Can BIM Inspire a New Direction in Architectural Education?

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What is true is made.
Giambattista Vico

If you want to survive, you're going to change; if you don't, you're going to perish. It's as simple as that.
Thom Mayne, speaking on the need for architects to adopt Building Information Modeling

The relationship between professional practice and architectural education has, at various times, been synergistic, antagonistic or simply detached. Now, in the 21st century, the two appear to be heading for intimate interdependency. Technological changes in representing and documenting buildings have been accelerating for the past several years, culminating in what many in the profession believe is the most disruptive technology yet: Building Information Modeling[1]. Building Information Modeling or BIM, is an object-oriented representation of a building that is rich with data, intelligent and parametric. From the model, views and data can be extracted and analyzed. Use of BIM has increasingly influenced project delivery and the interactions between architects and other stakeholders. BIM plus the new way of working it engenders, generally known as "Integrated Practice" (IP), hold vast promise– one can imagine having the power to control a wide range of information related to the project, full collaboration with a range of stakeholders, and virtual rehearsal of construction. With IP, practitioners recognize the opportunity for a fundamentally different way of thinking – unbound by traditional ways of working. One of the critical first steps in fulfilling the promise of IP involves architectural education. To prepare professionals who can leverage this tool, educators must shift the way they train students to think and work.

True change is needed – simply adding BIM to the long list of tools we ask the students to use is not an appropriate response. Teaching new ways of thinking requires far more profound alterations. There are many areas in which IP could trigger educational shifts: ranging from the ethics of practice to building construction and design theory. Change will eventually occur in all these areas, however BIM is primarily a representation tool and our discussion in this paper will focus on our experiments with alternative ways to think about representation.

Low Tech BIM

We developed a seminar with the assumption that our learning objectives should address the kinds of thinking that BIM could facilitate, but need not include the software itself. We arrived at this assumption after having considered an approach where students would understand the inner workings of BIM by choosing software that encourages the user to tinker with parametric codes (such as Generative Components or Digital Project). These programs have notoriously steep learning curves, even for digitally facile designers. We quickly realized that if we chose this strategy, students' time would be consumed by merely reaching a level of competence. So we began to wonder if the understanding we sought to achieve could paradoxically come from low-tech, traditional analog processes – descriptive geometry and physical models.

Descriptive geometry requires students to grapple with the flatland of the page while constantly keeping three-dimensional geometry in mind. The simultaneity of generating multiple views from fixed positions fosters supple spatial comprehension. Like the parametric relationship of points in a Building Information Model's database, points on the page become mentally associated to other points in other views. For instance, the projection of a shadow created by two intersecting forms onto a shaped plane requires the translation of one point through several geometric operations. The visual/spatial understanding of these intertwined relationships lays the groundwork for understanding (and exploiting) parametric linkages that go beyond geometry.

Building a BIM model has similarities to building a physical model. With models, the manner in which they are constructed matters. A take-apart model whose roof can be removed to reveal a floor plate reads differently than a model of the same building which can be split open to reveal its section. The exercise of physical model building remains a powerful design tool, and can illuminate the process of modeling with BIM. Alternation between the haptic feedback of an analog model and the digital manipulation of an electronic model provide complementary learning experiences – the media is different, yet both processes necessitate design decisions during the process of their construction.

Collaboration Through Full Scale Work

Much has been made of BIM and IP's capacity to return the architect to the role of the "master builder", the central position among a diverse team of experts. Architects functioning in this way must be able to listen well, synthesize information from a range of sources, balance a variety of needs and agendas, and elicit the best work out of each contributor, while always advancing the design intentions. Collaboration in its professional sense is hard to simulate in an academic setting. Professional collaboration forms among participants who have clearly defined (and complementary) roles, responsibilities and expertise. Collaborators come to the table with experience and maturity gained over many years of practice. It is difficult to create a facsimile of these conditions in an academic setting. Yet it is possible to teach collaborative ways of working if success is measured less on *outcome* (the primary achievement in practice) and more on *process* (a way of working that can be taught in school). The informed give and take commonly found in practice can occur in school if conditions are right. Academic conversations that most closely parallel the language and tenor of professional collaboration occur in settings where teams of students are working at full scale.

The Seminar

The central question posed in developing the seminar was "what is the primary advantage of BIM as a representation tool and how can we teach students to leverage this advantage?" We postulated that the greatest potential offered by BIM as a representation tool was its capacity to connect data (both quantitative *and* qualitative information) to form and geometry. It was notable that the model could altered by manipulating any one of the three and complementarily, information could be extracted in such a way to clearly show any one of the three points of view. Because of this "democratic" treatment of data, form and geometry, we saw the potential for all three to simultaneously influence the design process. While conventional architectural design methods put a premium on geometry, designers using BIM could potentially "see" data and allow it to become an equally powerful shaper of form.

In order to develop a pedagogical strategy to test a new way of "seeing" data, we had to take two major leaps of faith:

1. The media and formats identified above (descriptive geometry, low-tech models and working at full scale) had some inherent connection to ways of thinking embodied by BIM.
2. It was irrelevant that the media used to gain the understanding of data, form and geometry were low-tech and analog – students would gain insights that could be applied eventually to BIM.

Data / Form / Geometry

To lay the groundwork for the seminar, we looked across history at the ways geometry had be used to generate architectural form. Our study of form and geometry in architecture included typological examples from Durand and Quatre-mere de Quincy[2], formal partis in the Ecole des Beaux-Arts and experiments in Shape Grammar[3].We continued along this trajectory and found examples where data was used as an intermediary step between form and geometry, linking numerical information to geometry in order to generate form. Our discussion in this section included examples from algorithm-driven design[4] from early Marcus Novak experiments to current work from MVDRV and UN Studio, to mention a few among many. We established the foundation of the seminar through the following steps:

1. tracing the historical context in which architectural form has been rationalized
2. instilling respect for the established role of geometry in generating form
3. introducing the emerging role of algorithm/data in generating form

Visualizing Data

We also discussed the visualization of data by looking at a range of non-architectural topics from map-making to tracing internet-based connectivity[5] We found that some ways of looking at data were more satisfying than others. Algorithms based on natural processes (such as ice cracking) or geometrical patterns (such as packing) did not seem to have the same potency as the behavior of light on a wall, the interaction of space with sound or the impact of users on a space. As a seminar group, we set a goal to tie social aspects of human interaction in space to some kind of measurable data. Seminar students generated a simple strategy for collecting data about themselves, measuring their interactions with classmates in the studio.

Vault as Strategy: the Search for an Efficient Technology

In seeking a vehicle for the students' seminar efforts, we chose to use a geometric form that was easily documented and manipulated: the vault.

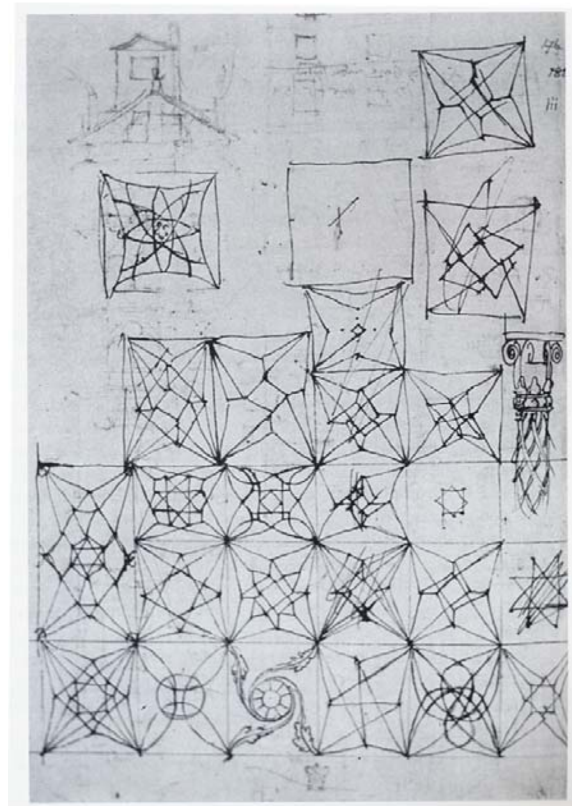

Fig. 1 Dürer's schemes for rib vaults

The understanding of vaults and their geometry is inherently related to their construction. Especially in medieval times, the masons' strategy derives from the search for an easy way to construct. For example, we can see this principle at work in the arch and its geometry: the semicircular arch provides adequate curvature to cover a particular span, a different curvature or different span would create a different geometry for which the arch segments would not fit; this arch is suited to its span and fits its geometry and no other. However, in a complex building such as a cathedral, there are many different spans, which would accordingly generate many different arches. The manufacture of stone pieces for vaulting a cathedral was extremely labor-intensive and masons sought to create a standardized method to work efficiently within a controlled production system[6]. The solution they arrived at is practical and simple: the pointed arch. The pointed arch will cover different spans independent of its geometry, and can even use arch pieces corresponding to an arch designed for a larger span; this is because the two branches converge on one single special piece (a keystone) or two pieces (when vertically joined) obliquely cut. The pointed arch provided solutions to some design problems but also inevitably created problems related with proportions and form[7] but those were relatively easy to solve and the Gothic cathedrals emerged as a significant contribution to the history of architecture. By the end of the Renaissance period, ribs and vaults became extremely complicated, culminating in provocative results like the so-called "geometric vaults" in northern Germany and Czech Republic (see fig 3). Even more imaginative vaults are found in the unbuilt sketches by Leonardo and Dürer (see fig 1 and 2).

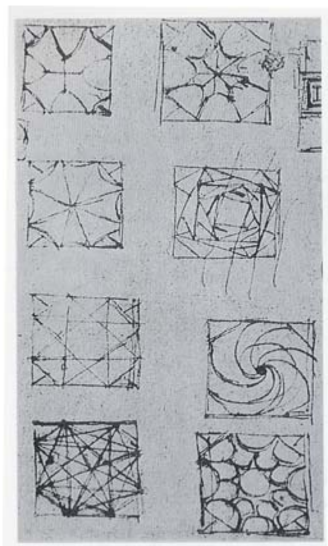

Fig. 2 Leonardo's schemes for rib vaults

Data Generated Vault

While recognizing the historical importance of the vault, we can also understand it as a group of independent elements (arches, ribs, voissoirs, etc.) that are articulated and combined to allow modification of geometrical shapes. By looking at it in this way, we find this accepted form contains the freedom for experimentation and innovation. The vault is not a fixed shape but an elastic system with different possibilities to explore. Another intriguing quality of the vault is its close tie with descriptive geometry. Any point on the vault can be located graphically, relationships between points are mapped with relative ease. For the seminar vehicle, we chose to work with the vault because if its geometrical potential and its close relationship with descriptive geometry. We conceived of our vault as a system of surfaces that could be tied to data, leading to what we call a "data generated vault".

Fig. 3 "Geometric vaults" in Czech Republic

We deconstructed our experimental vault into arches and surfaces, transforming them into straight lines and triangles, all inscribed within a sphere – this was our starting point. The regular geometry of our triangulated vault would next be transformed according to specific data we collected from the seminar group. Each seminar student was assigned a position at the vertex of a triangle within the triangulated vault. According to their "sociability factor", their position was shifted closer to or farther from their classmates. Each vertex was affected by change in any one point, so relationships between the vertices had some indirect connection with the relationships between the students themselves. The following drawing and table demonstrate relationships found on the data generated vault triangle.

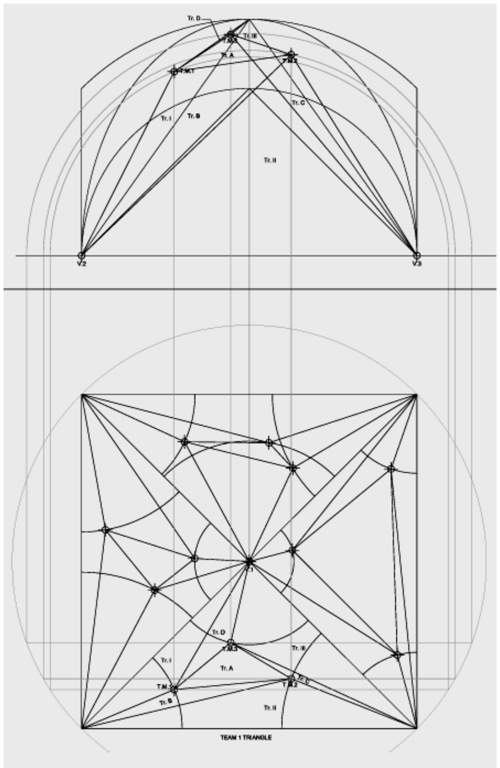

Fig. 4 Data Generated Vaults Scheme

T.M.1	Team Member 1
T.M.2	Team Member 2
T.M.3	Team Member 3
V.1	Reference point in vault 1 (cenit)
V.2	Reference point in vault 2 (base)
V.3	Reference point in vault 3 (base)
Tr A	Triangle Relationship between T.M.1, T.M.2, T.M.3
Tr B	Triangle Relationship between T.M.1, T.M.2,
Tr C	Triangle Relationship between T.M.2, T.M.3
Tr D	Triangle Relationship between T.M.1, T.M.3
Tr.I	Triangle for T.M.1 (with vault V.1., V.2)
Tr.II	Triangle for T.M.2 (with vault V.2., V.3)
Tr.III	Triangle for T.M.3 (with vault V.1., V.3)

The initial drawings (see fig.4) were used to construct a “full scale” version of the data-generated vault out of string and planes of foam core (see fig 5). Analysis of the resulting vault and its reflection (or lack thereof) of the actual social relationships in the group was part of a repeated cycle of revision and remaking. Small differences linking data with points on the vault led to radically different formal geometries. [note: at this point in the semester, we are in the middle of the revision cycle. By the time of the final paper and conference we can be more specific of how the iteration led to an understanding of how data, form and geometry were inter-related within the system.

Conclusion

[note: the seminar is currently on-going and conclusions are preliminary at best.]

We believe the particular opportunities offered by BIM and IP should inspire changes in architectural representation and the production of built form. The strategies from this seminar are not presented as suggestions for permanent transformations of architectural education but they are our first awkward steps responding to the emerging demands of a new medium; experiments with teaching alternative methods of seeing. In recent presentations, educator and researcher Chuck Eastman describes his vision of an architectural education altered from “handcrafted orientation to the machine-crafted world”[8]. There may never be complete consensus on the exact change required, however, as educators we should commit to experimenting with alternative ways of teaching.

Though we sought to question traditional pedagogical principles, we also had to rely on certain assumptions in order to move forward. We tried to call out these assumptions and explain the rationale (or intuition) behind them. We hope that these assumptions will be revisited and clearly tracked within the context of this work. These ungainly early experiments will undoubtedly be viewed with amusement when BIM and IP are commonplace in our schools. But until that time, we need to find ways to test our own thinking as educators and to stretch the thinking of our students. As we all become more nimble, we will open our minds to a way of working that may truly be new.

Fig. 5 Seminar students under the first model of the Data Generated Vault

Endnotes

[1] Recent literature on BIM is extensive, a good reference website summarizes the discussion as of last spring. http://www.aia.org/aiarchitect/thisweek05/tw0909/tw0909bp_bim.cfm

[2] Moneo, Rafael. “On Typology”, in Oppositions #13, 1978. pp 22-45

[3] Stiny G, Gips J, 1972, *"Shape Grammars and the Generative Specification of Painting and Sculpture"* in C V Freiman (ed) *Information Processing 71* (Amsterdam: North-Holland) 1460-1465. Possible Palladian villas : (plus a few instructively impossible ones) / George Hersey and Richard Freedman Cambridge, MA: MIT Press, 1992.

[4] Terzidis, Kostas. *Expressive Form*, Spon Press: NY, 2003, Forward (by William Mitchell) and Chapter 6 “Algorithmic Form”

[5] King, J.J., *“The Node Knows”* in Else/where Mapping. ed. Janet Abrams and Peter Hall, University of Minnesota Design Institute: Minneapolis, 2006, pp. 44-49

[6] John Fitchen has (*Construction of Gothic Cathedrals, Oxford Claredon Press 1961, pg 43-49*) described the gestation of the groin vault in such a way that makes it interesting as a reflection about the generation and the historic conditions, he takes the efficiency principle that the gothic try to achieve

[7] Viollet le Duc (*The Dictionnaire raisonneé: Vol 4 “Construction”, in The foundations of Architecture Selections from The Dictionnaire raisonneé, Goorge Braziller Press 1990, pg 128, 129, 150, 151, 154*) shows in different schemes the evolution of the vault proportions in the horizontal projection (plan), the first ones are based on a square plan and only diagonal ribs were used dividing the plan in four triangles, this are called quadripartite, this form was immediately followed by the sixth-partite which their geometry consisted in dividing the boundary arches attached to the walls in two smaller ones.

[8] Chuck Eastman in his presentation and in conversation with authors, *CIB conference, September 2006*. Alternatively, David Pye, in the *Art of Workmanship,* makes the distinction between the ‘craftsmanship of risk’ and the ‘craftsmanship of certainty’. Though there is a difference between the two men’s nomenclatures, both are calling our attention to the radically different way of working that one can take towards making - one that is variable and open ended, the other that is systematic and repeatable. Professor Eastman’s argument echoes many we have heard on the problems of an architectural education fixed in a 19th century model when 21st century thinking is required.