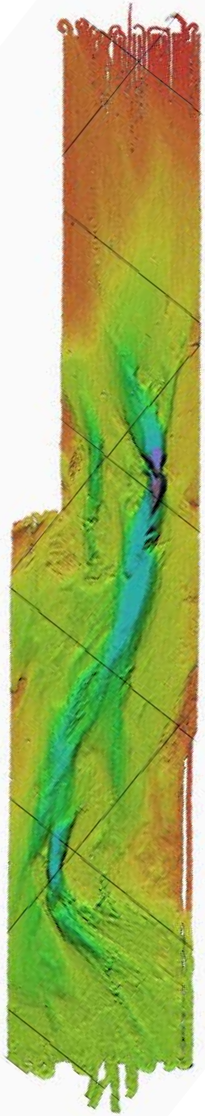


If one were to presume that every major shift in the perception and representational modes of architecture has its mirror in what is made, then we should be able to divine and critique the implications of making architecture through information technologies. We are only now beginning to enter speculations of what can possibly be made as a direct result of these systems. Already, the representation of digital space is undergoing a fundamental transition: From the highly precise facsimile of traditional Euclidean geometry, that we currently use in most CAD and modelling software to the visual interpretation of dense data arrays, as is emerging in GIS (Global Information Systems). This shift from a Vectorial world to a bitmap world is perhaps the most challenging to our historical and perhaps necessary assumption that Euclidean geometry , such as proportion and projection, is at the heart of making architecture. Does this shift imply an ultimately fatal divorce from the Vitruvian tradition of architecture through geometry or is it re-directing the interaction between computers and architecture into perhaps a more appropriate and creative realm of opportunity?

This paper hopes to address these questions in the forum of a theoretical and historical discussion focused on the representation of architecture and making.

“ a circle is a plane figure contained by one line such that all the straight lines falling upon it from one point among those lying within the figure are equal to one another”

Euclid [1]

Geometry began with what was apparent and tactile. Unlike our own understanding of geometry as an abstract algebraic postulate, Euclid’s “theorem” seemed to owe more to an exercise in experiencing the intentional limits imposed on space by the restriction of movement. It is easy to imagine that the demonstration of this proof was conducted with little more than a length of string and the controlled steps of a willing volunteer.

The tactile beginnings of geometry had implications in the origins of architectural theory and making. Vitruvius describes the same geometric figure as above:

“For if a man lies on his back with hands and feet outspread, and the center of the circle is placed on his navel, his fingers and toes will be touched by the circumference” [2]

From this definition, geometry described the boundary condition of the human body as being the idealized prototype for all orders originating from human endeavor. Vitruvian geometry described a proportionate spatial relationship between the human body and the material world. This discreet order at the origins of everything made could only intentionally be revealed through the work of the geometer, or more specifically, the artisan[3]. Geometric order was intrinsically tied to the gestures of the artisan as they spatially negotiated the crafting of material. The mediation of matter with this order had more to do with the dance of strings, steps, marks, cuts and jigs than the pure and rarefied theorem of what we have come to expect from a "Euclidean" mind. The successful appearance of geometry would depend on the practical artistry of the artisan and his/her seemingly mysterious ability to coax and encourage the transmutation of chaotic form into geometric order. Rather than being a rule, proportion helped with the difficult negotiation between idealized geometry and imperfect matter.

Architecture, it could be said, was a paperless endeavor. It relied more on the careful interaction of artisans in a communal project than on a singular and preconceived plan of a geometric object created by the domineering figure of the architect. The creation of the Gothic cathedral, for example, was an endeavor in revealing geometry through craft without total knowledge of the outcome[4]. The closest relative to the architect, as we perceive it now, would have been the master builder, whose task was largely involved coordinating the orchestration of building gestures and the interaction of their spatial geometries[5]. The prospect of the completed work could only be gradually revealed through the course of a project. True providence, that is, the ability to reveal and create the purest of geometry out of shapeless matter, was the exclusive domain of a divine geometer. Any mortal attempt to imitate these gestures could only be shadows of an idea fully resolved.

The inability of mortal craft to presume an ability to reveal idealized geometry through human endeavor lay at the core of mathematical theory of the ancient era[6]. Architecture was central to this discourse, presumably since its theory relied on the continual dialectical tension between theory and practice. Geometry, after all, was an operational practice whose transformative projective gestures were remarkably similar, if not entirely derived from, the world of architectural craft. The most sought after insights into the mystery of geometry were of an operative but not a theoretical nature as we know it today. Theory was the idea of a seamless geometric operation of a transformative nature such as the fabled operation for "circling the square" popular in the Renaissance[7].

Craft, then, stood as the essential bridge between theory and matter. This relationship would be crucial to making architecture, as long the limits to both theory and matter were culturally assumed. Yet, as we know, at some point the artisan's relevance to built work began to fade[8]. Given the dominance of operational craft as a key to mathematical theory, it is perhaps the mathematical speculation of matter being described in terms of pure theory that was coincident with the early stages of the long demise in the role of the artisan.

The Baroque invention of the derivative cleverly bridged matter and mathematical theory by allowing for the speculation of matter that was by definition infinitesimal, that is small, to a *theoretical* extremity[9]. The extension of that theory was that all matter could be described as a function of that assumption. One could only presume that matter had finally, in the geometer's mind at least, fused with theory. The fact that geometry was thrown into a realm so invisible that it had to be conceived of under theoretical terms altered the integral position of craft. The implications of this collapse were far-reaching; if matter could ultimately be considered in a theoretical manner, then any form could in fact be a dimension of theory. No longer could the perceptual faith of the lived world be taken for granted. Things found in the world most likely had an infinitely complex geometry as a substructure to its surface. If phenomenal reality was in fact questionable, then things made in the world could potentially take on any form, any iteration, and in fact could imitate anything. The unique plasticity of Baroque ornament could only result from this shift in perception. What a material ultimately beckons as its form is no longer important to the artisan. Material only becomes matter destined for a manipulation from theoretical principles rather than the discourse between geometry and material. Material now becomes transcendent through theory: wood may become stone; metal may become fabric.

It is ironic that, while the *embodied* truth of the physical world could belay its visual presence, scientific truth began to depend exclusively on the *dis-embodied* observation of empirical evidence[10]. It was no longer acceptable to assume the rhetorical structure to an object. To observe the truth, one had to divorce oneself from hearsay and myth. This deliberate distinction from the phenomenal world was conditional to the presence of an intermediary mechanism to ensure one's impartiality towards the object[11]. The telescope, the microscope or the rigorous protocol of natural observation were all designed to transfer faith from the inconsistent eye to a neutral mechanism. The once embodied structure was now a hidden geometric order that had to be visually revealed through dispassionate analysis of the surface.

The visual revelation of hidden orders beyond the scope of the naked eye were perhaps a turning point in the disintegration of perceptual faith. For as the careful analysis of the surface of things implied an underlying structure, the form of this hidden structure could only be another imperceptible surface waiting to be uncovered. It is perhaps only at this point in history that we see the emergence of the data map as a legitimate representational mode. Edmund Haley's visualization of the historical accounts of the trade winds attempted to create a visual compilation to reveal what was once visually hidden among the varied descriptions found in shipping logs, legends and anecdotal recountings[12]. Perhaps the most ironic variation of this desire to visually reveal the hidden world was the publication of the Diderot Encyclopedia [13]: an exhaustive, if not complete attempt to visually display everything known to humanity. Included among these revelations were the secrets of geometric techniques of all forms of craftsmanship and artistry.

In maintaining its dependence on operational geometry, architecture began to fill the void left by the departure of true artisanship. Philbert Delorme's *traits* or traces were direct ancestors of the operational geometry that was once the exclusive domain of the stone mason[14]. Complex geometric operations intended for the real and immediate conditions of the work at hand became the now familiar steps and procedures of technical drawing *as a condition* to building. Our contemporary obligations, such as working drawings, details or even specifications, are only recent conventions that have supplanted the original geometric craft of 400 years ago.

Our work has been dominated by what could be referred to as a form of *vectorial* projection. Like Euclidean geometry, our drawings have the intention of craft somehow embodied within the lines. We tend to *build* our drawings using projection (whether physical or theoretical) as a means of incorporating the narrative of making. Both our professional sensibility and perhaps our unique perception of drawing usually demand a rigorous geometric scripting of every relevant scope of work leading to a successful simulation of a work. We tend to build into our work the complex assumptions that could be interpreted as artisanal practices: Structural bays, dimensional modulars, hierarchical topologies and even precautionary tolerances.

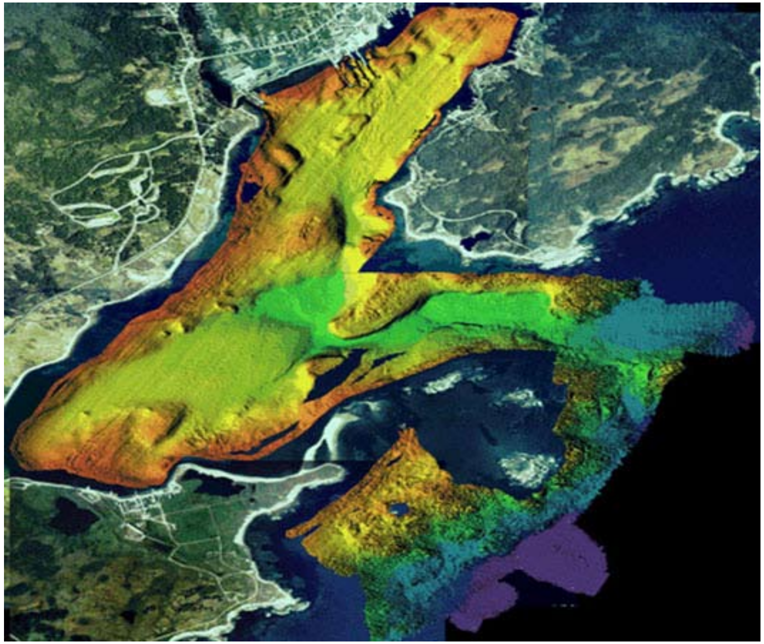
It is entirely consistent with this view that most CAD/CAM packages that have integrated themselves almost seamlessly into the practice of architecture. In principle, these innovations have streamlined the assumptions of technical drawing and predictability to an unprecedented degree. The commands that we commonly use such as extrusions, sweeps, layers etc. are fundamentally techniques of projection that have actually been around for quite a while. For the most part, the building arts have changed little while the standards of production within an architectural office have radically altered. One has to admit that projects such as Ben Van Berkle's Erasmus Bridge in Rotterdam or Ghery's Guggenheim museum in Bilbao have set a good standard for the potential of computer-aided projective geometry within the building arts. Although projects like these are becoming more and more common, they are still unfortunately at the periphery of the architectural mainstream.

One should be aware of the ultimate limitations of vector based geometries within computer systems. The algebraic interpretations of projective geometries conducted within the machine are quite pure; whereas their resolution at the interface with the real world are indeed another matter. No matter how hard software engineers have tried, the pure resolution of a circle at the interface with the user has been an elusive goal. Of course, drawing the *image* of a circle is perhaps one of the first minor accomplishments of graphic software development. It is rather easy to describe a circle mathematically, and visually. However a true circle can only be alluded to, using raster imaging and a good video card. Any one who has worked within these environments knows that ultimately (including NURBS and PATCH geometries) all surfaces and edges must somehow be triangulated: that is, segmented to a degree in which it appears to be pure and Euclidean.

While the *vector* based geometry of CAD software has dominated our work with for the last several years, there has been a growing interest in *bitmap* and data array visualization that may encourage a shift in perception away from our traditional modes of making. A common exploitation of CAD/CAM in recent years has been the photo realistic rendering and the use of image editing tools such as photoshop; these have been mediums used to represent the prediction of architecture rather than play a role in its making. There is a possibility that the dispassionate eye that had emerged in the origins of natural history has perhaps found its way into the revised scope of how we make architecture.

Unlike *vectorial* , geometry *bitmap* geometry is exclusively concerned with the empirical surface of things. The underlying structure, the origins or the generation of that surface are inconsequential to the formation of the bitmap itself. This is intended to be a two dimensional and dispassionate recording of a given state where interpretation is intentionally suspended during its creation. An archaeologist, for example, will only concern themselves with the surface of things. The quality or geometric intentions embodied in things would somehow taint the impartiality and hence accuracy of the recording process. We are familiar with the image of a suspended grid over an archaeological site or even the rigorous process of measuring artifacts through triangulation techniques. This technique of drawing is perhaps as far as we want to be from the intentions of building. What should be of interest to us, however, are recent scanning and point sampling techniques that have essentially automated the task of surface reconnaissance. The promise of such techniques is two fold; where surface measurement resulted in a two dimensional representation of a three dimensional form, visualization software has allowed for the interpretation of 3-D data into a virtual spatial construction. The introduction of heat, sound and motion scanning along side the traditional visual techniques are visually revealing once invisible topographies.

A particularly interesting use of this visualization is in GIS or Geographic Information Systems. GIS is a carefully constructed protocol designed to freely exchange data between sensing interfaces, data arrays and visualization systems. This protocol has enabled geographers to visually reveal a hidden topographical dimension outside of what is immediately apparent to the naked eye. The example used here is of recent mapping research of the ocean floor at Louisburg Harbour conducted by the Bedford Institute of Oceanography using a multibeam bathymetric scanner. This visualization is possible through first the creation of the data set, and the rigorous scanning every square meter of sub-ocean surface. As an idea this procedure is rather simple (one could conceivably do the same task using a weight, rope and a pad of graph paper). Secondly manipulation of the data set is necessary; every piece of data is then interpolated to its both its proper beam orientation and its place in the spatial itinerary of the ship as recorded using GPS. Once this data has been spatialized it is then “cleaned”, or filtered to distinguish between geological, biological and thermal data[15]. This process is dependent on both the creation of algorithms designed as “filters” for this data set and the manipulation of this data in large volumes. The success of such an endeavor is in the volume of information through rapid data collection and the orientation of GPS (Global Positioning Systems).



View of Louisburg Harbour. Bedford Institute, 1998

As one can surmise from this brief description, the principles behind such an endeavor are relatively straightforward. What makes this manner of visualization possible is the processor speed and storage capacity. There is no real "invention" in this system, only a carefully constructed web of interdependent filters, checks and balances at every step that automate an infinitely complex web of tasks into a relatively manageable task. Its success is in the ability to capture every minute piece of data and guide it to its desired place:

"GIS are simultaneously the telescope, the microscope, the computer and the Xerox machine of regional analysis and synthesis of spatial data"[16]

As described earlier GIS acts as a neutral mechanism, specifically to distance the eye from the subject. What is unique about this protocol is that it has the ability to spatialize things that up until this point were entirely invisible either for reasons of scale or discreteness. Any space has a multitude of topographies hidden and coinciding with the lived and real space. Space can be objectified and sculpted by selecting filters that construct a topography of light, heat, air flow dust accumulation. The implications for architecture are indeed interesting. For inherent within even the most banal of spaces there are possibilities of other forms overlaid with the concrete and immediate. Any data set imaginable has the possibility for form.

Conceivably, the design of form could be generated by manipulating the data array itself. For every possible data set that is acquired, one could just as easily be created. Traditional Euclidean geometry no longer needs to be the principal language behind what is proposed as architecture. By exploring the potential of data sets and bitmap geometry we might discover that the appropriate tools for design would be in the category of Photoshop, not AutoCAD.

The important issue for us is not so much what new topographies we can discover, but what impact these new inventions can have on the lived world. We would be obliged to develop a new craft, a new "sensibility" of making that is derived from the inherent abilities of Information technologies . In order to do so, the narrowing the gap between the idea and making must be accelerated. A good starting point would be of technologies that are currently available to us such as rapid prototyping.

While rapid prototyping (stereo-lithography) falls short of our ultimate goal of building digitally, it does provide clues as to how we can translate digital form into realty. The principle of Rapid prototyping is remarkably similar to building a topographic model of a building site: Using robotic action, an object is formed by the gradual accumulation of sectional layers. The virtual object is essentially sliced into an accumulation of "plans", each of which is individually added to the growing object. The general rule is that the more desired the precision, the more frequent the sectional layers of a smaller sectional depth. The key to this method is twofold; first, a protocol of translating the sectional geometry in the virtual environment to the robotic movement of the construction mechanism; second, the automated "work" in which time and mechanical work are directly proportional to the desired precision. Like GIS, the "invention" lies in the careful creation of an interface protocol capable of translating the graphic content of the computer environment into the algorithmic movements of the robotic mechanism.

The fact that this is really nothing more than a protocol reveals the possibility of applying this mechanical principal to the large scale of the building arts. Every component of rapid prototyping could be assembled at the building scale using the techniques, tools and forms of construction that we are already familiar with: similarly, we do have experience with accretive materials such as concrete or even masonry: Large scale construction mechanisms have been commonly used on sites for the last 50 years; robotics has adequately evolved to the point where translating the movement of larger scale machinery to the boundaries of a line drawing are common tasks. Even robotics at the small scale of nano-tech could be applicable to the building arts as well, permitting not only structural construction but even detailed construction at the scale of ornament. The challenge for us then would be to develop an interface protocol for the building arts in the same spirit that GIS had been developed. This interface could be as simple as creating a clear sequential procedure for translating virtual geometry into building guides, or even at the complexity of fully automated construction systems. Either way, the essence of this protocol would be about the translation of pure geometry into artisinal movement.

I would like to suggest that our research should focus more on the development of digital artisanry; that is finding ways to make virtual models real. What is needed is an exchange among the architectural community about the creation of the interfaces that

Impossible topographies: Dalhousie University, student installation constructed from a computer model. Summer 1999

make, based on what we know and what we are most familiar with as architects. Like GIS, our protocols should take full advantage of the processing power and potential of automation that is currently available to us. This protocol should be simple and straight forward enough for it to be conducted by hand. In short, we need to get our hands "dirty" by tinkering with how the computer interfaces with the lived world. In this way we may possibly narrow the gap between *conceiving* and *making.* In achieving this we may bring the idea of geometry full circle and back to Euclid's original definitions.

notes

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