Building, Seeing, Thinking:
The Use of the Computer in the Investigation of Visual Logic

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A body of speculative work, produced with a solid modeling program, demonstrates how the use of the computer can radically transform the range of questions asked by the designer, affects the type of work produced, and questions the foundations of design logic and visual perception. Reality is a function of the tools and conventions used to describe it.

Implicitly, the work speculates on a "virtual reality:" the reality we read into and mistake for representational conventions and the "reality" which results from an application of non-traditional logics to existing architectural form. Using "real" architecture (existing buildings) as a point of departure, the methods described below consist of the application of processes which break down distinctions between the 2nd and the 3rd dimension (between the object and its representation) and which break down the distinction between "architectural" and "natural" (genetic, generative, etc.) processes.

The examples given suggest a number of alternatives which might help us define the role and realm of the computer, suggest directions which have yet to be pursued, and evaluate versions of reality which have been hitherto unavailable to the architect. The examples take the form of a series of exercises which break down in the following ways: 1) exercises which use simple computer models to question the threshold between 2D and 3D projections (eg, between plan and perspective), 2) exercises in the logic of form which use grouped scaling, translation and rotation functions to generate new buildings from existing buildings, and 3) a final exercise which applies that logic to urban design.

The questions which I hope to raise with this work are critical and timely. As three-dimensional modeling programs become available for architectural design what operations and capabilities should they offer? What constitutes the realm of the arcane in design? How theoretical is too theoretical? Should the computer serve the needs of the traditional design studio or should it chart for itself an entirely new realm of visual investigation? Should the computer serve the "real" or should it redefine it?

The projects presented are limited in scope and speculative in nature. It is not my intention to propose a new architecture divorced from the exigencies of structure, function or economics, nor to suggest that traditional methods of building and building design are not sufficient to their task. As commercial CAD programs have demonstrated, the efficiency of the status quo can certainly be enhanced by the use of the computer. Rather, the projects presented below suggest a point of departure for a discussion of new design methods appropriate to the capabilities and possibilities of a new technology.

Dimensionality and Projections.

Behind every two-dimensional composition lurks the possibility of a third dimension - the dimensionality of any composition has as much to do with the view from which the composition is being presented than with any absolute dimensionality inherent in the object represented¹. A square, for instance, may be a cube seen frontally and it is not until the cube is rotated that a third dimension is revealed. Conversely, in the absence of movement all three-dimensional objects are encountered as projections on a two-dimensional plane (our cube, once rotated into perspective, can be interpreted as a two-dimensional composition of contiguous rhomboids). The space of the canvas, page or screen is an ambiguously dimensional space. It
renders ambiguous the dimensionality of the object depicted and in so doing it leaves the representational intention of the composition undefined. The same set of figures can be labeled "plan," "axonometric" or "perspective." Not until the figures are rotated into another view do differences between them become apparent.

Two-dimensional compositions and projections (whether images on paper or on a computer screen) can be taken as occasions for misreading. By questioning the authority of representational conventions, for example, a perspective drawing might be mistaken for a plan - and such a misreading might operate as a means by which to introduce and absorb perspectival distortion into the composition as a structural effect. There is a well-documented history of such "abuses" of perspective both pictorially and architecturally - from anamorphosis in the Renaissance through the forced perspectives of the Baroque to the more recent explorations of Aalto and Eisenman. Even Cubism, if treated reductively, can be seen as a quasi-systematic set of transitions from the second to the third dimension - an oscillation between plan and perspective in which additional faces are generated over successive iterations.

While the two-dimensional representation of the three-dimensional object has always harbored a compelling ambiguity, perhaps nowhere is this ambiguity more pronounced than in the "modeling" environment of the computer. In contrast to a model built of chipboard which can be touched as well as seen, the viewer's relationship to the computer model is abstract and visual. Yet, unlike the conventional perspective or axonometric constructed by a draftsman, the computer model is more than a drawing for it is capable of sponsoring an infinite number of views and projections. The computer model affects an autonomous three-dimensional existence by allowing itself to be rotated relatively fluidly, manipulated on a number of levels and pivoted in and out of the third dimension simply by toggling between views. In creating a computer model, then, one is acutely aware of interacting with something three-dimensional, yet, in the absence of a tactile experience of the model, one's experience is still limited to two-dimensional projected views.

Thus the computer model always exists for the viewer somewhere between the second and the third dimension - between the three-dimensional object and the two-dimensional projection. While there appears to be a "real" object there (an effect heightened by animation, shadows and sophisticated rendering techniques), this "reality" is, for the designer, never more than the sum of its projections. The question of what is there and where there is remains open ended and ambiguous. The question is also provocative.

For this reason the present generation of three-dimensional modeling software offers a propitious environment for questioning both the conventions of representation and the question of dimensionality. It not only facilitates various modes of representation by quickly calculating complex projections (such as perspective), but in so doing, it introduces a dynamic dimension to the projection which appears to erase the difference between the object and its representation (or projection), i.e., between the second dimension and the third. When the distinction between a two-dimensional view and a three-dimensional object is simply the angle from which the object is being viewed, both the projection and the object "itself" lose their authority. When everything is projection, both the status of the object and the dimensionality of the projection are up for grabs. The model qua projection is dimensionally ambiguous. When considered, the indeterminate dimensionality of the model/projection is similar to the concept of a fractal dimensionality (although it bears a different relationship to the question of scale than, for instance, the Koch curve or Mandelbrot's coastline). It might be assigned a dimension of 2.5.

When Alois Riegl developed his "tactile/optic" distinction to describe the difference between representational and pre-representational art in antiquity it was to address the relationship of the model or depiction to some "reality" external to it - the representation to the represented. The representational conventions used in the Egyptian art, for example, comment on the status of the deity depicted. The absence of perspectival space and spatial overlap in the work of art suggest that the deity (pharaoh, etc) did not occupy the three-dimensional realm of
the viewer but some less corporeal realm plane. The relative "two-dimensionality" of Egyptian relief sculpture indicates that ideality was largely incompatible with the physical space and time of human experience. Two dimensionality, then, stands in for a notion of "other" dimensionality - whether fewer or more than the three dimensions in which human existence is wrought. Conversely, the high relief and spatial overlap which characterized late Roman relief sculpture corresponded with the subject matter of the representation: human beings and human history. A strong three-dimensionality pervades this work as art came to terms with the world of space and time.

Dimensionality, according to Riegl, is not neutral, but indicates the relative reality or ideality of the object represented. A work of art is "tactile" in the absence of representational conventions such as perspective which evoke the third-dimension. In the absence of these conventions it is also abstract and spiritual. The presence of the third-dimension in painting and relief sculpture (as evoked through representational conventions) generally indicates a correspondence between the pictorial space and physical reality. Conventional representational art depicts entities as they exist in perceptual space and as they obey the laws and physics of that space. Conversely, as exemplified in Egyptian and Early Christian art, two-dimensionality is the domain of the spiritual.

The development of representational conventions corresponds to a self-reflective interest in history and a progressive desire to represent human, rather than divine, subjects. With the interest in human history came the need to represent space. With Renaissance perspective came the ability to place the viewer into the space of the painting and extend the space of the painting to encompass the space of the viewer.

Such a reading of representational conventions allows us to comment on a number of changes to pictorial space which took place at the beginning of this century - transformations which were anticipated by Riegl's writings. In the context of representational painting which dominated western painting since the Renaissance, the Suprematist compositions of Malevich seem paradoxical and jarring. The intentional suppression of the third dimension in these canvases appears as an explicit evocation of abstract spirituality. As banal and familiar as they are, Malevich's two-dimensional geometric figures emerge in almost metaphysical ideality, and the spiritual connotations of the second dimension lend them an iconic power. The influence of theosophy and interest in alternative dimensionalties (fourth dimensionality, et al) manifest themselves as simple two-dimensionality in Suprematist work, whereas other kinds of projections were attempted in the Constructivist work which followed. This two-dimensionality was effective, however, in underscoring the spiritual agenda of this questioning of representational space. More than Kandinsky's lyrical brand of abstraction, Malevich's geometric figures are equivocal - they are simultaneously non-representational and recognizable as form.

Breaking from the influence of Malevich, El Lisitskii employed overlap and axonometric projection to inject the third dimension into simple geometric forms. His work and the work of several of the De Stijl group mixed abstract and non-representational form with the three-dimensional. Again the sense of paradox: how can something which does not exist in any literal way (geometric form) be represented in three-dimensional space? What is the relationship between abstract representation and the third-dimension? If the representation is not real, what is the status of the space? It is not surprising that space, for these artists, existed as a spiritual rather than physical phenomenon.

Both the spiritualized space of Lisitskii and the quasi-representational connotations of the geometric form share affinities with the computer model. The perspectival projection of the computer model does not describe something which exists in space and time - there is no reality external to it for the model exists nowhere. The perspectival projection is a projection of some "thing" which does not exist, and yet can be rotated, manipulated and even constrained as if it were a physical entity. We are doubly removed from physical/perceptual reality, the projection describes the model (what model?), the projection "exists" but the model does not and the model depicts some built or build-able reality. This notion of a projection describing a model, which for all intents does not
exist, is reminiscent of the shadow analogy in Plato's allegory of the cave. Ideality is not something which can be addressed directly but must be meditated through projections.

While the question of the drawing or model's relationship to reality continues to surround much theoretically based work in architecture and fuels the debate over the status of "paper" or unbuilt architecture, the ambiguity we are considering here is "internal" to the model. This ambiguity describes not the relationship of representation to represented but the relationship of the projection to the computer model. Again, we are twice removed from "reality" and a new dimension of ambiguity is introduced.

Also akin to the "spiritual" realm of the Constructivist painters is the notion of a mathematic or algorithmic "reality" which is simultaneously an ideality. What is the ontology of an algorithm? How can we suggest that the computer model "exists"? How can something exist and be nowhere? Clearly the reality of the model is virtual. But, removed from the contingencies of real space and time, it is also ideal.

The question of the projection also raises the question of point of view in a new way and, by implication, explicitly involves the viewer in the question of reality. If the two or three-dimensionality of the composition is a function of the position of the viewer (the view from which it is being seen) than the question of dimensionality lies not with the object but with the viewer. Dimensionality in this sense is a function of interpretation and interpretation a function of the conventions of representation. Reality, again, relinquishes its capacity to transcend interpretation and is increasingly difficult to define. If the perspective and the plan suggest two very different locations and states of authority for the viewer, the fluid interchange between the two can effectively displace the viewer and open the question of the relationship between viewer and viewed.

On a more rudimentary level, the difficulty of manually constructing axonometric and perspectival projections tend to make these drawings ends in themselves. The availability of these projections in three-dimensional modeling systems allows them to be treated as steps in a process in addition to presentation tools. The misreading of these non-orthographic projections as plans or elevations is but one example of how these projections might be used to inform the design process.

Objects and Projections.

(between the 2nd and 3rd dimension)

As explorations of this ambiguous dimensionality, the following series of exercises took up the issue in a number of ways. The first of these used two-dimensional Constructivist compositions as a point of departure. Employing the extrude function, compositions by Malevich and Liassitak were projected as a set of three-dimensional objects in space. The idea was to maintain the integrity of the composition from a particular point of view (e.g. x,y) such that its three-dimensional attributes would not be apparent when viewed from this view. The same operation was then performed on another composition. By interpolating between the two compositions a composite construction was derived which, when looked at from one view (x,y), corresponded to the first composition and when looked at from another view (y,z) corresponded to the second composition. The goal was to move from Composition A to Composition B by rotating once around the z axis then once around the x or y axis. The composite compositions thus contained the attributes of both the initial and final compositions (figures 1 through 4).

The following exercise further explored this ambiguous relationship between the second and the third dimension by comparing an object as it might be seen in perspective with how it might be interpreted as plan. The three-dimensionalised Constructivist composition from the previous exercise was projected as a perspective, copied into drafting (two-dimensionalised), copied back to modeling as a plan then extruded as a new model. This model was then projected in perspective and the operations were repeated. The intention was to observe the transformation of the object over successive iterations (figures 5 through 12).

As stated above, a fluid movement between plan and perspective introduces a potentially
ambiguous dimensionality into the composition. Converging lines which could be taken as an indication of perspective might be non-rectilinear forms seen in some other projection, it is impossible to know until another view is taken. Being dimensionally indeterminate the composition might be assigned a composite dimension of 2.5. Simultaneously, the effect of this exercise was to progressively increase the number of faces of the object, given that the transformation from plan to model at each step effectively transforms faces into objects. A face with four sides, for example, extrudes to an object of four sides, three of which might be visible when projected in perspective. Thus one face with four sides produces an object with three visible faces, each of which produces objects with three visible faces, and so on.

As the effect of this operation is to produce fractured objects which are "cubist" in sensibility, a comparison with Cubism seems appropriate. While not constrained by a reductive systematicity, the Cubists worked very much in this vein, using various projections of the model to breakdown and redefine the model. Not only did they question the distinction between the object and its two-dimensional representation as a projection (or heighten the sense that the object depicted on the canvas was pure projection and therefore not constrained by likeness to the model), but their apologists (including Gleizes and Apollinaire) spoke passionately of a new dimensionality. This dimensionality was most often referred to as a "fourth dimension," but the term was sufficiently ill-defined to encompass any number of alternatives to the traditional two-dimensionality of the depiction and the three dimensionality of the object represented. In the collages of synthetic cubism the ambiguous dimensionality of these combined projections was heightened by the presence of actual objects on the surface of the canvas. Now the model being depicted was contained within the depiction.

The fourth exercise built upon the third, substituting orthographic projections for perspectives and incorporating Boolean functions. In place of the Constructivist compositions used in the previous exercises the point of departure was an architectural model. Models of well-known modernist buildings were projected as 90 degree axonometric, copied into drafting and copied back to modeling as plans. As per the previous exercise three dimensional values were assigned to this "plan" using the extrude function. An attempt was made to translate two dimensional information into the third dimension systematically (by interpreting, for example, elevations of walls as floors, tops of walls as relocated walls, etc.) such that the new model contained space and was convincing as architecture. The new 90 degree axonometric model was then laid over the original model to form a composite model. Using the difference function available within the Boolean operations, the new model was then subtracted from the original model. The 90 degree axonometric model existed as a trace within the original model (figures 18 through 29).

Visual Logic/Design Logic.

In a fundamental way these exercises are about logic. When working with a computational tool such as the computer one is constantly aware of how it "thinks" - how it translates computational data into visual data and vice versa. The next project (the "barn" project) was explicitly about logic, about extrapolating and interpolating rules from a given condition. The point of departure was three simple buildings which sat together in a flat field: a large barn with an interior structural grid and a second floor, a middle barn with simple spanning rafters and a small outbuilding. The exercise was to speculate on a logic that described the relationship between the three buildings and to use that logic to extend the given conditions.

The first step was to analyze the three buildings to determine rules which might describe the relationships (proportional, associative, etc.) and to choose a set of operations which would allow those relationships to be acted upon. For example if B building lies exactly between A and C, what building would lie exactly between A and B? Between B and C? By following through on such questions additional buildings can be generated which interfere with and transform the existing conditions. By operating on existing buildings the structural and material conditions of those buildings are carried through the process.
An example of this can be seen in figure 23 where a rudimentary A is to B as B is to C logic is applied to the buildings. Beginning with simplified solid models of the buildings the small building C is picked up, moved and scaled to fit onto building B. Through the macro function this double operation of translation and scaling is saved. Now the same macro is applied to building B and a new building B’ is produced such that C is to B as B is to B’. A similar operation is applied to fit building B to building A and a new building A’ is produced. Similarly, the same operation is used to compare buildings A and C and produce a new building C’. Having produced these new buildings A’, B’ and C’ the logic can be applied again to produce further iterations (C is to C’ as C’ is to C” and so on).

The next step was to begin to differentiate the real buildings (A, B and C) from those produced by the application of the logic. In this case the new buildings (A’, B’ and C’) are treated as “negative” buildings. Using the difference function in the Boolean operations the new buildings are subtracted from the existing buildings. Because a three-dimensional scaling function was used in the generation of the buildings, the new buildings were distorted vertically and left a trace of their position in the ground plane when differentiated.

Finally, being satisfied with the results of the logic, the process was applied to articulated models of the three original buildings. Interior perspectives of the final model were taken showing the effect of the differenting on the structural systems of the buildings (figures 24 through 28).

In another example (figure 29) attributes of the three buildings were transmitted one to another through a logical, communicative process. Building B was scaled proportionally and placed on building A. Since the two buildings are not exactly proportional building B subdivides building A, leaving a small portion at the far end. Building B also transmits to building A its roof structure which is proportionally lower with a different roof pitch. The composite building A now has attributes of both A and B. Next, building B is scaled proportionally and placed on building C, then composite buildings C and A are taken back to B, transmitting to B their attributes. Composite building B is then taken back to A and C and the cycle is repeated.

Over successive iterations the attributes of C make their way to A via B, similar to the way genetic attributes are transmitted through reproduction. The result is a composite building B which contains all of the attributes of A, B and C over the successive generations of the process. This composite building B (figures 30, 31) is then distorted slightly to conform to the attributes of the initial building B (figure 23) and a series of perspectives are taken (figures 33, 34). Because the set of operations has been performed in modeling, the entire range of three dimensional attributes has been carried along in the process and is immediately available for a full range of three-dimensional views.

In both of these examples formal logic is aligned with a quasi-genetic logic: architecture begets architecture in a process of interpolation and extrapolation akin to mating. The rules which determine what is produced are not a function of formal symmetry or adherence to an ideal type, but a function of the idiosyncrasies and attributes of the context as interpreted by the logical method. The ideal (grounded in typology) and the genetic represent very different points of departure in the generation of architectural form. The ideal type is something which can be arrived using simple visual logic, proportioning systems and residential architectural tools. Genetic process, on the other hand, requires the use of scaling and Boolean functions which allow two entities to be compared and combined. Such a process is often difficult to predict and requires extensive geometric computation. Methods such as this, which began to be viable with the use of tracing paper and the advent of the enlargement/reduction mode on the xerox machine, are now greatly facilitated by the computer. A full range of operations including scaling, translation and rotation can be accomplished on complex building models.

In short, our conceptions of culture, history and knowledge in general have shifted from ideal to genetic models in the course of the last two centuries. While Architecture, too, has shaken off most of its ideal paradigms and has turned to function or economics as its ultimate arbiter, the type is still the standard to which architecture attaches itself. The genetic model suggests an interesting alternative - an emphasis on method
as opposed to an emphasis on form.

In a third example a slightly different logic is used. A rectangle is drawn around the three buildings defined by the extreme boundaries of the buildings. Diagonals from the corners of buildings are crossed to find a center. A square is then drawn around the three buildings, conforming to the extreme boundaries of the buildings on three sides. A similar set of diagonals marks its center. Next the real (rectangular) and idealised (square) figures are overlaid such that the two centers align. The result is an initial location of the buildings and a new location which shows the buildings translated along the diagonal (figure 30).

At this point the drawing lays itself open to interpretation. Because of the diagonal displacement of the two plans the drawing can be read as an axonometric in which the two plans are interpreted as elevations. The drawing was then reconstructed to conform to this reading by projecting the three dimensional attributes of the buildings upward (as plan) and back into the drawing as elevation. A composite model was formed (figures 35, 37) and a number of views of this model were collaged together in the drafting environment.

The solutions to this problem are as varied as the number of logics applied. While it is beyond the scope of this article to describe all possible outcomes, figures 38 through 43 illustrate a range of results.

The Institute for Urban Logic.

The final and most ambitious project attempted in this investigation applied this analytic method to another aspect of vernacular form - the commercial strip. Whereas the intention of the previous project was to define a logic which described the relationship between three buildings, the final project applied a similar strategy to the extension of a city. Based on two pre-existing urban conditions (a small courthouse town dating to the early 19th century and a commercial strip which has developed at an interchange on the outskirts of the town), various logics were developed to predict future urban development for the area. In essence the problem was one of formal extrapolation and could be formulated as an A is to B as B is to ? problem where A was the old town of Cambridge, OH and B was the commercial strip.

After developing a speculative "master plan" for the area using various operations available in the software program, the problem involved locating a site and designing an institute dedicated to the study of logic. The institute was comprised of five distinct branches including a development office which would raise money for research through land speculation.

The problem began with analysis of American urban form and discussions about the morphology of the city since World War II. A range of texts was reviewed from Learning from Las Vegas to Jean Baudrillard's America, and input was sought from philosophers, urban economists and computer scientists. While the investigation of the city was essentially speculative and formal in nature, the problem was written to explore the panoply of forces which determine urban form, placing specific emphasis on the commercial strip.

By traditional architectural standards the commercial strip lacks integrity, buildings don't align, spaces lack definition, no geometric structure is apparent, the third dimension has been excised from buildings (and relegated to a state of pure attenuation in the sign), the notion of frontality has been compromised, and clearly defined circulation routes have been reconstituted as amorphous eddies of parking lots and access roads. While a clear expression of the logic of free enterprise (within parameters defined by zoning), the strip eludes traditional formal analysis. The analytical tools of architecture (axes, alignment, proportion, geometric figures, regulating lines, figure/ground studies, etc.) are virtually useless in describing this formal structure which, since WWII, has become the predominant structure of the American city. The impact of the architect is limited to the isolated building or building complex and does not inform the larger morphological structure.

Faced with such difficulties the architect has three choices: 1) to accept that the order of the city has in some way transcended the language of architecture - postulating that architectural order thrives under centralised systems of
government but falls apart in the atomised environment of free enterprise, 2) to rehabilitate the urban environment through strategic interventions, forcing it conform to time-honored typological standards (this was the mission of the "Cornell School" of architects which dominated academia in the 1980's), or 3) to broaden the definition of the logic of architectural form to encompass what exists. The latter addresses the alienation of the architect without taking a nostalgic, moralistic or reactionary position. At the same time such a proposition is open to criticism for the lack of judgement implicit in accepting "what exists." Nostalgia and utopianism aside, however, this third option may be the only route realistically open to us. It would remain for architecture, then, not only to accept "what is" but to critically confront it on its own terms. To do this we must establish just what those terms are, understanding that to define the situation is already to redefine it.

In short the strip demands a language. It has been demonstrated in the shape grammar literature that even apparently random or highly intuitive designs can be "reduced" to a set of rules. Yet to aspire to reduce the economics of free enterprise to a simple formal logic would be no less utopian than the aspirations of Pugin or Leon Krier with respect to the past. What must be changed is the definition of rule rather than the desire for a descriptive language. The notion of "rule," "logic," and "language" in architecture must extract themselves from time-honored conventions in order to evaluate both the environment and the conventions themselves. Conventions must be critically rehabilitated. It is because of the complicity between the convention and the tool that the computer offers such significant possibilities.

Because the logic of the strip is not properly a plan logic but a logic of perspectival arrangement from specific points of view, a number of the projects returned to the issue of perspective as their point of departure. Bart Overly set up a series of three-dimensional cones of vision relative to bends in the road and to points of access into the strip from the exit ramps of the interstate (figures 44 through 46). These cones of vision were used to predict where development should occur as well as to determine optimal heights for signage in order not to be obscured by buildings or signage in the foreground. Where these cones of vision intersected he located the various branches of the institute - atomised and distributed along the strip to correspond to the prevailing morphology. The perspectival cones were subtracted from regular geometric solids which were then developed into buildings (figures 47 through 53).

Also taking perspective as a point of departure, Mark Niemi used drawing conventions to question the threshold between the second and the third dimension. Early on in the project he noticed a strong affinity between an aerial perspective of the strip and a plan of the strip distorted in the horizontal dimension. By using the scaling function to stretch the plan, a distorted two dimensional drawing could be made to imply the presence of the third dimension (figures 53, 54). When stretched further (to approach a horizontal line) the plan assumed the characteristics of an elevation. The process might be described in the following way: one begins by looking at a landscape in plan and slowly lowers one's point of view (or rotates one's view upward) such that the view moves through perspective to elevation. In this respect the aerial perspective can be considered to exist exactly between the plan (x,y projection) and the elevation (x,z or y,z projection).

Having postulated this link between the second and the third dimension the designer used the vertical locations of the signs (in perspective and in elevation) to predict the location of new development in plan. The plan was distorted, overlaid with the elevation (figures 57 through 59), then undistorted - leaving the perspective distorted as a series of lines overlaying the plan (figure 61). The end points of these lines (corresponding to the tops of signs in the eye-level perspective) then predicted new locations for buildings. According to which sign corresponded to which building, signs and buildings were moved to new locations and a new elevation was taken. The process was then repeated to predict successive generations of growth (figures 60, 62, 63).

In addition to manipulation in perspective the macro definition functions (with which one can group sets of operations) proved useful in exploring interpolation and extrapolation. Paul Kaczmaraki divided up the commercial strip according to functions (fast food, motels, retail,
etc.) and set up a macro particular to each function (figures 64 through 67). The macro was performed on the last of each of the functions on the strip to predict development on the south side of the interstate. The same macros were then applied to successive generations of new buildings to trace development further and further down the strip. The resulting development gravitated toward the airport - confirming the soundness of the strategy - but produced forms which were too large to be interpreted as buildings (figure 68). He then corrected the scale relationships (figure 69) and read the plan as an aerial perspective to account for some of the distortions which were a result of how the macros were set up. The final proposition was for a "strip of billboards" set up along the landing strip of the airport. The logic was as follows: Main St. in Cambridge at the scale of the pedestrian is to the commercial strip at the scale of the automobile as the commercial strip is to a new two-dimensional city of billboards at the scale of the airplane. Why not advertise the amenities of the city to a visitor approaching by airplane in the same way one welcomes a motorist to the city with billboards?

Ben Cantrell used a two step logic which utilised the mirroring (reflection) function in conjunction with macro definitions. He observed that not only was the strip (Rt. 209) laid out as a regular pattern of bends, but commercial development close to the highway seemed to be disposed symmetrically around a line of reflection perpendicular to a line tangent to the apex of the bend. Following this logic he set up lines of reflection through the apaxes of all the bends and mirrored the existing commercial development, step by step, southward along Rt. 209. Concurrent with this he observed that buildings on the strip increase in scale as they move back from the road: the small, fast-food establishments in the outlets give way to the larger retail strip centers set back from the road which give way to the warehouses and lumberyards behind them along the railroad line. Using a macro comprised of a translation and scaling operation he generated this next scale of development to the east and west of Rt. 209. He then took three similar forms and, extruding one in the x,y dimension, one in the y,z dimension and one in the x,z dimension, passed these forms through each other and intersected them to create a composite form. The form was then placed back into the landscape and rotated to register with the forms from which it had been derived (i.e., the same structure was placed in three different orientations and three different locations in the site). These forms were then developed as components of the institute.

Although their primary focus was on logical process and its impact on form, both the barn project and the final project were structured to produce new buildings from existing conditions. Because the majority of the operations were undertaken in the modeling environment, the sectional, structural and elevational attributes of the original buildings were carried along in the process. In the case of the final project, the proposal for the architecture of the Institute was in most cases an amalgam of the existing architecture of the commercial strip.

As with the barn project the balance of the solutions to the final project were varied although most involved manipulations of the scaling and macro definition operations - operations which were specific to the capabilities of the computer. One project translated the existing architecture of the commercial strip into musical notation, then used this notation to apply a "progressive" piece of music to the proposed future development.

Conclusion.

It has been my proposition that the nature of the logic available to us as designers is directly related to the tools at our disposal - what we can do is a function of the means available to us. Operations such as scaling and three dimensional overlay which are relatively simple to perform on the computer would take an inordinate amount of time if done by traditional means. Consequently, such operations do not play a significant role in traditional design methodology. Because of its computational power, the computer can be used as a tool for observing relationships which would not be visible otherwise, a lens through which to see what was not previously apparent. It reopens the question of what might constitute a valid design relationship by redefining the field of formal relationships and logic available to the designer.
Comparable to linguistics, a concept is not readily available to us unless there is a name associated with it: the concept and the name go hand in hand. Similarly relationships such as scaling relationships are not persuasive or significant to the designer unless he or she has ready access to them i.e., a means to describe and manipulate them. The computer opens up a range of logical relational possibilities within the realm of form. It allows us to describe and decode in increasingly persuasive ways relationships which by most standards appear indeterminate or chaotic.

Significant, too, is that complexity is the "natural" state of the computer. As the computer's capacity for generating and describing complex formal relationships far exceeds that of the designer, it is easy to arrive at complex compositions by applying a few simple rules to a simple point of departure. Complexity, as an end in itself, is unmasked and de-mystified by the computer. This puts the designer in a radically different relationship to his or her design than when working with a T-square and a triangle. Because formal hypotheses are so easily tested on the computer it is possible to run rapidly through a broad range of avenues of inquiry. Through this process the designer becomes aware not only of the design which is being produced but of the logical process itself. The emphasis switches from the physical effort of production to the intellectual effort of choosing and defining a process.

Because the computer is set up to obey commands, the designer must be aware of which operations he or she is asking the computer to perform and why a particular sequence of operations might constitute a design logic. This suggests that the almost metaphysical emphasis on the design solution which one associates with traditional design shifts to an emphasis on process. The computer forces the designer to be conscious of the process. As the product is a function of this self-conscious process, it is difficult to evaluate the product apart from the particular logic or path of inquiry which produced it. In this sense the computer can not only break open the creative process but can de-mystify it. The design solution is no longer an absolute "thing in itself" to which the designer gives birth, but the trace of a logic which the designer designs. As the logical/methodological possibilities increase with the technology, the pedagogical issue becomes one of defining and critically evaluating a logic apropos to the product it produces.

This emphasis on process is one important aspect to a paradigm shift in architecture from the typological to the genetic.

Finally, as suggested by a number of the examples above, the computer raises significant questions about the nature of representation, and the relationship of projections to models and models to "reality." I have attempted to position these questions in the context of the use of representational conventions throughout history, although much more can be said on this account. The computer model is more than just another form of illusion or simulation. One's experience of it is qualitatively different than the experience of illusion in film or in animation because one interacts "directly" with it - tweaking it, moving it and transforming it with the use of the mouse through perspectival space. As one's sense of its three-dimensionality is greatly heightened by this dynamic interaction with the model, the boundaries separating reality from virtual reality (as a mediated, reconstituted or simulated form of ideality) and the projection (2D) from the model are increasingly blurred. The realm of the third dimension is no longer exclusively the realm of the real - and the concept of the "real" is in need of extensive rehabilitation.

The concept of reality is defined against an opposing but complementary concept of ideality. As ideality gives way to virtual reality, reality loses the standard against which it is operates. Concurrently, the emphasis of fixed things, standards and types gives way to the notion of genetic process and method. There is no what there, only how.

Footnotes:

1 Assuming, of course, that the composition is representational. We should distinguish between a composition, a projection and a representation. A two-dimensional composition may or may not be a representation of something else, whereas a three-dimensional projection
such as a perspective or axonometric usually describes an autonomous object. We will develop this argument further below.

2 see Eisenman's House 10 and Software Institute projects. Regarding Aalto see, for example, the Parochial Church at Riola, Italy and the Villa Schidt.

3 the reader might refer to Michael Benedikt's ponderous descriptions of cyberspace.

4 see Stilfragen, 1893 and Spärmische Kunstindustrie, 1902

5 Two-dimensionality, according to Riegl, is also the realm of ornament. The difficulty of differentiating between a higher, more spiritual form of art and the domain of ornament troubled Kandinsky - who worried that his canvases resembled silk tie patterns. In De Stijl, also, the program of forth-dimensional spirituality manifested itself in the two-dimensional surface decoration of rooms. It is at this point in the history of art that the difference between ornamental and representational art begins to break down.

6 It is probably not coincidental that they preferred the more abstract axonometric projection over the more literal perspectival projection. Like the geometric forms themselves, the axonometric is ambiguous about its relationship to the viewer's perceptual space.
