HOWE, NATHAN
Kansas State University

PARAMETRICS: TEACHING DIAGRAMMATIC DESIGN PROCESSES

ABSTRACT

Diagrammatic drawings are often used to communicate architectural ideas. However, they can also be used to clarify design ideas and design intent. Learning to use and apply algorithmic and parametric software can expand students' understandings of design and stimulate them to think more rigorously about the design decisions they make. Their decisions can then be effectively communicated to their peers and professors, and eventually their clients using the same software.

Just as a carefully executed façade drawing reveals to students a master architect's use of alignment and proportion, emerging software can be used to teach students to see parametric and algorithmic relationships in the buildings they design. This paper will describe the use of new and developing parametric software in furthering student learning in the design process. It will show how students use parametric software to both think about and learn from the work of master architects. It will also demonstrate students' use of algorithmic and parametric software to communicate their analyses and discoveries to their classmates and professors.

In a precedent exercise, students in my class create analytic diagrams of master architects' buildings using algorithmic and parametric software. They then use these analytic diagrams as models for representing and then thinking about their own work. In modeling the case study diagrams, students clarify their thinking about their own designs. This teaching strategy combines rigorous analysis with cutting edge parametric software to create advanced representational techniques that I found advances students' understandings in the design process.

Using these software tools to model a master architect's spatial intentions enables students to transfer what they learned to representing spatial and tectonic intentions in their own work. The outgrowth of this methodology augments individual students' communication of their design ideas and provides more rigorous spatial thinking within design education.

PAPER

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Just as a carefully executed façade drawing reveals to students a master architect's use of alignment and proportion, emerging software can be used to teach students to see parametric and algorithmic relationships in the buildings they design. This paper will describe the use of new and developing parametric software in furthering student learning in the design process. It will show how students use parametric software to both think about and learn from the work of master architects. It will also demonstrate students' use of algorithmic and parametric software to communicate their analyses and discoveries to their classmates and professors.

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Parametric Diagram

Parametrics is the direct use of software to create associative connections between various parameters. This connectivity allows for dynamic controls within the design process. Although this is a relatively new software-driven paradigm, the parametric diagram and parametric thought is found latently throughout the history of architecture. As far back as Vitruvius' *The Ten Books on Architecture*, diagrams and the use of parameters in clarifying design intent have been abundant. One has to look no further than his treatise on columns to see clear parametric relationships in the order of correct proportions of base to height (1). A more modern example is Le Corbusier's Modular system as the consummate unit of measurement within the Unité d'Habitation in Marseille, France (2).

Software, such as Generative Components, Digital Project, Processing, Rhino Scripting, and Rhino's latest plugin Grasshopper, has made the connectivity of explicit logic more accessible to architects. The potential for exploiting the dynamics of designing, where various parameters can affect entire buildings, is exciting. Performative measures are also being incorporated into this design approach, providing greater validation of parametrics value to the built environment. All of this has coalesced into a new style termed Parametricism, which started in avante-garde architecture firms and is quickly becoming mainstream. It is now essential that all students of architecture be exposed to the concept of parameter-based design.

How does one define a diagram using parametrics? In Patrik Schumacher's article, *Parametric Diagrams*, he discusses the differences between ordinary diagrams and extra-ordinary diagrams. The *ordinary diagram* has a mimetic relationship to what it represents, creating a clear causality between the logic and what it represents. *Extra-ordinary diagrams* have a less direct relationship, representing a construct of thinking which is open-ended and therefore totally indeterminate as to outcome. As Shumacher states, "The crucial difference between ordinary and extra-ordinary diagrams does not reside within the graphic or digital object itself, but in the patterns of its use." (3). Both of these types of diagrams can work in conjunction, however in starting to teach parametrics, the ordinary diagram is the clearer starting point. It allows students to grasp more easily the objective and its power for design thinking.

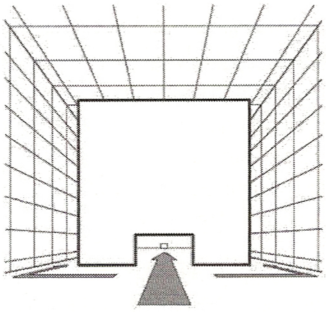
Case Study

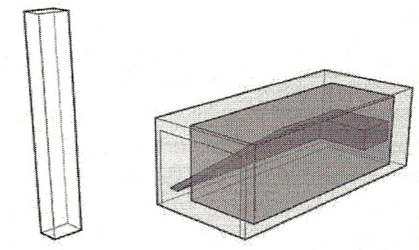
Considering ordinary diagram thinking, the case study becomes a valuable way to first determine the direct connectivity of logic behind the design process. The case study is an assignment used to teach students how to interpret, research, and represent the works of masters through a set of three-dimensional diagrams. The students, who are in their third or fourth-year levels, are just learning to connect all of the design dots in regards to their own design methodology. This assignment helps them to understand the process of making through the lens of a built piece of architecture, as they learn to more fully dissect and digest a piece of architecture. Drawing an object in space helps one to better comprehend an object. In fact, the very act of drawing helps one internalize the object to be used later in one's own creative work (4). The dissection of a building analogously helps one internalize the process of making built form.

The obvious precedent for this type of case study is *Precedents in Architecture* (5). Although this exemplifies a clear taxonomy of architectural buildings, it does not fully dissect the logic of the building to the tectonic level. Perhaps a better example of this type of dissection can be found in *The Function of Ornament* (6). It leads to a better understanding of three-dimensional representation of major ornament in regards to form and tectonics of built work. The case study the students are asked to perform lies somewhere between these two examples. *Precedents in Architecture* provides a better overall example of discussing the major ordering systems of a building: massing, natural light, circulation, structure, while *The Function of Ornament* provides a more clear three-dimensional representation example of tectonic assemblies.

A more subversive aspect of this case study is to have the students reconstruct the basic building object through the use of Rhino and Grasshopper. Using this tool, the student constructs the inherent logic of the geometric construct of the building by explicit parameter-based logic. They also learn the parameters used to formulate the building and how to manipulate these variables.

Geometry

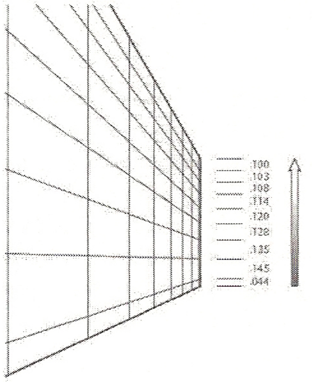


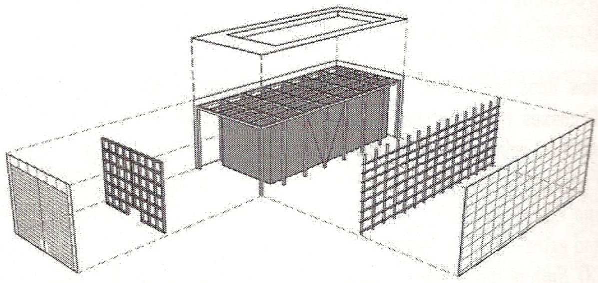


Layers of Privacy are formed by various degrees of enclosure in combination with the pure, non-intersecting geometry of the church. The service spaces, being the most private, are detached from the public experience.

Circulation is similar to a traditional cathedral with main circulation on the primary axis. Secondary circulation takes place between the two shells, honoring the tradition of historical pilgrimage churches.

Tectonics

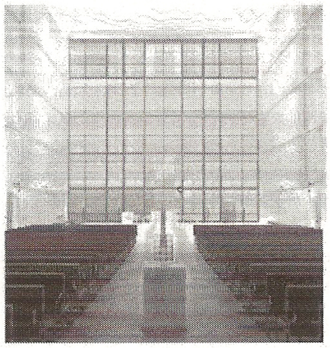


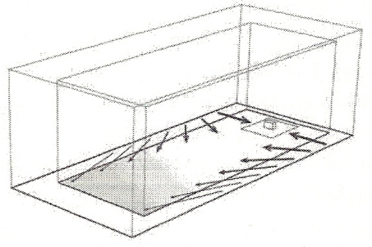


Structure is composed of three groups: a light steel frame to support the roof, a system of glass fins to stabilize the curtain wall, and a heavy hydraulic system to hold and operate the 14 meter doors during certain holy days.

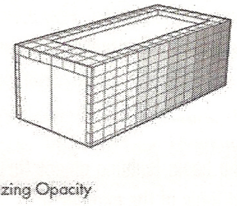
Glazing Size varies according to vertical position. The space between each horizontal joint decreases towards the roof of the church to create an increased sense of verticality.

Luminosity

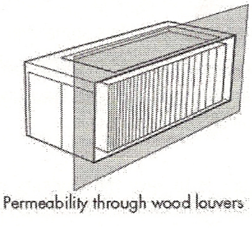




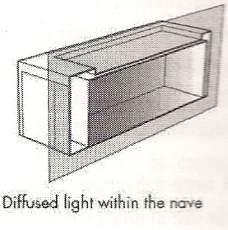
Diffused Light is used to create an ethereal atmosphere within the nave. To reach the nave, light must pass through both the interior shell of wood louvers, and the varying translucency of the exterior shell. The amount of diffused light is maximized towards the front of the nave where the materials are most white. The combination of these two components create a bright, radiant space at the altar.



Glazing Opacity



Permeability through wood louvers



Diffused light within the nave

Figure 1: This illustration shows the basic diagramming of the Herz Jesu Kirche created by students Ethan Rhoades and David Bartlett.

An example of a case study is Herz Jesu Kirche by Allman, Sattler and Wappner in Munich, Germany. Within this church, its mass has a proportional logic in plan of 7:3. Instead of just noting this proportion, the students created a structural grid using the same logic. They also built into the logic the possibility of changing these variables; for example, the proportional ratio 7:3 might change to 6:2. The students then looked at adjustments of different proportional systems dynamically and continued to build in the various tectonics and volumes of the building. As seen in the *Tectonics* diagram in Fig. 1, the major structure, the envelopes, framing and panelization were also studied.

The result of the case study project is students learn the inherent rationality various components have to the whole. Students then develop a tectonic logic to the detail of their own designs which is an essential outgrowth of this assignment. Further knowledge is built when the students subvert the logic the design is based upon and explore potential variations within the design.

As shown in Fig 2., the original louver positioning in the church provides a darker entry to the sanctuary that graduates to light streaming in from the sides as the altar is approached. The students working on this study decided to consider variations on louver positioning. Using this exploration, the students illustrate the diverse iterations which the original architects may have considered before deciding on the final design. This process provides students with a new tool to make critical iterative design decisions: the use of adjustable parameters to simulate multiple ideas set within similar logic.

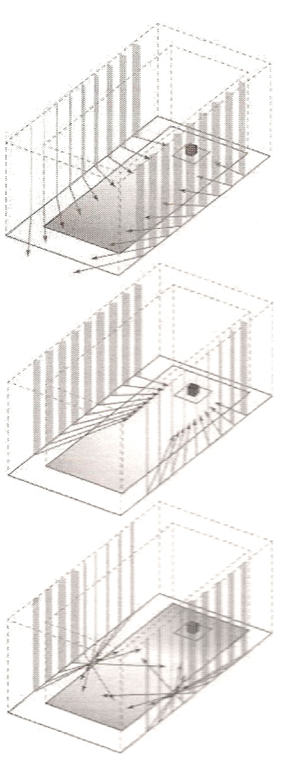


Figure 2: This illustrates the various louver studies. The first image diagrams the existing condition, the second shows all louvers oriented toward the altar, and the final demonstrates a gradation of closed to open to closed again.

Design Process

Up to this point the diagramming has all been *ordinary.* When considering the systematic relationships of the case study, there should be a clear connection between various components of a building; thus the mimetic relationship makes sense. However, as students begin to grasp the explicit logic, more advanced techniques can result. Students begin to combine the ordinary diagramming with extraordinary.

This project was for a one-artist museum in the SoHo neighborhood in New York City. The student, Max Taylor, desired to keep the design simple. Using a simple cube as the formal generator, he analyzed various strategies of locating the cube within the corner site. These diagrams, supplemented with subsequent physical models, were essential in the act of discovery of the contextual impact the various designs had both internally and from the city street.

The diagrams in Figure 3 represent a continued use of creating three-dimensional representations of every major design decision. Once the final scheme was chosen, a more extensive use of parametric diagramming ensued. The major element of the cube floats one story above the street on a glass plinth. This cube's surface is responsible for any natural light coming into the museum. (It should be noted the museum's artist is Tony Cragg, whose work is mostly sculptures.) Bringing light through the surface without large amounts of direct solar gain was the first priority of the design. After a careful precedent study, Taylor found inspiration in the Rail Switchtower in Basel, Switzerland by Herzog + de Meuron. In this project the architects twisted copper ribbons to create various gradations of porosity. The museum design takes a similar tact. However, the degree of twisting is parametrically driven to allow little to no natural light into the building.

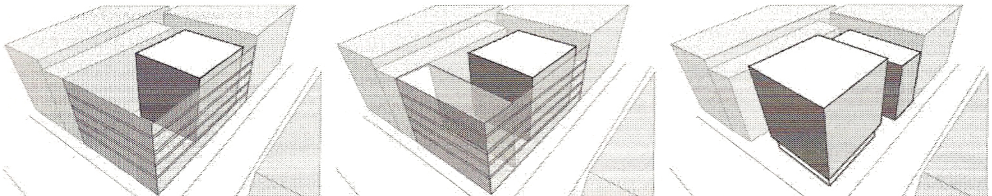


Figure 3: These illustrations of Taylor's design represent various iterations of scheme with the first on the left and the final scheme on the right.

The design of the cube allows it to be free of adjacent connection, except for the support mass to the north, thus creating four distinct sides to consider for daylight studies. The SoHo site is also not true north, and requires consideration of a 37-degree clockwise rotation. As one can see in Fig. 4, the twisting of the metal ribbons is controlled by the vector of the sun at times of the day that the sun would penetrate each individual façade. Therefore, the parametric diagram itself dictates the formal quality of the skin, and each louver's position becomes a highly accurate modulator of light. The diagram's systematic progression remains rather open-ended, particularly in reference to the end formal qualities of the louver skin.

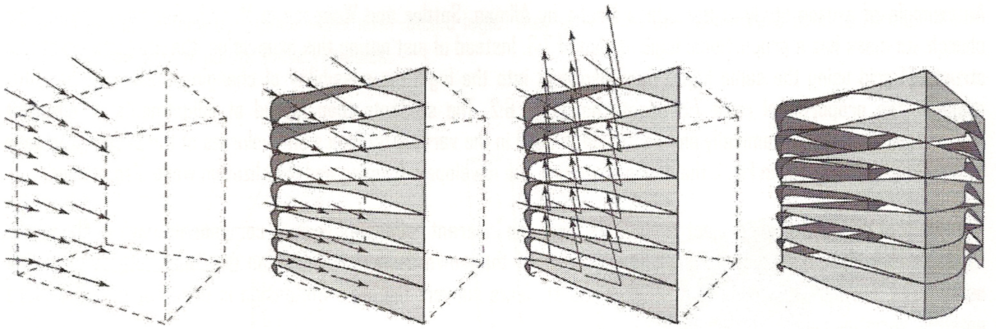


Figure 4: This diagram shows a scaled version of how the solar vectors hit the south-facing façade from 10:00 AM to 2:00 PM December 21st. The ribbon then directly reacts to these vectors, twisting to block the solar rays.

This is not exactly the *extra-ordinary* diagram of which Schumacher speaks: "a Deleuzian (extra-ordinary) diagram is an abstract machine that is valued precisely because its downstream implications are totally open"(7). This louver diagram resides somewhere between ordinary and extra-ordinary. Its final formal implications are somewhat predictable, yet given the dynamic nature of the site's rotation, its final outcome is unknown until the methodology plays itself out.

From this louver diagram, Taylor set up a series of similar design parameters to the case study exercise to establish a more concrete tectonic rationale. Each metal ribbon is attached from behind to the glass curtain wall system. This glass curtain wall system is subsequently attached to the superstructure. This series of tectonic assemblies each have parameters of proportion that establish a pattern based on size of available materials (i.e. glass in no larger sections than 12' by 8', the metal ribbon being attached at a minimum of 8' intervals and concepts of separation of envelope from museum stacked floors). The beauty of this explicit approach is it falls in line with clear architectural practice, yet these decisions are being made in a fluid and dynamic way.

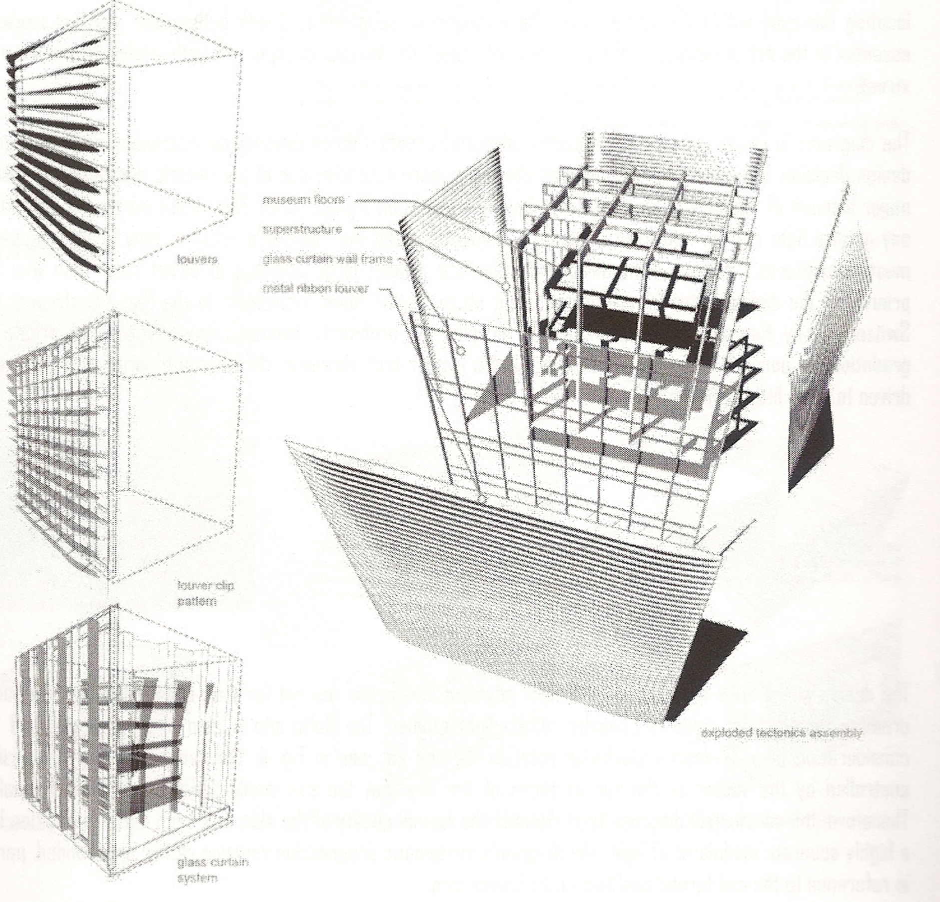


Figure 5: The scaled figures on the left show the associative logic amongst the various assemblies from louver system to superstructure. The exploded perspective to the right helps clarify the assembly at full-scale.

In the example illustrated by Figure 5, Taylor dissected the facade into its various parts: metal ribbon louvers, clips to hold the ribbon in place, curtain wall and superstructure. Each of these components have their own parametric needs but also relative associations between each other. This creates a rather sophisticated connective logic. In Fig. 5, the relationship of the various parts can be seen. The top diagram establishes the position of the louvers which have already been defined by the vectors of sunlight. The middle diagram then shows how the clips hold the louvers in place from below but also their positioning defined by the vertical mullions of the glass curtain wall. The bottom diagram shows how the vertical mullions of the glass curtain wall system are subsequently ordered by the superstructure with every other vertical mullion aligning with the superstructure columns. The horizontal mullions are then aligned with the various floor levels. While each of these alignments may seem prosaic and defined by just "good design", each of these decisions is built into a parametric model, so if more columns are needed within the superstructure, the design would dynamically reflect this change within the vertical mullions and then the clips for the louvers.

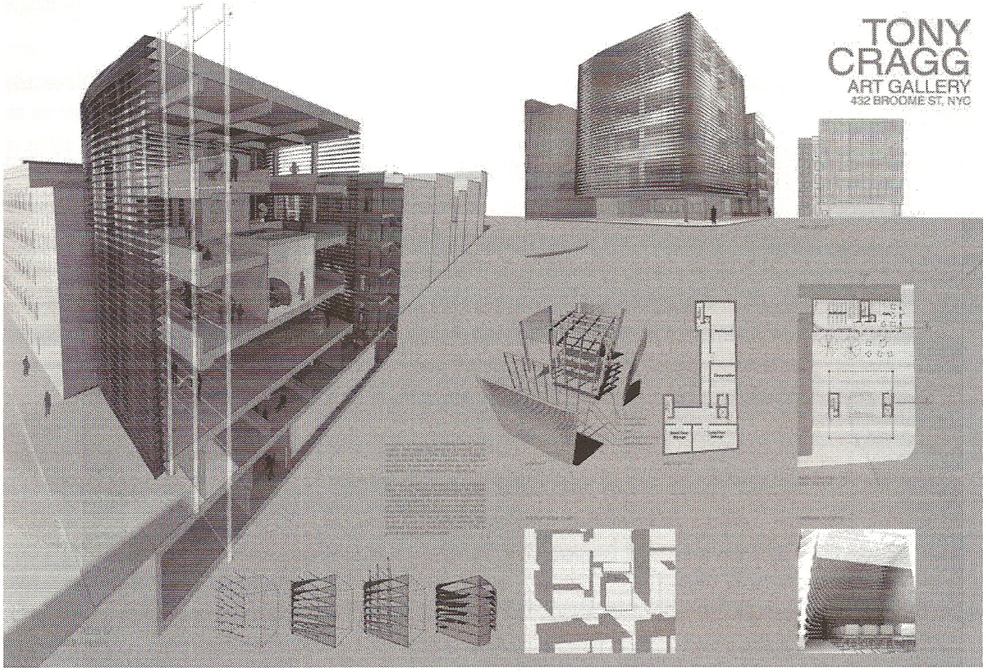


Figure 6: This is part of the final presentation of Taylor's design.

Conclusion

Cutting edge, parametric-based technology allows designers to gain more control over the design concept and technical assembly throughout the process of creating. By explicitly dissecting the works of masters and other precedents using the latest software and three-dimensional techniques, students are gaining a more thorough understanding of how a building concept has connective logic followed through to its assembly. Students are finding a clearer way to make choices based on both geometric logic and material logic, and can further validate their work as not just a formal design gesture but as a parametrically-driven, performative concept. They are learning to dissect their intentions in clear three-dimensional diagrams which help them distill and represent the essence of their design work and the logic behind it. These skills will not only be useful in the classroom, but will translate into the practice setting.

NOTES

1. Vitruvius Pollio, *The Ten Books on Architecture,* trans. Morris Hicky Morgan (Cambridge: Harvard University Press, 1914), http://www.gutenberg.org/files/20239/20239-h/29239-h.htm, 78.

2. Le Corbusier, *Towards a New Architecture* (London: Architectural Press, 1946), 71.

3. Patrik Schumacher, "Parametric Diagrams," in *The Diagrams of Architecture,* ed. Mark Garcia, (West Sussex: John Wiley & Sons, 2010), 260-61.

4. Frank Ching, *Drawing: A Creative Process* (West Sussex: John Wiley & Sons, 1989), 5.

5. Roger Clark and Michael Pause, *Precedents in Architecture: Analytic Diagrams, Formative Ideas, and Partis*, (Hoboken NJ: John Wiley & Sons, 2005), 3.

6. Farshid Moussavi and Michael Kubo, *The Function of Ornament*, (Cambridge: ACTAR, Harvard University Graduate School of Design, 2006).

7. Schumacher, "Parametric Diagrams," 261.

BIBLIOGRAPHY

Ching, Frank. *Drawing: A Creative Process.* West Sussex: John Wiley & Sons, 1989, 5.

Clark, Roger and Michael Pause. *Precedents in Architecture: Analytic Diagrams, Formative Ideas, and Partis*. Hoboken NJ: John Wiley & Sons, 2005, 3.

Le Corbusier. *Towards a New Architecture.* London: Architectural Press, 1946, 71.

Moussavi, Farshid and Michael Kubo. *The Function of Ornament*. Cambridge: ACTAR, Harvard University Graduate School of Design, 2006.

Pollio, Vitruvius. *The Ten Books on Architecture*. Translated by Morris Hicky Morgan. Cambridge: Harvard University Press, 1914. http://www.gutenberg.org/files/20239/20239-h/29239-h.htm, 78.

Schumacher, Patrik. "Parametric Diagrams." In *The Diagrams of Architecture,* edited by Mark Garcia, 260-61. West Sussex: John Wiley & Sons, 2010.