ADVANCED PARAMETRIC THINKING

Most emerging parametric metaphors that are in architectural academia are still well entrenched on the contemporary manner in which we consume architecture. Parametric modeling has already been critical to build many projects however most of those endeavors are related to the geometrical representation of the building. They are usually not connected to databases. They are not associated to heuristic knowledge that can aid design evaluation using many other criteria. This doesn't allow for a large number of evaluations of design ideas, materials, and many what-if-scenarios.

More Developed Narrative

A more developed parametric narrative will allow groups of architects to associate geometrical 3D data to an increasing number of design, construction, and performance conditions. It will allow a new generation of architectural thinkers to develop group intelligence or collective intelligence which will be able to improve design coding over time.

Parametric Futures and Academia

As mentioned before architectural academia has changed very little for many decades. The introduction of parametric thinking will not impact significantly design education without creating a more collaborative environment. A more advanced level for architectural education could be achieved when we began to code our design intelligence in a more holistic way. The cases of Parametric Topology and Parametric Meta-heuristic described in this paper are an initial move in that direction.

Since the Renaissance the discipline of architecture has not been directly involved in the construction of buildings but has been occupied in creating heuristic practices and processes of everything that occurs before construction. Designers, when scripting or using the relational capabilities of parametric, are forced to make explicit their design process and the conditions to which their design respond. Computing no longer mimics the traditional environment in which the architect has to model everything every time. Architectural models are no longer frozen. They became malleable, manageable, and associated to different types of performative conditions and data.

Parametric thinking is deeply relational. In contemporary academia most knowledge is deeply fractured in different courses and mediums and students have great difficulties bringing different realms together.

For example, students in a typical studio have part of their knowledge in lectures, reviews, program outlines, reference projects, code requirements, books, and in the material covered in other courses (such as structure, environmental systems, professional office practice, etc). When students are confronted to make a decision about structure and materiality they might use a book such as the "Architect's Studio Companion" (Allen and Iano 2007). The book gives basic rules of thumbs of different construction system but the students are usually not well informed of the many implications of their decisions. They can not quickly explore what-if-scenarios and the knowledge are vastly dispersed. The students' understanding is difficult to be clarified by just one studio instructor. In most cases the students' decisions are left in a context vacuum while they are quickly frozen in a 3D CAD system. A more advanced way of treating this simple example would be to work in a parametrically coded environment in which the rules of thumbs about structural decision can quickly be tested and observed by the student. Overtime, students and professors can add more knowledge to the system. The design scenarios would become gradually more complex and sophisticated as the information of the parametric model evolves. Eventually, large numbers of parametric design studio case scenarios can evolve and shared across schools.

CONCLUSION: PARAMETRIC ARE THE FIRST STAGE OF ARTIFICAL INTELLIGENCE

Parametric is part of human-computing tradition that is constantly evolving and very much dependent of the accelerating growth of computing power. Parametric is the most basic level of Artificial Intelligence. We are beginning to enter into the first of parametric age in architectural design with the Parametric Formalism, Parametric Topology, and Parametric Heuristics. This first age will be characterized by allowing architects to make more explicit their design process and promoting collective intelligence.

A second stage of impact of artificial intelligence in Architecture will began to occur when computers will be able to analyze the processes of design and construction. The computer would have to be designed to perform concept learning and concept formation. A third stage of Artificial Intelligence will emerge when a device is no longer programmed and evolves primarily by learning. Computer power today is far from achieving the second and third stage of Artificial Intelligence. But in a non-distant future this might be possible. By 2029 computer power will allow us to reverse engineer the human brain which will be a significant advancement. In the mean time we are bound to begin to open the design black box and develop the initial steps of a parametric knowledge base.

As described in this paper this not only means the application of technology but also the development of new scholarly collaborations that could help us develop computational environments in which the learning process can be aided by a more intelligent system. Form-finding in generative systems that search for higher intelligence of human settlements, beyond just geometry, can expose our way of working and reform our urban and spatial DNA.

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