The Stylus Vector

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Among the many aspects that have made drawing critical for the practice of architecture, one of the most important may be that it produces a field for exchange between geometry and perception, between technical regulation and aesthetic desire. As the discipline of architecture has taken on digital techniques substantial changes have occurred in these exchanges. It remains to be seen of these representations should still be classified as drawings.

These changes have raised concerns in both architectural practice and academia. One fear is that what is being lost is the rigorous control of architectural organization that drawing would traditionally regulate through geometry. This can be tied to pragmatic concerns of construction and space planning, or to more theoretical aspects relating form to geometric logic. A second lament is that what is being lost is the range of expression regarding a designer's sensibility through the subtleties of manual drawing. This likewise has pragmatic aspects related to the ease of quickly iterating alternate schemes, and an aesthetic concern involving the qualitative character of handmade representation. In short, digital representation is accused of being too free, too expressive, out of control, and too restrictive, too mechanical, too controlled.

As contradictory as the two fears may seem, the following paper argues that they stem from three aspects of digital modeling that are necessarily intertwined in the software. The issues at hand are firstly, how a digital environment measures, or more precisely computes, secondly, the mediation of scale, and thirdly, the methods in which numeric computation is visualized. The mode of measurement affects the manner in which designs are generated, transformed, and translated toward construction. Visualization affects the manner in which the designer interprets and modifies information. It should be obvious that digital visualization is dependent on the numeric computation. But, the methods of computation used in digital modeling are in part driven by the desires for certain modes of interaction with graphic visualizations. This play between the conditions of measurement and its visualization contains an aesthetic dimension. The following paper holds that the interrogation of modeling software along the lines that connect geometry and sensation is a productive place to understand the nature of the shift from a manual to a digital mediation of representation.

To explain the effects that this shift has on architectural representation, let's look at how to "draw" a measured curve.

In traditional manual drawing a curve is either regulated or freehand. If the drawing is intended to translate toward construction it must be regulated, two prominent methods are the template and the compass. Templates can be straight or curved, a straight edge and a french curve are examples. A stylus is run along the edge of the template leaving a trace of its movement as residue in a medium. A compass can swing portions of arcs of different radii. There are two transformations at work here, translation and rotation. [1] Templates regulate the translation of a point while compasses regulate the rotation of a point. The difference between the first and last point along a translational path is the measured length. The angle of an arc swept by a line perpendicular to a curve at the first and last point of the rotation about a center is measured in degrees or radians. This line from the centerpoint, normal to the curve, describes the radius of curvature which allows calculations of distance along curved lines. These processes of measurement are secondary processes, brought in to regulate the extensive quantities of graphic notations in relation to a scaled unit. It will be the numeric measure that is read off the graphic visualization when the drawing is translated into a construction. Relations between lines will be measured as well, most often to a matrix such as a grid or a baseline datum.

In a digital modeling environment <u>all</u> curves are measured automatically, most often through an algorithmic computation that goes by the acronym of NURBS, Non-Uniform /Rationalized /Basis-Splines. A series of control points are defined in 3D space. The control points are associated to each other in a sequential order creating a control polygon. The first two control points establish a tangent vector for the first point of the curve. The last two control points establish a tangent vector for the last point of the curve. [2] The control polygon is subdivided through an algorithm that bears the name of its founder De Casteljau, who worked for the car company Citroen. The curve that is generated is called a Bezier Curve after its founder and first publisher, who worked for the car company Renault. [3] The De Casteljau algorithm is a recursive algorithm that subdivides the sides of the control polygon evenly along a bounded parameter, initially 0 to 1. Through linear interpolation, each corresponding point of the subdivision of the polygon sides is joined by a line which is in turn subdivided along the same parameter.[4] This subdivision is repeated using the interpolated lines as a new control polygon until the iterations are stopped either by the amount of sides in the control polygon or by setting a specific degree for the curve as a whole. The final subdivision iteration defines a collection of points and related vectors. Each point is on the curve and each vector is a tangent at that point and directed by the bounds of the parameter. This parametric representation allows the curve to be manipulated in several manners along the domain of its construction; degree of iteration, individual weight parameters at control points, addition or subtraction of control points, moving the control points, and by altering the subdivision through the addition or subtraction of knots. These knots join Bezier Curves into Basis-Splines which have the property of being parametrically continuous at the knot sharing a tangent vector that is of the same direction and length. [5] Curves are generated and measured through the rate of change of tangent vectors; the first differential gives the instantaneous vector direction at any point along the curve, an intensive measurement of curvature variation.

The first difference to direct our attention to is that the measurement of entities in a digital model is through the variation of vectors in three dimensional space. Mathematically, this is the world of differential geometry. A curve is measured through the rate of change of vectors tangent to the curve. As described above, to draw a curve the designer constructs a control polygon that is then subdivided into these very vectors. Transformations are likewise directed by vectors in three dimensional space. The translations of a line along a single vector (extrusions) or along variable vectors (sweeps) are common surface constructions. Furthermore, surfaces are measured through vectors perpendicular, or normal, to their surface. This results in the ability to calculate local variation in curvature, often visualized through Gaussian Curvature maps. [6] These vectors normal to the surface also relate to the flat tessellation of a surface, as each normal vector locates a single flat plane in three dimensions. [7] The smooth and the faceted are different in degree, not kind. The apparent qualitative differences between the smooth and the faceted are due to the quantity of computational iteration, subdivision, which has the visual result of increasing or decreasing resolution.

The blunt result of this for architects using modeling software is that there is no longer any necessity for the privileging of a plane of projection. The traditional drawing sets of plan, section, and elevation are orthographic projections that bring three dimensional information to the flat plane for measurement.[8] The drawing of a curve in a manual drawing is one of direct contact on this plane between template, stylus, media and medium. The drawn visualization is an index of a material act, while measurement is a secondary conceptual act entering the drawing to regulate length, angle, and proportion. Of course the traditional drawing set contains a wealth of disciplinary knowledge beyond the act of measurement, but, the following question must be raised. How much of the value we attribute to these drawings has accrued over time through the repetition of use and how much is due to an internal disciplinary necessity? The earliest “plan” drawings are markings of the earth for surveying or foundation layout. [9] An elevation, in its Renaissance refinement, is a drawing that distorts vision but is true in its measure on the plane. [10] This is a drawing explicitly required by the architect as put forth famously by Leon Battista Alberti and in the letter to Pope Leo X attributed to Raphael. [11] These privileged projections owe much of their power to this necessity of flat planes for measurement. Digital modeling makes the coincidence of measurement with the planar projection obsolete, thus as architects we need to consider what other reasons we have for requiring these more traditional interfaces.

The question of scale is radically different in digital mediation. For obvious reasons a hand drawn orthographic projection cannot be full scale, but has to be reduced. This reduction is geometrically handled through the regulation of similarity by proportional scales. Similarity also functions visually as we understand the shapes on our drawing board to be the same shapes in a building in all aspects besides size. This understanding of similarity has been in western culture since Euclid, and is so foundational it often goes unnoticed. [12] But this seemingly neutral perceptual leap has large conceptual and aesthetic consequences for drawing and design. The reduced scale at which architecture is drawn brings with it an abstraction as the line is continually changing the material or organizational conditions it signifies. Consider the differences between the lines in a thumbnail sketch, the lines in a building section, and the lines in a construction detail. These are shifts between lines as perceptual cues, to lines as indices of virtual cuts, to lines as conventions defined by a profession. Drawing scale is a condition that structures this slippage of interpretation. This abstraction due to scale thus allows the drawing to delay specific reference to a physical condition and instead organize spatial and formal relations, often shifting scales in the process until a more concrete articulation is determined. In a digital model, every line is automatically full scale and related to an entity. The abstraction that comes with a reduced scale is absent, and the temptation is to very quickly articulate an object. The designer can “zoom in” to model as much detail as time permits. The model becomes the building in all its detail, a full scale simulation of a physical material future.

This condition of simulation in important to point out as a curve in a digital environment can be continually redefined and rebuilt through altering the parameters defining its computation. This is in large part due to its numeric computation as a parametric representation. In the hype that has surrounded the conversation of parametric design in recent architectural discourse, it is well worth remembering that almost all entities in a digital modeling environment are parametric by necessity. Parametric representation allows the entity to be manipulated in a three-dimensional space without being altered by that movement. That is, its numeric computation is dependent on an independent range of values, parameters, not the xyz of the global space. [13]

The curve in the discussion above is an example of one such entity. The control points are established by the designer, these set the parameters for a recursive linear interpolation that builds vectors tangent to the curve. The designer interfaces with these points in order to alter the simulated visualization of the curve. Besides the first and last points the manipulation of the curve is through control points that are not coincident with the curve, implying a control polygon like a constellation of stars surrounding the curve. This push and pull of control points is what gives the feeling of a marionette like action, where there is a real time result for actions taken at a distance. It also gives the disturbing feeling of a curve only ever being an approximation, intuitively pushed and pulled from a distance and never truly “touched”. Only a final collection of interpolated points is visualized as the curve, not the control points, not the control polygon, not the levels of interpolation within the control polygon, none of the constructive geometry in the generation of the curve. There is a tradition in architectural design of equating formal rigor to the ability to be able to account for the process of each design move. Drawing is the layered repository, explicating the sequence of marks and measures that tectonically build up the final design. Because the designer does not see how the curve is being constructed in modeling software, there is a break in the understanding of what each design action is producing.

This triple condition of three dimensional measure, full scale representation and visualization through simulation are significant alterations in digital mediation and understandably raise concerns for architects. But, these aspects of modeling software did not occur by accident, the software was explicitly designed to operate in this manner.

Digital modeling software, especially NURBS based modeling, was developed by the automotive industry for the "styling" of car surfaces and their digital fabrication. The algorithms needed to be precise numeric computations for fabrication yet flexible enough to be intuitively controlled by the designers that were using them. [14] Differences between software platforms are too often overlooked. It is not the introduction of the "computer" or CAD in its standard format that we should think about when we speak of how digital technologies have radically changed architectural representation. These technologies are updates on machines that perform numeric calculations and there is a direct line of ancestry heading continuously into early modern times as architects have searched for mechanical aides in computation. [15] What was dropped into the lap of the architectural discipline in the 1990's was something distinctly alien to the discipline's standard representational processes. This is software that provided an intuitive control through parametric representation of "freeform" surfaces in a virtual 3D environment. "Freeform" surfaces are major concerns for ship, aircraft, and automobile designers. When these industries went digital in the 1960's they were specifically focused on engaging the digital fabrication mills emerging at the time. [16] The software they developed was a strange hybrid of shipbuilding contour drawing techniques; calculus based differential geometry, and digitally coded recursive algorithms. This mutant environment was half drawing/half modeling, and is the basis of the software that almost all architects currently use for digital design.

A car body designer is a "stylist" working with the explicit concerns of arousing desire through surface curvature; desire for luxury, for efficiency, for attraction, for individuality. Their work is affected by aerodynamics, but it is rarely pure pragmatic optimization that drives the design. For most car designers the aesthetic performance is just as crucial as the wind tunnel performance. [17] This balance situates the car designer in a different relationship regarding the rigor of geometry. Instead of the concerns with logical procedure that architects associate with rigor, the car body designer is obsessed with issues of surface continuity and discontinuity, often as a relation between tactile and visual sensations. To be able to precisely control the continuity of discrete panels forming a surface requires control over matching tangency along that edge. This control was achieved for the first time numerically with Bezier Curves. [18]

These techniques for parametrically representing surfaces were taken up in the 1980's by the entertainment industry. It is this industry that pushed the software into the form that was brought into the architectural discipline. The entertainment industry also wanted intuitive control over freeform surfaces, but to create rendered images, not built reality. This industry pushed the increased performance of surface tessellation and subdivision meshes in order to render ever more realistic qualities in a surface. [19] They also developed animation controls by associating multiple geometric transformations parametrically that approximated the bodily deformations of movement.

The interface with a parametrically defined surface performs in an interesting manner regarding these concerns. The apparent real-time variation begins to give the surface a kind of strange tactility. It begins to give a sense of deformation, which is a material property, not a geometric property. [20] Rubber deforms, as does wax or clay as pressure is applied. It is much more important for a car body designer or a digital animator to have this real-time simulation of deformation than it is for them to have a trace of the procedural logic that builds a form. If the manipulation of a surface or a curve continuously left a visual residue of its process, it would cloud the visualization that the designer is continuously evaluating. The car stylist and digital animator want the geometric construction to disappear from view in order to focus on the resultant affects of the object under design.

To recap, the modeling software that architecture uses was developed to give rigorous numeric measurement of freeform surfaces through an intuitive control of curvature. And on the other hand, visualize qualities such as color, texture, luminosity, reflectivity, transparency, and animate the smooth deformations of motion. Described in this way these attributes begins to sound strangely reminiscent of late 19th century aesthetic discussions.[21] Aesthetics address theories of perception thus lie at the core of this paper's questions. The three issues discussed earlier, loss of planar projection, loss of reduced scale, and loss of procedural index, are conceptual and aesthetic problems for how architecture understands and exploits the mediation of representation. The change is not a loss of concept or a loss of aesthetic, but difference. Traditional manual drawing is not a neutral field for exchange between geometry and perception, between technical regulation and aesthetic desire. The flat plane for geometric regulation leads to an aesthetic condition that trusts judgments made in the two dimensions of plan and section over those perceptually implying three dimensions. The necessity of scale reduction introduces a destabilizing abstraction that allows drawings to be interpreted in multiple manners. A procedural buildup in layers of material residue provides a trail of design process but can just as easily become a fetish of labor. These aesthetic conditions of architectural representation are all altered by digital mediation. The question remains as to how architecture understands the impact.

If architecture is not to outright reject digital working techniques, it has to consider the impact of these changes. The middle position is to use the computer to mimic traditional representational methods, a position which ultimately stunts both manual and digital representation. It thus becomes crucial to explore alternative aesthetic conditions that digital mediation opens for architectural exploration.

One position that the discipline could take has already been suggested. This is to take on the aesthetic desires of the design practices that originally developed this software. Some suggestions have already been hinted at in car body design. The other is suggested by the entertainment industry with animation and game design. Although I find these practices to be fascinating, and to offer much in the way of challenging long held representational tropes within architecture, there are other aesthetic desires that as an architect I feel are necessary to pursue.

The drawings presented as part of this paper offer an initial exploration. They look at each of the questions above and attempt to engage an alternate possibility contained within digital environments. The flat plane may not be necessary for measurement and geometric regulation, but the vector is. How can we visualize these vectors, and begin to operate directly on them? The abstraction of reduced scale may be missing, but the relations between the limit of the pixel and resolution of display are novel abstractions ripe for exploration. The digital environment understood as a field of vectors of differing directions and intensities likewise begins to hold off the finality of a closed object. A parametrically defined surface offers an alternate interface for working variation. How can we gain a visual trace of parametric variation?

These drawings are experiments that seek to renotate a series of curves under transformation through making explicit their vector construction of lines tangent and normal to the curves. The desire is to foster an aesthetic from the visual residue hidden within the construction of curvature in a digital environment. The curves are controlled through manipulation of control points, but the judgment of the transformations is focused on the related vector lines. Length of line, density of line and color of line are then manipulated parametrically along a gradient. The issues at stake here have to do with sensations of depth, movement, speed, intensity and the vibrations of moiré effects that occur as the systems of lines drift and overlap; all qualities that open aesthetic questions around painterly effects.

The methods that architectural representation deploys in order to describe spatial relations are techniques related to an extended aesthetic discourse. Many techniques are specifically tied to the flat plane of the painting or drawing and its frontal reception. These are questions such as how to structure a composition in relation to the edge of the frame, how to imply depth in a flat plane, or how to give a sense of dynamic movement to a static image. Architecture is directly involved in these questions of planar organization and spatial implication. Manual drawing is a wonderful mediation for architects because it holds all of this potential together. It can be loose, sketchy, abstract, and free. It can be precise, measured, template regulated and compass divided. It can be linear and geometric, but also can suggest depth through tone, shading, chiaroscuro, and in the repetition of marks, motion. [22] As architecture engages digital technology, many of the conditions that established this aesthetic discourse in terms of mediation become altered. If digital modeling is to become a mediation technology to rival design drawing in its traditional modes, architecture will have to explore the differences within an aesthetic discourse. It is in asking questions such as these that continuities with the traditions of drawing can be articulated, and provide the discipline a connective tissue as it transitions systems of mediation.

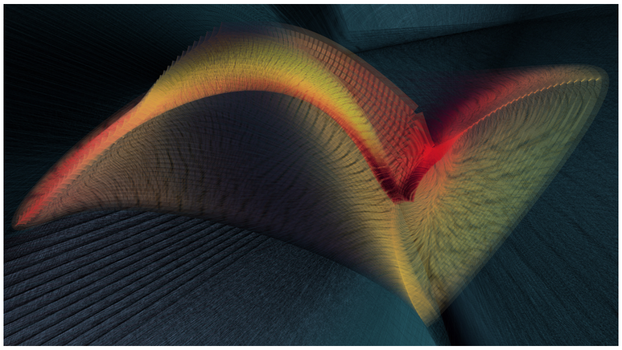

Figure 1. Involution 1 – The Sprawl – 2011 - Drawing by Author – All Rights Reserved

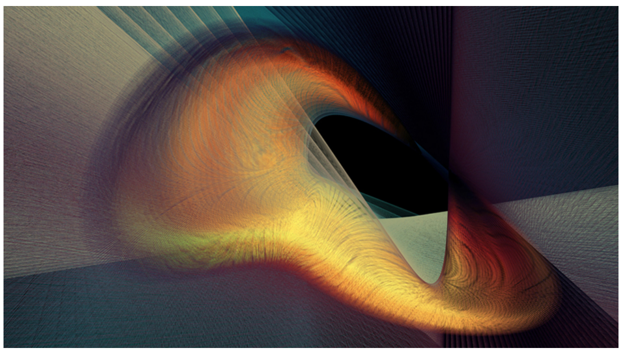

Figure 2. Involution 2 – Eliminator Jr. – 2011 - Drawing by Author - All Rights Reserved

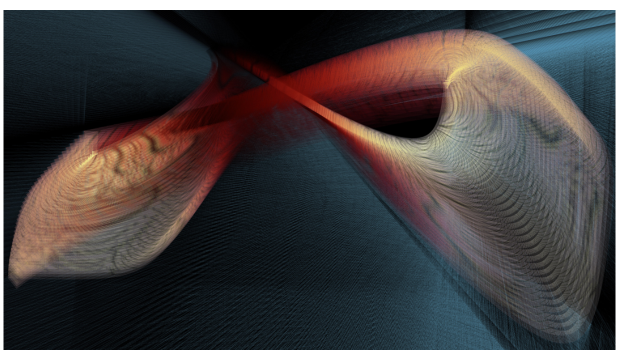

Figure 3. Involution 5 – Silver Rocket – 2011 - Drawing by Author – All Rights Reserved.

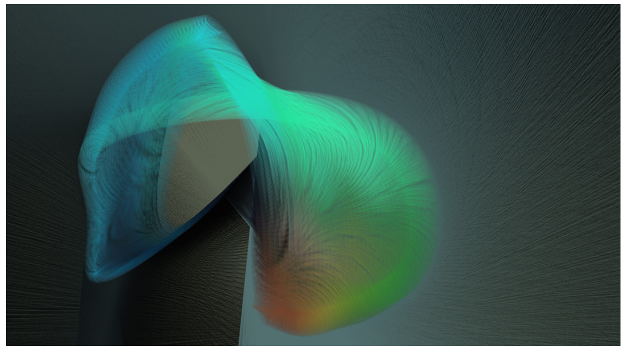

Figure 4. Involution 8 – Rain King – 2011 - Drawing by Author - All Rights Reserved

ENDNOTES

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