**ABSTRACT**
This paper claims that a speculative design space exists within the crafting of digital rule-based associations in parametric modeling environments, which promises to support potent contemporary designs in architecture. In addition to reviewing some diagrammatic frameworks located within the techniques of associative design modeling, this paper also details a project for a research-oriented practice based on the development of a registry of digital diagrams called “re-usables.” Working with “re-usable templates” of association, a precise sequence of design logic is invented for each project, while some of its aspects are re-used and re-configured. Such practice aims to operate between the “one-off” world of the all-custom and the entirely reproducible world of “copy-paste.”

**INTRODUCTION**
This paper seeks to position parametric design both as an agent of change in architecture and as a support of speculation in design. While parametric models have primarily been perceived as most useful in addressing complexity and money-management issues and, thus, have gotten a bad rap in academic circles, this paper reclaims the significance of parametric design in regards to design methodologies. This review of the operating frameworks intrinsic to associative design attempts to reveal and exploit their constitutive properties. At the same time, this paper advances the significance of digital jigs and the associated concept of re-usable digital templates. “Re-usables” are sequences of recorded operations that, like a diagrammatic chart, may be adapted, may evolve, or may mutate in order to address a range of conditions similar to the ones for which they were initially intended. For architects, this suggests a shift from a commission-based practice organized around the production of one-off projects to one that develops an inventory of jigs and “re-usables” that anticipate a range of architectural problems and commissions. Though architects have traditionally sought the efficiency and expediency of re-using details for material assemblies, digital templates present a different potential for the discipline. They suggest an entirely new speculative, variable, and provisional design space able to take on both intrinsic design criteria while simultaneously anticipating a range of extrinsic conditions. The potential of these methods is illustrated with examples of student work produced in both studio and seminar environments. Two additional examples illustrate the broader applicability of these techniques in architectural practice.

**REVIEW OF ASSOCIATIVE ENVIRONMENTS AND THEIR THEORETICAL IMPLICATIONS**

1.1 WHEN GEOMETRY ASSOCIATES TO GEOMETRY
In an environment that fully supports associative modeling, all geometric objects are defined in the digital model, enunciated through both geometric and mathematic rules. Associative modeling keeps track of the interdependences within a given model—a model that has been constructed through long sequences of interdependent geometries whose behavior is regulated by rules. For example, one can create a representation of the geometric theorem of “the witch of Agnesi” as a curve, described as flowing, through points obtained from the intersection of two lines, constrained by the laws of the theorem (see fig. 1). The relationships are the model. There has been little conversation in the field of architecture about the design implication such a setup offers. It is definitively new to architects that a model is not a throw away, and the questions shift to which types of relationships are meaningful to the architectural project.
Diagrammatic invention here has to do with thinking through the relationships of geometry within the model: their type, their order, their grouping, their degree of insularity, and their repeat pattern within the tree or an area of the tree.

The sheer quantity of information produced by the relationships in such a model needs to be managed carefully, which leads into the discussion of the role and significance of data in these models.

1.2 WHEN DATA ASSOCIATES TO GEOMETRY AND GEOMETRY ASSOCIATES TO DATA

There are two possible scenarios in this association between data and geometry that bear consequences for diagrammatic thinking. One is an association where a data set dictates the position or characteristics of the geometry like the values of coordinates, length, area, volume, mass, etc. In this case, the code flows from the data to the geometry. Data is the input of the model and geometry the output. The other possible association consists in collecting information from the geometry in the model and producing a tabulated representation of it—where the information collected is specific to the purpose of the model. In this case, the code flows from the geometry to the data. The geometry is the input and the data the output.

The implications of data sets as the “inputs” of geometry for contemporary diagrammatic possibilities for the field of architecture are twofold:

First, data allows the geometry in the model to be abstracted and conceptualized numerically. Numbers are becoming part of the representation within the design project: numbers materialize—this has been engineer and mathematician Cecil Balmond’s project and contribution. Further, this means that the many and diverse abstract mathematical quantities developed in the sciences are now available for actual manipulation by architects. Architects no longer have to discuss scientific models as an idealized condition that any given project, at best, simulates but, rather, may integrate them into the inner workings of a project.

If we elaborate on the example of working with the mathematics of the “witch of Agnesi” curve, a lotus pod may be modeled not as the formal reproduction of the lotus formation but as the mathematical function associated to its growth (fig. 2).

Second, a data set is a renewable, mutable quantity. Hence, a given geometrical model whose input is a data set is constantly in flux. The model is a provisional condition with many possible actuations or virtual conditions. Architectural critic Michael Speaks speculates that Excel is the tool that allowed financial speculators to create an understanding of
When data is extracted from the geometric elements of the model and organized through tabulation, it is observed that the diagrammatic consequences are as follows: the moment such abstract data is able to collected, ways to optimize are imagined. Data may be formatted to undergo evaluation cycles to determine how well it performs under certain criteria. The performance will be measured either numerically or graphically; both methods allow the design team (or the computer, in the case of automated processes) to adjust the initial assumptions of the given geometry in the model to create an optimization cycle. Software packages increasingly collapse parametric modeling, optimization, and analysis tools and interfaces. The potential here for design invention is not that architects may replace the structural or environmental engineers, but, rather, that they may invent new criteria and experiment against them on their own early on in the design process, possibly inventing new types of assemblies, materials, and environmental conditions. Architects, while developing their own calibrated and disciplined set of intuitions, may start using models in novel ways. Being able to conduct and observe an experiment in the form of a digital simulation will augment the intuitive understanding of the forces at play in a given model that has previously been understood with traditional analog tools and human aptitude.

In this student work example for a Parisian outdoor market cover, the students collected data about daylight throughout the year and produced a pattern in response to their findings. Further, they exploited the color spectrum of light that relates to the four seasons. This is an example where analytical and performance considerations led to the invention of a new material order that orchestrated the spatial qualities of the market (fig. 4).
Within the exposed technical possibilities and potential diagrammatic associations for architecture described above, we may be able to identify strategic patterns that manage meaningful links between geometry, data, evaluation methods, and computing. What constitutes an interesting pattern in setting up parametric digital models? Are there some systematic organizational logics or tactics that offer a productive, speculative, and experimental framework to an architectural project?

2.1 JIGS

A jig is a simple abstract framework that isolates a parametric behavior from the complexity of the larger model. In the article, “Some patterns for parametric modeling” by Robert Woodbury, Axel Kilian, and Robert Aish, the authors propose three frameworks for making parametric patterns: jigs, an organized collection of points, and component placeholders. They suggest that these techniques be combined in the making of parametric models. These frameworks are, indeed, powerful because they categorize types of abstraction that relate to types of architectural problems.

Of particular relevance to the idea of re-usables is the analogy of a digital jig to a physical jig used in physical construction. A complex physical assembly may be broken down and aided by jigs that perform and control a particular task. Within the setup of the jig, one has to orchestrate the proper amount of control in anticipation of the complexity of its assembly within the whole. An effective jig, according to the authors, is one that “appears and behaves like a simplified version of the end goal, has relatively few geometric inputs (or controls), and its internal structure captures the intended behavior.” A well thought out physical jig may be used to aid in the construction of similarly complex situations. We can conceptualize a digital jig in the same manner. Hence, an effective framework for a pedagogical exercise is the translation of physical jigs into digital jigs (fig. 5).
2.2 RELATIONSHIP BETWEEN PARAMETER SET-UP AND PARTS TO WHOLE RELATIONSHIPS IN ARCHITECTURE

Parameters link the characteristics of one entity to the other. Parameters might be intrinsic to the jig, as in local parameter, or extrinsic to the jig, as in global parameter. When a parameter is internal to the jig, the modulation within each jig is unique to that jig; when it is exterior to the jig, all the individual modulations are yet again controlled globally, thus, producing variation that is both specific to the unit and in relationship to the whole (fig. 6).

Grasping the implications of this notion of types of control, local versus global, and when to actuate one versus the other is crucial to the production of new architecture that would elaborate on the traditionally split position of either ordering the detail in the service of the overall form or letting the overall form dictate the detailing. Architect and theorist Greg Lynn correctly foresees the promise of parametric tactics for the discipline of architecture to be “the ability to fuse the hierarchy of parts and whole to produce a deeply modulated whole as well as infinitesimal variation among parts,” thus, working within the collapse of bottom-up and top-down hierarchical order.

3 DEPLOYING ASSOCIATIVE PATTERNS

3.1 RE-USABLES

The promise in the elaboration of digital jigs is that they are infinitely re-usable, as they may be adapted to address problems that are similar to the one for which they were initially intended, like in an evolutionary process. For architects, this suggests a shift from a practice organized around making one-off projects once they have secured a commission to a practice that develops an inventory of jigs or “re-usables” in anticipation of commissions, thus, mimicking the provisional qualities of a financial data sheet. “Parametrics” is the medium par excellence for a speculative practice.

3.2 REGISTRY

In anticipation of the reuse of certain digital techniques or jigs, a registry is created, recorded, and archived. A jig is then activated to serve different projects in a unique iteration, inscribed within its “provisional state” or hybridized with another. The activity of design manages the logistics machine and works at organizing templates, or repertoires of patterns, tapping their potential for activation as spatial and structural configurations. Practice becomes organized around the generation and management of these “re-usables.” The precise assembly of the design logic is invented each time, while some of its aspects are repeated and re-configured based on previously developed strategies that have been captured, recorded, and archived.

In this example, for rendering a facet of geometry planar with the help of a jig, three student proposals using the same basic jig setup produce three different versions of work. The same jig was at play: based on four given points in space, three will always belong to the same plane; the fourth point will not be and, therefore, will need to be projected into the plane defined by the three other points (fig. 7).
3.3 CREATING A REGISTRY OF DIGITAL DIAGRAMS IN THE CONTEXT OF TEACHING

In the context of teaching advanced design studios and special topics seminars, a pool of digital diagrams is created. The pedagogical framework consists in researching a rule-based physical manifestation that may be studied and analyzed. Based on the analysis and understanding of the rules at play, students are asked to transpose the rules into, first, a physical model and, second, a digital model. The analog observations students have made while developing the physical models were critical to understanding tactics and frameworks for digital parametric models. These tactics led the students to propose a digital jig for their model, making their models re-usable in the future; thus, they participated in the creation of a pool of digital templates.

The most productive results were projects that not only achieved the transposition of the rule set into a digital model but also invented a new condition that emerged as a result out of doing so. Several of these projects have already been illustrated in this paper.

![Figure 8](image1.png)

**Figure 8** L-system branching system showing 4 iterations of branching

![Figure 9](image2.png)

**Figure 9** Lynden Meyer branching system as a “re-usable” template—bridge project

3.4 PRACTICING IS AN OPPORTUNITY TO TEST THE IDEA OF REGISTRY

These two examples from practice utilize branching as an underlying diagram to different ends. Based on an L-system, a recursive pattern of splitting is produced. The basic rule for each step is as follows: based on a line L1, a new line L2 is placed at its endpoint, at an angle relative to it, and of a length that is a function of the length of L1. This process is repeated n times (fig. 8).

In the example for the Bloomingdale line revitalization, a system of variable urban infrastructure becomes a series of bridges. The splitting informs the quality of the structure of the bridge, which relies on structural redundancy created by the accumulation of the splits. The discrete changes in the geometry of the splits, in turn, may inform the overall trajectory or deviation of the bridge. Bent steel tubes designed to bend only in one direction construct the splits (fig. 9).

In the example for a luxury chocolate retail boutique, splitting has transformed into a rather leaflike texture that informs the interior skin of the retail space, filtrating views, engaging the visual and tactile senses of customers, making for a complete sensory experience (taste and smell are produced by the chocolate merchandise). The splitting here materializes as a laser-cut, two-dimensional pattern (fig. 10).

The point these two projects make is that, based on a singular diagrammatic matrix, splitting, the actualization of splitting, is inflected by the program, site, and conditions inherent to the project. The underlying parametric model is re-usable yet affords specificity.
CONCLUSION

Provisional modeling, the term coined by Michael Speaks, projects parametric modeling beyond the purely technocratic environment and has implications that support the architect in the anticipation of design. Hence, this platform in support of visionary architecture goes far beyond the assumed roles of efficiency in management-oriented tasks traditionally associated with the word “parametric.” The environment of parametric modeling works to support visionary contributions. Design anticipation may be developed through the making of digital “re-usables” and may form the basis for a speculative practice.

Parametric environments may be the catalysts bringing about accelerated changes in the intuitive ability of architects to grasp criteria in conducting performance analysis and in their own experiments, both digitally and with analog tools. Architects are collaborating with specialists in their respective scientific fields to form computational performance analysis study groups. More importantly, for the discipline itself, architects are inventing new combinatorial interdisciplinary conditions that produce a new set of material and physical effects. This result emerges from the fact that parametric modeling environments collapse geometric modeling with various types of scientific data. This newly accessible data that architects can now manipulate at will has highlighted physical and material conditions that may not have traditionally been put to use in the field of architecture. A good example of this is looking at air, light, heat, or sound as abstract material models whose behavior at the molecular level is becoming increasingly relevant to the architectural project.

Lastly, though computational frameworks for conducting performance analysis with digital simulation are increasingly powerful, many problems remain unsolvable either computationally or due to computational thought-space not yet invented. The physical observation method for developing intuitive frameworks of thought (jigs) has historically proven to be very effective. Look to the work of Antonio Gaudi’s loaded string models that best approximate the mathematical properties of catenaries curves or Frei Otto’s soap films that best approximate minimal surfaces. This paper suggests a commitment to studying the physical phenomenon as a way to reflect upon and best anticipate the rules and orchestration of the parametric digital model. The pedagogical framework presented here focuses on the translation of the observed physical behavior into a digital system, and is intended to be a reproducible model for practice. While the paper presents jigs in physical material terms, it is foreseeable that jigs will become increasingly abstract and requisite to the formulation of the architectural project.

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