Novel Affordances of Computation to the Design Processes of Kinetic Structures

by

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ABSTRACT

This paper is a discourse into the relationship between the process, computational tools and the role which symbolic structure can play in both. I argue the relationship of the process and tools is dialectic, whereby the tools we utilize in design develop new heuristics, the methodologies in turn, if reflectively understood, can be more aptly facilitated through the development of novel tools. The tools and the process then evolve together.

A theory is laid out exploring the human visual information processing systems pertinence to the limitations in mental three-dimensional imaging and transformation operations relevant to the operations of drawing and mental visualization within the architectural design processes, substantiating the designers "necessity" to draw (by traditional means, but more importantly here, through the inclusive integration of CAD within the process). The "necessity" to draw is explored as a re-presentational process to the visual system predicated upon the existence of a structured internal "library" of diagram-like representations. I argue that the ways we utilize such idiosyncratic libraries is predicated upon the ways in which we go about structuring the perceived "experienced" world around us into "symbol systems". And finally, the ways we utilize our reflective understanding of the heuristic transformations of these "symbols" within the design process in the context of a CAD environment are explored as a means to an enhanced understanding of that which is being designed and consequently as a vehicle for the development of future CAD systems to better facilitate such methodologies of designing.

A personal design process of several kinetic structures is carried out in order to arrive at a localized process analysis within computer-aided design environment. Through an interactive, reflective process analysis, conclusions are drawn as to the affordances and limitations of such tools as suggestive of the operations a CAD environment might perform so as to better foster future methodologies of designing. The design "experiments" are utilized as a vehicle to understand the process. Specifically three kinetic projects are exploited for the prototypical "operations" they display. When difficulties or mental limitations are encountered with the operations, specific "tools" are developed to facilitate the limitation or to overcome the problem.

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Directing Development

0110 :: ON THE EVOLUTION OF CAD TOOL DEVELOPMENT

In the very near future, computer-aided design systems will be the primary tools by which architects design. I question the extent to which the integration of computational tools into the "design" process of architecture is a "change" in the larger paradigmatic sense, or simply the beginning of architects understanding how to work with novel tools for designing. As I will show in the course of this investigation, the ways in which tools influence the processes by which we go about designing can have a potentially profound effect on that which is actually designed.

I suggest the direction of CAD tool development could go in several directions: The tools become many, each with respective affordances and limitations and united in the ways in which we approach learning to use such tools, in that with a generalized computational fluency the learning of a new piece of software is not much different than the previous. A second road may be the consolidation and standardization of the software. The standardized company assimilating the affordances of other tools as add-on "attachments. This, of course seems a rather valid prediction were the software to be used for the latter stages of designing and as tools for shared communication and presentation drawings. I feel however, that the case is different when speaking of tool development for the design process of architecture. I see the tools as constantly evolving with technology and through insight into the design processes of architects. A potential third direction may be that of the software reduced to a programming language whereby designers are allowed to customize their design environments through idiosyncratic tool development of an extremely sophisticated and malleable software. The point is, the directions of tool development is not being led from within the field for which they are being designed. I therefore urge designers to play a stronger role in the development of their tools for designing.

0120 :: ARCHITECTS NEED TO DIRECT TOOL DEVELOPMENT

There are then several approaches we can take in a generalized development of CAD tools tailored towards facilitating the design process. One, we can look explicitly at "traditional" approaches to designing in order to tailor tools to facilitate such defined methodologies. Two, we can "step-back" and look at the novel affordances of computational tools as a means to completely re-thinking approaches to methodologies of designing architecture in the context of working with such tools. And thirdly, we can look at the design methodologies of those working from within a CAD environment, which lies somewhere between the two. In a more general sense, technological development takes place within context, and this technology subsequently leads to fundamentally changes in societies' ways of thinking and doing.[30] We as architects ought to ask, what is architectural about computation, not the inverse, and in doing so, direct the development, while those inquiring into the methodologies of design ought to, in parallel, direct the context.

Visual Information Processing

In computer-aided design systems visualization is synonymous with creation. The ways in which we think visually in the design process is a process derived through a medium of images. We will begin then with a brief exploration into the visual information processing systems in our heads. We will see how limitations in our understanding and manipulating capabilities necessitate a re-presentational process of three-dimensional imagery. Furthermore, we will see how this re-presentational process is predicated upon the existence of an internal "library" of diagram-like representations structured in the ways in which we perceive and store information from the perceived "experienced" natural world around us.

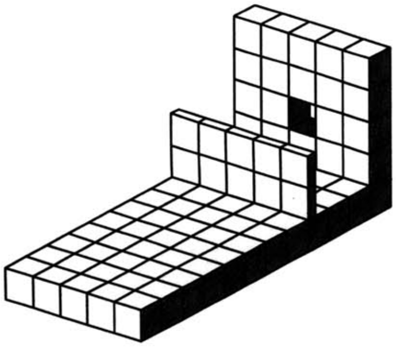
0210 :: MENTAL IMAGING

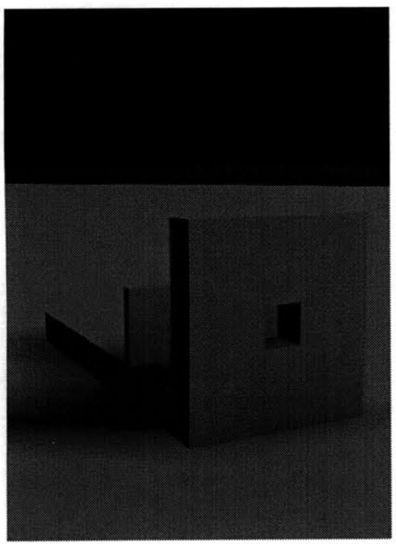
An enlightening aspect of imagery research is that when subjects are given a task which explicitly or implicitly requires them to make use of visual imagery, they report that there is in fact visual (mental) imagery present, and furthermore, their performance correlates strongly with what they report is happening in their mental image.[17] A recent experiment has demonstrated that when viewers were shown two perspective line drawings of three-dimensional objects out of rotation with respect to each other and asked to judge whether they were the same figure, the viewers reported they performed the task by mentally rotating one of the figures in their minds. The time that it took to make the judgement varied linearly with the angular difference in the objects orientation.[28] In other words, images are assembled for internal display, and once on this internal "screen", they can be understood and manipulated.

0220 :: LIMITS OF IMAGING

The logical next question then ought to be why is it necessary to draw in the first pace if we have access to mental imaging? Why would we bother rendering a shadow or drawing an aesthetic variation of a line or making any problem-solving mark for that matter if the pattern-rendering and pattern-analyzing mechanisms in our brains could understand each other; if we could simply view the image in our heads? In other words, if there were a screen in our minds eye upon which the virtual images were displayed, why is it not possible to simply view the screen and work from there? The fact is, although mental imagery is indeed present, we are hampered by a limitation to understand the image without re-presenting it to ourselves.

Now when I speak of mental imagery, I am speaking metaphorically, as the images are not actually real images, but are rather, diagram-like representations from which actual drawings (external representations) can then be produced. This is why we make drawings in the design process, for it would clearly be unnecessary if the pattern-rendering and pattern-analyzing mechanisms in our brains could understand each other. When I speak of pattern-rendering and pattern-analyzing mechanisms of the brain, I am referring to the mechanisms we necessarily utilize when re-presenting an image to ourselves in the act of drawing. When our brains cannot carry out the computational tasks involved with translating the coding and labelling of three-dimensional information, we must draw (pattern-rendering) and look at the drawing (pattern-analyzing). This we must do whenever there is a problem to solve necessiating more than this moderate limit in our mental imaging capabilities. It is therefore often practically necessary to draw even though it is not necessary in principle. The production of a problem-solving drawing then, arises out of the necessity to communicate information to "oneself" by means of re-formatting it to the visual system. When one tries to imagine particular scenes without the act of representing the information to oneself, the results are quite often sketchy and unreliable. D. Dennett describes computer-aided design systems as vastly amplifying the imagining powers of the designer; he terms such systems as "imagi-





nation prostheses". To enunciate this point, I have constructed a three-dimensional object in a visually-ambiguous manner so as to deny the process of internal manipulation as a resource. (fig.220a) The object is modelled after a similar object created by Dennett, claimed to be modelled after the origional models by Metzler. I asked a number of my peers (most of whom were architects) whether or not the dot is visible through the hole in the back wall of the model. Of those asked, none were able to give an affirmative answer through simply rotating the image as in the above Shepard-Metzler examples. The typical means of finding an answer to the question was through the act of re-drawing the object in section and drawing sight-lines in order to confirm to themselves an answer. Perhaps a bit redundant to the point, I modelled the object in a CAD system (Alias, but the choice of particular software is negligible)
The point is that a solution can be ascertained without the need for other representations by simply rotating the image and viewing it. (fig.220.b) In a more complex architectural example, we can imagine the valuable utility of such tools in the process; of the enhanced ability to explore, understand, and control shapes and spatial relations beyond the marginal limit in our ability to understand and manipulate any three-dimensional imagery.

0230 :: INTERNAL LIBRARY OF REPRESENTATIONS

Human beings then not only present themselves with external representations, but also with parallel idiosyncratically designed internal virtual images (diagram-like representations) which serve as suitable raw material for latter stages of visual processing. The mental imaging capabilities are predicated by the existence of an internal library of diagram-like representations. The system in our heads uses a format of attaching simple codes for properties and labels to places; some spatial properties are shown, others are only told about by labels. [4]
We are then organizing the information (parts) into "perceptual units". For example we would reference the sequence of dashes "-----

Fig.220a-b

Top : 3-d Visualization Experiment;
Viewers were asked whether or not the dot is visible through the hole in the back wall of the object*
Middle: Modelled in CAD and Rotated

-" as a line, and not as individual dashes, and "XXX000" as two units and not three X's and three 0's. These tactics of attaching codes and labels come naturally to some extent, but they can be learned or invented; and in fact can be highly developed as with the case with many architectural designers. There are numerous organized laws as for how we proceed with such operations in perception; but what is relevant here is recent evidence that these types of "units" are also stored in memory.

S. Kosslyn forms a number of testable hypotheses on the cognitive neuroscience of mental imagery; specifically, that there are structural processes of mental imagery storage and retrieval. He points out a relatively new notion of cognitive science: that mental facilities consist of multi-component information processing systems[16]

0240 :: ACCESSING IMFORMATION TO CONSTRUCT AN IMAGE

First off, a clue must be able to trigger some relevant information that is stored in the memory but that is otherwise difficult or impossible to tap; as an old friends name might require the first letter of that name to trigger a recollection of that name, visual clues work similarly, mental images exist only when called upon; secondly, these image patterns are built up a part at a time. Numerous experiments have supported the hypothesis that images are built up by activating parts individually and that these parts are imagined in roughly the same order in which they are typically drawn; that is, relative to one another. The question here is why all of the parts are not activated at once to construct the image rather than being activated individually and sequentially. M. Mishkin postulates that the ways in which the information is retrieved is directly related to the ways in which it is stored in memory; quite simply, the shape (what) is stored in one place and the location (where) is stored in another. The "what", then is located in the inferior temporal lobe (which contains cells sensitive to shape properties and color) and the "where" is located in the parietal lobe (which contains cells sensitive to motion and an objects location (relative to the eyes position). The "what" and the "where" are then carried out by two separate processes in perception, and therefore also in storage and retrieval; that is, the parts are stored separately and retrieved individually and sequentially as relative to one another. In summation then there seem to be two distinct classes of processes; one which accesses the stored visual shapes and one which access the stored spatial relations to arrange the parts correctly.

0250 :: STRUCTURE IN PERCEPTION

David Marr has described a structure as a sequence of representations, starting with descriptions obtained straight from a retinal image but which are carefully designed to facilitate subsequent recovery of gradually more objective, physical properties about an object's shape.[21] Firstly, describing the geometry of the visible surfaces, since the information encoded in images (stereopsis, shading, texture, contours, or visual motion) is due to a shapes local surface properties. The objective of peripheral mental computations is to extract this information. This theory has been criticized for the fact that it depends upon one critical vantage point. What is needed then is a transformation of the viewer-centered surface description into a representation of the 3-D shape and spatial arrangement of the object as independent of viewing direction; an object-centered description rather than viewer-centered. R. Jackendoff proposes a theory in terms of a sequence of discrete levels of representation, each with its own characteristic primitives and principles of combination, and each linked to the next in a sequence by correspondence rules. The most peripheral being the retinal image, the most central being the object-centered 3-D description. These can be further broken down into formal levels of description. The information derived from the retinal image is termed the "primal sketch"; essentially that perception of form first of all depends on the detection of discontinuances of intensity on the retinal image. The "primal sketch" is hierarchically ordered in that each of the primitives used are qualatively similar symbols referring to increasingly abstract properties of the image.[15] Yet at this point no notion of a physical object has been described. The next level of description then is termed the 2-1/2D sketch. This level includes a viewer-centered representation of the geometry of the visible surfaces. Stereopsis, texture, shading, motion and surface contours all depend on information present in the primal sketch, and all provide information needed to determine depth and orientation. The 2-1/2 sketch provides the unified locus at which the above computations can converge. This level yet represents only visible surfaces and not volumes, and does not account for shape and size constancies. For this we turn to what is termed the 3-D model. This level is volumetric and is object-centered; it represents objects as occupying volumes in space. It represents objects in terms of a hierarchical decomposition of parts and parts of parts. In such an "object-centered representation, the parts are specified with respect to the main axis of the object as a whole, independent of the viewers position. An important aspect of the 3-D model lies in the abstracted encoding of variations in form among individual of a common type; a geometrically parameterized encoding to be utilized for future identification of similar models: for instance our ability to discern and categorize a desk as a desk regardless of differing retinal projections (size and perspective) or surrounding contexts. Our ability to carry out such tasks through the use of symbolic structure will be exploredin depth in the next chapter. Furthermore, the importance of this ability to the ways in which we utilize tools for designing for purpouses of re-presenting images to ourselves cannot be understated. So it seems that top-down effects of some sort exist in visual perception; what we see is affected by what we know about the world and what we expect to see. The experience is one of seeing

Let us take a look for instance at the ways in which we judge depth or distance of surfaces from the observer. There are number of cues which we use to make such judgements. One is the degree of accommodation the lens (retinal) in order to focus precisely. Another is the disparity in the angle at which the eyes must focus on the object. Another is stereopsis, which is the disparity in the view as seen from two eyes (appx. 3.5 inches apart). Another is texture gradient, and lastly judged occlusion (i.e. the vase or faces illusion). In typical viewing of real situations all of these factors (and perhaps more) contribute to perceived depth, their effects overlapping in some cases and separate in others. These factors seem to operate in a preferential rule system: At this point I won't delve into preferential rule systems suffice to note that such mechanisms may account for the intuition behind prototype theories of categorization. On the bright side such a mechanisms' decompositional properties make a possible computational model feasible. Also preferential rule systems seem to reinforce the notion that the theory of categorization ought to deal in mental representations of the world rather than in the real world itself. On the dark side, the combinatorial and logical properties of preferential rule systems are yet a mystery. There are been few actual analyses in terms of preferential rules in order to understand the combinatorial problem specifically referred to here. Such systems have been described however as playing a major role in our cognition of music, and also seem sufficiently established in psychology.

0260 :: RELATIVE RE-PRESENTATION

We have now a general understanding of the processing system in our heads; a system which contains a structure, a structure which operates on automatic internal inferential principles tuned to the general properties of the perceived (experienced) natural world, re-enforced by all idiosyncratic representations previously presented to oneself. The ways we go about structuring the perceived world will be explored in a bit more depth in the following chapter, but for now let us look at the idiosyncracies in re-presentation and their effects on our understanding and manipulating capabilities. As I have already stated, the ability to understand and manipulate three-dimensional images is relative to the internal library of diagram-like representations accessible to the visual processing machinery of the brain. Now we all know others with different imaging capabilities, at which architectural designers are some of the best. In fact, J Hochberg identified the perceptual differences in three-dimensional image understanding and manipulating capabilities at a cultural level.[14.] What is behind the differences in these capabilities, to what extent can they be enhanced, and exercised, and what role ought CAD systems can play in facilitating and responding to these differences? In response to the former, can we say that the differences are predicated upon experience, or perhaps, intuition. I posit intuition is experience. Experience inclusive of the individual, and by no means limited to the individual; it is both genetic and memetic (which is the study that sees cultural rules (memes) as analogous to genes.

It seems that when we do not have the experience of direct perception, we use "hunches". This is intuition: habitual patterns. Where are these habitual patterns or intuitive ways of "seeing" formed if not through analogues; analogues to our previous experience. We build up entire cultures, civilizations, arts, sciences and languages in terms of these analogues. We seek out images from past experiences and create analogues to define the nature of the experiences in order to understand them. A. Einstein once claimed, "There is no logical path (to arriving at universal laws); only intuition, resting on a sympathetic understanding of experience". So people see things differently because they come at them with differing sets of analogues. The ways in which we think is necessitated by a medium called language (verbal). The ways in which we think visually is similar, yet it is a process derived through a medium of images; of images, as we will see, structurally decomposable to a language(symbols). Furthermore, we will see in the next chapter how the role of conventions in the syntactical structure of such a language tolerates idiosyncracies in visual thinking and supports novel forms of synthesis. Clearly we have yet to recognize the potential role of visual reasoning (through imaging) in many instances of problem-solving; and in computational design tool development, and we ought to optimize rather than bypass such insights. Many see visual imagery as characterized by solely by such intuition, responding to emotional needs and not necessarily rational ones. The design process also includes rational aspects subject to logical, functional, and scientific analysis and compatible with implementation requirements, the balance between these two poles is designing.

Structure in Mental Processing

We have now a general understanding of the processing system in our heads; our "seeing" then, is based upon an underlying representational structure by which the operations of the visual processing machinery are carried out. We have seen that the mental 3-D model encompases a geometrically parametarized encoding utilized for future identification of similar models. In order to gain some ground as to how this is actually utilized in the processes of designing architecture I will explore here some of the notions of how we are structuring the world around us. For the ways in which we perceive and structure the world around us, predicate all else; in that our "internal libraries" in our heads are the by-products of the visually perceived world.

0310 :: SYMBOLS AS STRUCTURE

The philosophical notion of structuring as a means to understanding has quite interestingly evolved. As paraphrased from N. Goodman: I. Kant exchanged the structure of the world for the structure of the mind, C. I. Lewis exchanged the structure of the mind for the structure of concepts and now the structure of concepts have been traded for the structure of symbol systems.[10] L. Strauss points out, a bit more abstractly, what has been enunciated in the last chapter, specifically, that we work inventively with what is already available in our minds in order to solve problems. That we devise concepts and make comparisons not because they satisfy "biological constraints", but because they satisfy cognitive constraints. Furthermore, he posits, human beings never create absolutely; the best we can do is choose certain combinations from a repertoire of ideas which we then reconstitute. Now this is a fairly important statement which I have embraced, and one for which many have been challenged, specifically for it's limited potential to deal with "creative" thought. This is really not an argument I intend to immerse myself in within the context of this paper, suffice to say that although there may be a limited number of forms "symbols", the amount of invention and creation which can be generated from them is, as a practical matter, unlimited. Furthermore, structure in not necessarily by definition, static. Such argumentation follows that our reality is "created" by symbolic forms; that symbol systems constitute, rather than reflect reality.

0320 :: IDIOSYNCRATIC NOTATION

What is of pertinence of the above larger argumentation to this paper lies in perhaps the ways in which it has been developed and articulated by the likes of Goodman into practically useful terms for it's utility into a constructive reflection into design processes and consequently the development of future tools to facilitate such processes. As a premise, he claims that the ways in which one "reads" a symbol depends upon the context with which it is encountered; the graphic context which surrounds it and the particular frame of mind of the one viewing it. His approach lies in an analytic study of types and functions of symbol systems. This is accomplished through the establishment of a notational system resting upon syntactic and semantic criteria. Whereby, the whole range of symbols can be classified by means of which they approximate or deviate from the notation. Furthermore, what psychological processes are involved in dealing with specific symbol systems of varying degrees of notation can then be analyzed. In architectural design, then we can see the fulfillment of syntactic requirements in the ways we recognize decomposed elements (primitives: points, lines, surfaces and solids) and their relations. It is furthermore to note that these are not "fixed" entities with respect to the ways in which their hierarchic relations can be interpreted through the decompositions. If we recall from 0250, the most central level of representation lies in the object-centered 3-D description; in describing the geometry of the shapes visible surfaces, since the information encoded in images (stereopsis, texture, contours, or visual motion) is due to a shapes local surface properties, and it is the objective of peripheral mental computations is to extract this information.

0330 :: REFLECTION THROUGH SYMBOL SYSTEMS

Let us go back to Goodmans' claim that it is by virtue of functioning as a symbol in a certain way that an object becomes, while so functioning, a work of art. As we have seen above, this structure, can be syntactically specific to realms of the arts in a constructive manner, yet retain idiosyncracies through semantic interpretation. The great utility of such notation lies in it's insight to some of the toughest questions within the design process, specifically, the ways in which we judge "right" from wrong, or that which is most "right". Those that are "right" are those that seem to capture significant aspects of our own experiences, perceptions, attitudes, and intuitions. Let us look then at H. Gardners interpretation of the aesthetic as a means to understanding and identifying those aspects of a drawing which contribute to it's functioning: 1) Syntactic and semantic density: whereby the finest differences or changes in the drawing may constitute a difference between symbols. 2)Relative repleteness: Where many aspects of a "symbol" are significant. 3) Exemplification: Where a symbol, whether or not it denotes, symbolizes by serving as a sample of properties that it literally possesses. 4) Multiple and complex reference: Containing several integrated and interacting referential functions, some direct and some mediated through other symbols. Essentially a penumbra of overlapping and difficult to separate meanings, each contributing to the drawings overlapping meanings

What is important then is the utility of the above in deciphering those aspects of symbolic content which contribute to it's functioning as per one's intent. In other words, the designer with a sufficient understanding of the properties and functions of symbol systems is allowed to create designs which function in an effective manner; works that are replete, expressive and allow for multiple readings. This understanding can allow one insight into what questions to ask oneself and others in the process of designing. Designers, in general need to reflect on what the mind undertakes to solve a problem while simultaneously understanding how to solve the problem, in other words, we need to learn to separate the description of what we are doing from that of actually doing it. Furthermore, such reflection can afford us insight into the appropriate development of future CAD tools, as the mediation of tool development must be predicated by an understanding of the designers actions within the process of design. We are now in the subjective realm, and the role that future computational-aided design systems are to play in this realm is not to be taken lightly.

0340 :: SYMBOLS IN TRANSFORMATIONS

Transformations are the geometric operations applied to the primitive symbols. For now I will consider them as geometric operations (this will be questioned in 0430) as they are really no treated no differently syntactically although semantically they are vastly different. If one is to view the design process as an open, flexible, and constantly evolving knowledge-containing device, one can see the immediate benefit of integrating such a concept as transformations into CAD systems. The formalization of transformations are called grammars which are used to generate a set of legal design solutions to a problem, legal in the sense that the shape conforms with the formal definition of the language. George Stiny has been exploring this vein of shape grammars as central to the process of creative design. The "seeing" of ambiguity in a representation, he argues, encourages a diversified reaction. In focussing his attention to CAD representations, Stiny calls to light the limitations of current underlying formal structures. Specifically a CAD system recognizes only subsets of existing elements. Anything not explicitly input into the system is unrecognizable. The "situated knowledge" approach postulated by Edith Ackermann is thereby limited. The underlying structure of current the current CAD systems seems to hinder rather than assist the creative process in design. Shape grammars contain a structure which is congenial with conventional design methods; a structure with inherent flexibility. As design is ensnared in a constantly evolving context (speaking with respect to architecture) necessitating ultimately unknowable descriptions, the shape grammars must therefore be responsively flexible through inclusive recognition. To do this the rules of the shape grammars are constantly changing, constantly evolving. Every representation can be resolved into its primitive components and no shape need correspond to any single decomposition. The primitive components are allowed to evolve and transform discontinuously. Thereby such a model(system) is capable of inclusive recognition and the representation(shapes) are able to inform back to the designer. A novel aspect of the formalization lies in its ability to reveal retroactively design "states" through a decomposition of cumulative past descriptions.

Design Reflection

0410 :: REFLECTION IN CAD

I have already mentioned the utility of reflection; the need to separate the description of what we are doing from that of actually doing it. Typically this process is one of conjecture and reflection. I will argue in my design analysis that in CAD processes it is often that of conjecture-reflection-reflection; specifically that the tools necessitate a reflection of the operations prior to the actual operations, a conjecture (transformation), and a reflection which affords immediate self-adjustment within the process. In addition to this process of reflection, designers should utilize as well, an intermediary reflection which allows one to step back or outside-oneself to look at a number of steps inclusively for a holistic "perspective". Through informed reflection all aspects of designing are re-enforced through self-criticism and critical analysis of not only the product but also the process.

0420 :: QUESTIONING THE CAD ENVIRONMENT

Tool development must be predicated by an understanding of the designers actions within the process of design. The ways in which we ought to approach this has been previously explored in 0110 where I argued for the need of architects to direct "their" design tool development. For in formally identifying the "components" of the process we can see their use in a computationally aided environment as facilitating the process, not merely describing it. My approach lies in making explicit (through reflection and documentation) my process "through" the exploitation of a near-hit/near-miss tool (environment) up to it's limitations and extending it (inclusive of speculation) in ways I could only understand through my experiences use of that

tool. Of course this is only one route which I might have taken in my design explorations.
As I touched upon already, there is great utility in the emulation of processes of the traditional designing environment for the transitional phase of computational tool development which we are currently experiencing. This also is a fairly safe approach as such processes are the best understood and most well documented. Yet, I enunciate again we cannot limit our development of novel computational tools merely facilitative emulation of such "known" processes. The tools I argue, develop new heuristics, the methodologies can in turn be tracked and more aptly facilitated. The tools and the design then, on the generalized level as well as the specific evolve together. Furthermore, I argue, we need to "step-out" and look at the novel affordances of computational tools as a means to completely re-thinking approaches to methodologies of designing architecture, and that this "stepping -out" can be more insightful if predicated by an initial immersion within a computational environment.

0430 :: REFLECTION ON THE HEURISTIC

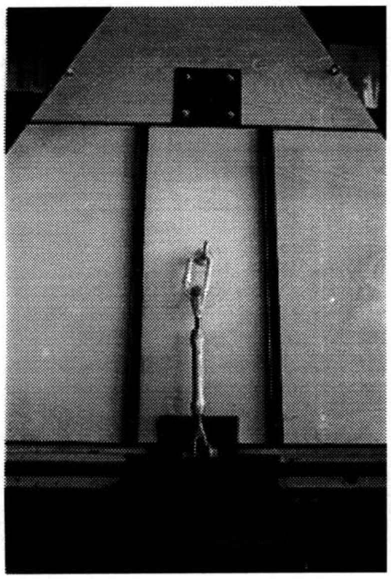
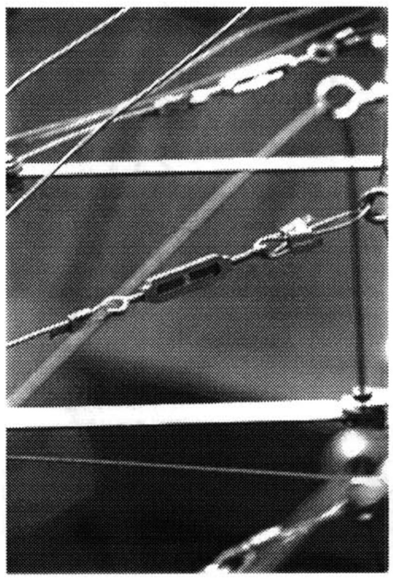
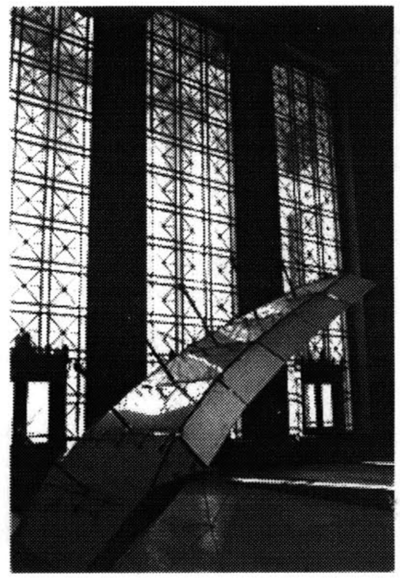
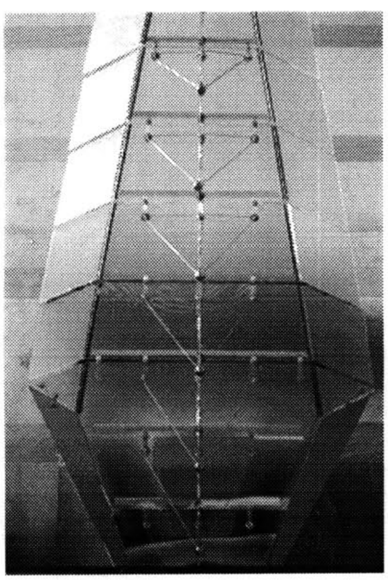
Allow me to preface this section with a disclaimer: Heuristics in the design process of architecture and the role which computation can/ will play in this realm is huge, and admittedly not here afforded it's due justice. Yet in the context of this paper I feel that it must touch upon it with contextual brevity.
Clearly we cannot, in architectural design, reduce the process to an exclusive effort to achieve fitness between two entities; the form in question and the problem situation. Architectural design is simply too inclusive. In the process of designing architecture, heuristics is all we've got; a structure of guidance and revelation. Architectural design is a myriad of complexity, uncertainty, instability and on and on. It is a process which acquires step by step transformations, associations and reconsiderations. To say that our methodologies are structured linearly is a deleterious proposition, to say that they are structured is constructively useful. What is the role that computation

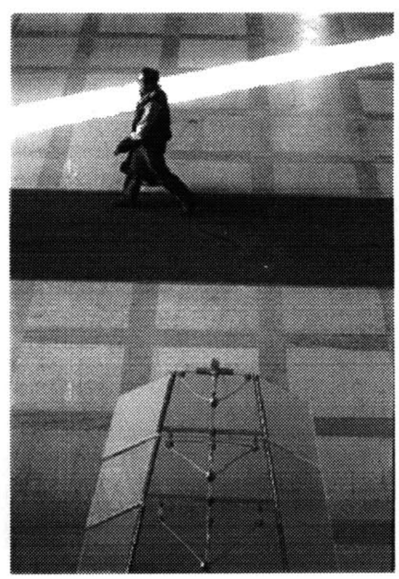
can play in this realm of subjectivity then? The initial argument against any role of computation within the realms of that which lies beyond objective consensus comes about from the above notions of idiosyncracies in heuristic processes. Such idiosyncracies are derived from experience inclusively.

The ways in which we think visually in design is a process derived through a medium of images; of images, as we have seen, embedded in structural processes, encoded symbolically for the future identification of similar models. The images then, can be understood by means of which they approximate or deviate from structured symbolic systems and potentially utilized through shape grammar transformation rules. Furthermore, we have seen how the role of conventions in the syntactical structure can tolerate idiosyncracies in visual thinking and support novel forms of synthesis in their transformations.

Design Investigations

0510 :: PUBLIC COMPUTER DISPLAY



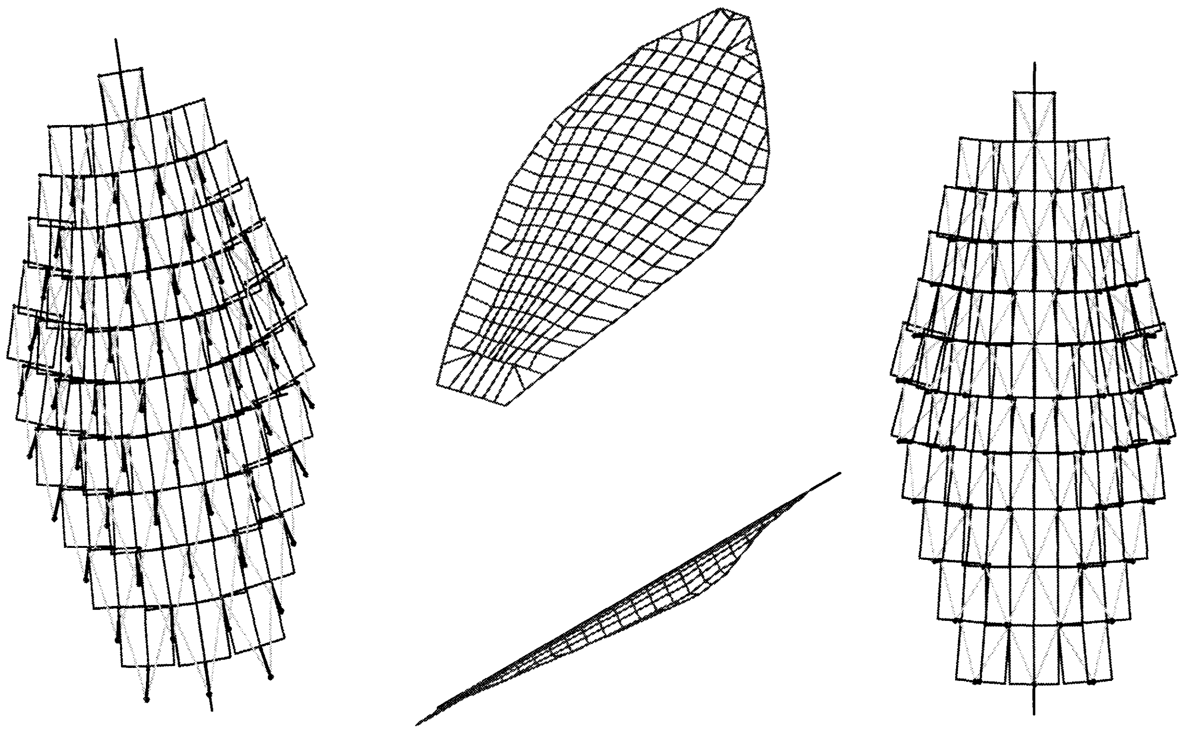
0511 :: Description

The "transformer" is a structure which houses a computer exhibition at MIT located in Lobby 7 off of the main entrance. During the off hours on the exhibition, the object is a closed and simple pyramid; while functioning, the structure transforms into a framed shell for communication. The structure was designed to express the conceptual aspects of the project (for the 1996 Lyon Biennale) in reference to language and communication as constantly transforming systems with multiple encapsulated meanings.

0512 :: Aims

This design investigation explores the process of designing through utilizing a CAD system in the early stages of problem solving; beyond idiosyncratic mental limitations in my three-dimensional understanding capabilities and the affordances of the system to assist me in over-coming these limitations in kinematic problem-solving. I explore the affordances of working with a 'correlated' three-dimensional model early on in the process; of the ability through CAD to have the entire model re-presented to me in three-dimensions, available for inclusive transformations, associations and reconsiderations; of the liberty to move myself around the model, to have the model presented in various formats (axonometric, isonometric, orthographic and perspective), to zoom in and out (scale) the three-dimensional model. Furthermore, to explore the virtual motion of the model through inverse kinematics, and eventually, stages of true kinematics through force analysis. This exercise also confronts issues of data information for replicable structural componentry and explores a tool for the intuitive storage and retrieval of such information.

0520 :: OUTDOOR AMPHITHEATER

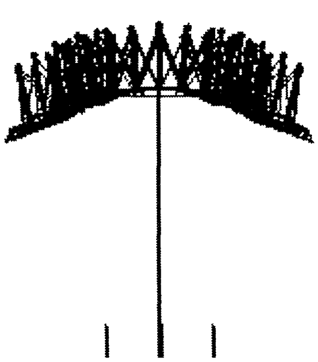


0521 :: Description

Above: Roof structural system with panels
Below: Roof structural system viewed from the front
Fig.520a-e

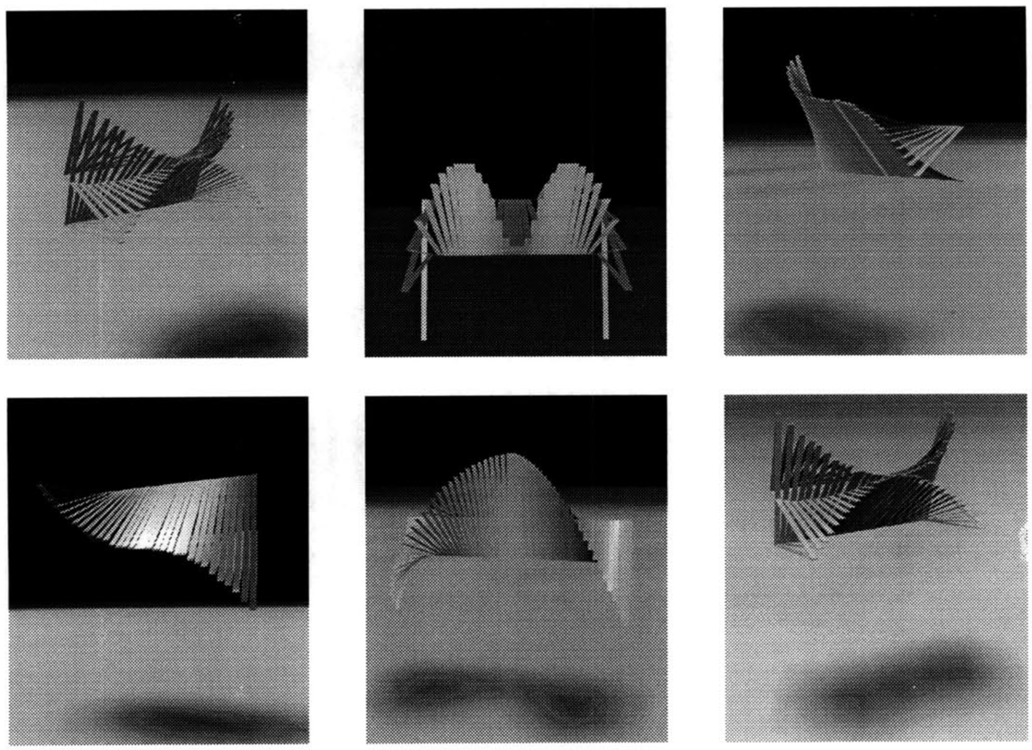
The outdoor amphitheater was designed for no place in particular; the intent is that while the structure is open it would function as an acoustic shell and shelter for outdoor performances at a fairly large scale (250-300 persons). When not in use the structure can be closed and transported on trucks for summer events at various sites.

0522 :: Aims



The design investigation deals with the "emergent complexity of form". It explores the visualization affordances of a CAD system in a process which literally denies the designer the utility of mental imaging as a resource; of form necessitating a medium for understanding. The process challenges one with forms and systems previously unimaginable or practically un-realizable and utilizes a CAD environment for nearly inclusive development and articulation, through which generations in form and structure can take place without the use of physical models. In this investigation, several tools are developed within a CAD environment to assist in overcoming mental limitations associated with storage and retrieval of past design explorations as a means to the visually intuitive retrieval of information (both hierarchically structured data information and past design variations).

0530 :: GENERATIVE DOORS



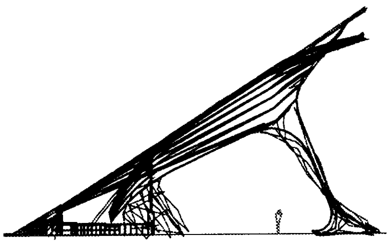
0531 :: Descriptions

This investigation explores three-dimensional transformations of two-dimensional forms which are difficult to understand prior to the transformations. Specifically they are computer generated variations of a door which opens into a three-dimensional form determined by the curve cut onto the two-dimensional form. As an innovative waiver, I note here that the "inspiration" came from a window shade in Venezuela as well as (later on) a door designed by the Spanish architect, Santiago Calatrava, for which I give sincere thanks and of course, apologies. Regardless, the intent here lies in the exploration of the generative role of the computer with respect to forms existing beyond my three-dimensional imaging capabilities. It is essentially a very specific exploration which is used to articulates some of the most important issues surrounding the integration of computation in the design process of architecture.

0532 :: Aims

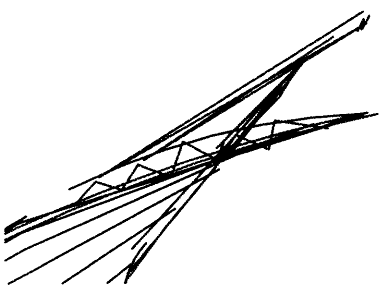
One of the most compelling potential applications of CAD lies in the generative role of the computer in the design process. This project explores a particular instance of a larger "architectural" design. Specifically, this investigation explores the affordances of CAD with respect to deferred judgement (the ability to complete an expression of an idea before discarding that idea, or before articulating further any one idea) The generative role of the computer affords the designer insight into potentialities he/she may never have had the time or energy to explore. Perhaps the end result is the same, but the path to arrive there is different, and may lead to new insights which were not previously afforded. It explores a process whereby the human provides rules for the computer to take generative steps in offering varied solutions or 'variations on a theme' from which the human is then free to select the design which is the closest approximation to his/her intent. What then is the appropriate input that the human must provide prior to generation; what are the rules for transformation and haw can they be defined without limiting the exploration of form. Perhaps equally important this investigation brings about an issue to be further explored in section 0700; specifically, the layers of methodologies in determining the spatial geometries within the CAD environment, and of the overlapping use of symbol systems in discrete and static space within a CAD environment.

Operations

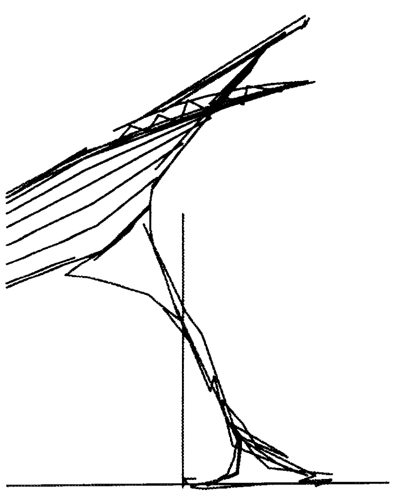


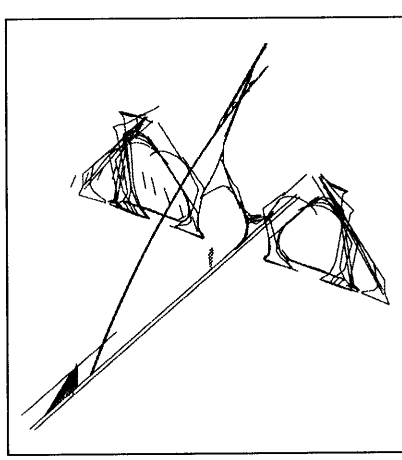
The following section is predicated on the assumption that it is impossible to understand design thinking in depth without zooming in on episodes like the ones I will be describing. What matters here is not the particular software being utilized for problem-solving in the process, (Autocad r13, Alias, STAAD, AutoLISP) but the methodology followed in defining design "operations".

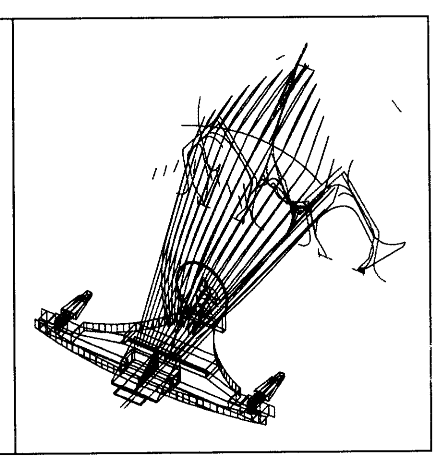
0610 :: TRADITIONAL ABSTRACT OF SKETCHING



The tools we utilize, I argue, develop new methodologies for problem-solving in designing. Methodologies which in turn can then be more aptly facilitated in future tools. How we can accommodate the act of sketching on CAD systems is perhaps the most pertinent task facing the generalized acceptance as a "design" tool. Sketching is a deeply sentimental act to many architects, years of training and practice are required to develop efficient means of re-presenting information to ourselves through sketching. I have argued already against merely emulation such traditional methodologies. My stance lies in limiting the foreseeable potential of future CAD systems. However, to accommodate such methodologies seems imperative. I argue we ought to abstract what we are doing when we create problem-solving drawings and work to facilitate the abstraction.





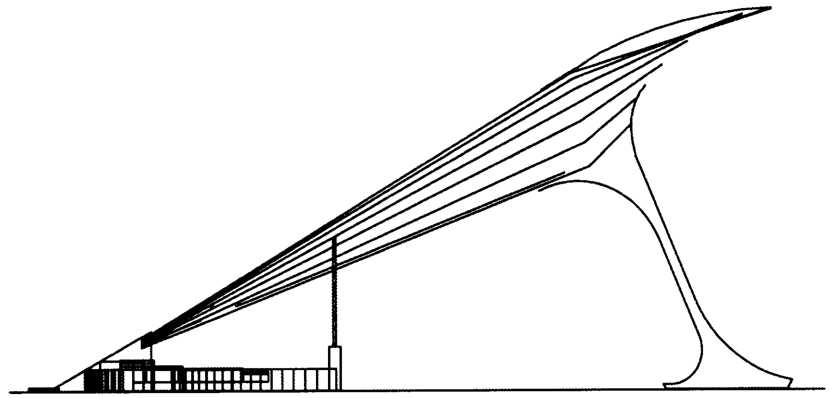


Above: many superimposed layers of sketches,
Right: Vieved in 3-d, with and without the entire model

Fig.610a-e

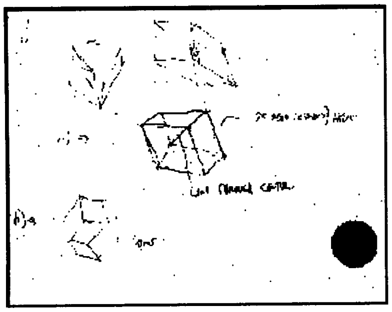
Previous "sketches" articulated into a hard-line section through the amphitheater

Fig.610f



Often when I sketch on the computer, I am simply searching for the right line in re-presenting the imaginal image, demonstrating that we can never actually know what it is we want until we see what it is that we can have. However sketching with most available 3-d modelling software is a very awkward experience. To draw with a mouse on the horizontal desktop to a monitor vertically in front of ones' face in not a very intuitive procedure. Previously I have argued that intuition is experience, and that learning to sketch in such a manner is simply a matter of the learning the skills necessary to accomplish the task. However I also argue for a notion which is rather difficult to pin down, which is perhaps most aptly described as a tool which "feels right". More specifically, a good tool is one which is a natural extension of the body as ergonomically generalized. A pencil I suggest, when used by a skilled designer becomes a natural extension of the hand. One learns to use an awkward laptop computer keyboard with narrow spacing between the keys and soon becomes extremely fluent in typing with it. I argue the "normal" keyboard spacing is such for the way that it fits our fingers, and a number of wonderfully designed keyboards have come out in the past few years in order to better facilitate this "extension" of the hand. I have dwelled on this in order to make a distinction between the "tool" with its associated techniques for use and the things that we are doing with the tool. Differing tools limit and facilitate differing techniques. Techniques furthermore can be broken down to qualities they display and the utility they serve. What I argue for then is not necessarily an emulation of the qualities of traditional sketching techniques, but rather an understanding of the abstracted utility which differing sketches serve. An analysis of the act of sketching in the design process could be a thesis in itself, I here enunciate only that typically they are drawn in a very ambiguous way; all with freehand lines, with uneven width and density and to no apparent scale. However, due to the consistency, I argue, such ambiguous drawings take both skill and experience as a means of efficiently displaying needed information for their utility. The above sketches which I have done on the computer serve the utility of searching for the right line, and an idiosyncratic reading which requires of me often many attempts before I am satisfied. Sometimes the utility of the sketch is merely aesthetic, others it is to solve a particular structural problem. The sketches are done on "layers" and put into "blocks" in the program AutoCAD. Layers allow the sketches to be different colors, for me the darker the sketch the better it blends with the background of the screen and the less importance it takes on; the colors are often changed if I wish for the sketch to still be present in the drawing but to display less importance. Furthermore, the sketches are each put into "blocks" which allow for any number of entities to be grouped under a single name and stored away, this combinatorial use allows the sketches to be combined changed and turned on or off and cary differing "weights". Therefore the weights are analogous to the differing thicknesses of pencil marks and the layers and blocks together are here utilized as analogous to layers of tracing paper. While many aspects of such methodologies are uncomfortable in the "feel good" sense described above, they have been developed to allow me to solve problems in designing. In addition to such methodologies, I argue in favor of a complete re-thinking of our methodologies of sketching with computation., whereby a sketch on the computer may serve the same utility as one done on paper but look nothing like a traditional sketch in the ways it is displaying the needed information. Such methodologies I posit, are derived from the confrontation of design problems while immersed within a computational environment.

0620 :: OPERATIONS IN 3-D SPACE

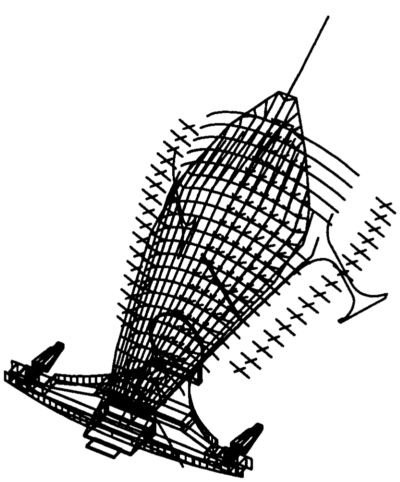


Above: Problem-solving Drawing Experiment:: Description of the geometry of the visible s surfaces

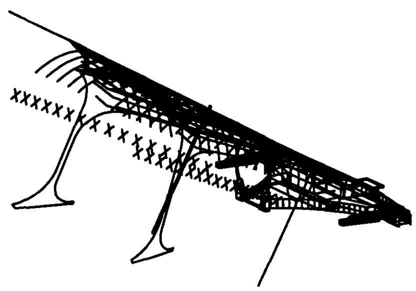
Fig.620a

The aim of this experiment was to make explicit the specific properties of drawing used in understanding and representing a difficult 3-d object. I had presented a small wooden object consisting of four symmetrically joined rhombi-dodecahedrons, and asked the subjects to draw one of the quadrants as separate from the whole. All of the resultant drawings again used a very specific type of drawing on order to solve the specific task at hand. In this case they were line drawings used to define the surface edges of the object. This seems to make sense for as we have already seen, in order to factor out a description of a shape that depends on the structure alone, the description must be based on readily identifiable features of the overall shape. Clearly the key to understanding here lies first in describing the geometry of the visible surfaces, since all of the information encoded in images, for example by stereopsis, shading, texture, contours etc. is due to the shapes local surface properties, and in this case was of no practical use in formulating an answer to the question. This task seemed to make explicit many of the common characteristics found in architectural problem-solving drawings noted in the previous section.

0630 :: CORRESPONDENCE IN THREE-D SPACE

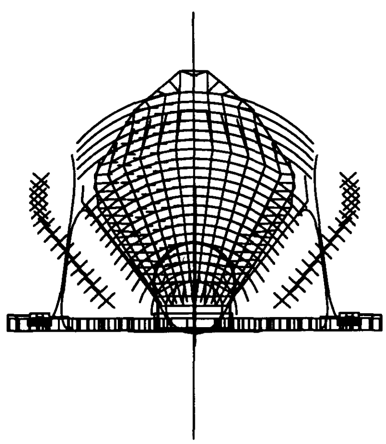


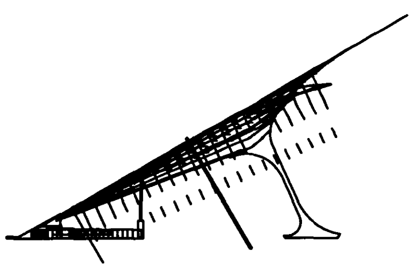
I question here the correlation of two-dimensions in "traditional" methodologies; in that when drawing with 'paper' I typically draw a plan and draw a section and conjecture a correlation in my head of the third dimension. Granted, there are precise descriptive geometric utility to the two-dimensional representations (not to be dismissed). However, my concern here lies in the fact that when I sketch by "traditional" means, my three dimensional understanding or interpretation of the correlation between the two-dimensional representations often does not correspond to my plan or my section or either. I am suggested through differences in the drawings, things I might otherwise not have become aware of. I then revise one or the other to achieve a correspondence and the process goes on like this. This is



not the case in CAD, where the above correlation is imperative. I explore the affordances of working with a 'correlated' three-dimensional model early on in the process; of the ability through CAD to have the entire model re-presented to me in three-dimensions, available for inclusive transformations, associations and reconsiderations. Although the actual "drawing" then is carried out on a two-dimensional plane, it is often done while viewing the model in three-dimensional space. For the essence of CAD lies in the viewing of three dimensions in 2-d space.

0640 :: DESIGN SPACE

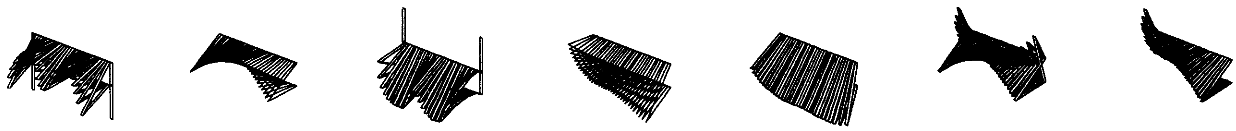




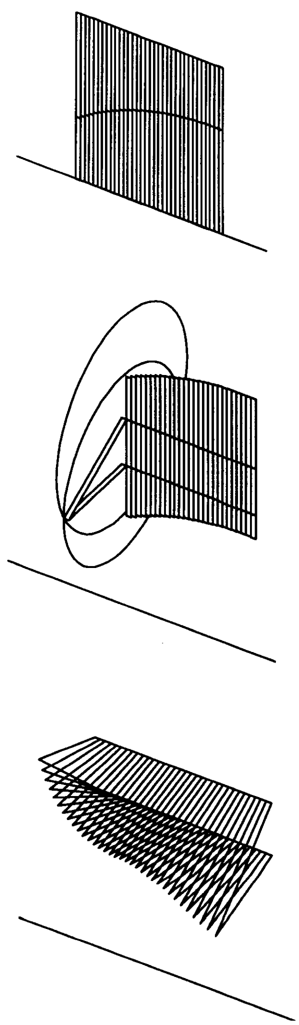
Above: operations in "corresponded" 3-d space

Fig.630a-d

I utilize several general methods in CAD for problem solving which define for me differing conceptions of the design space. The first involves the form being mapped to points in determining the geometric entities (symbols). The second involves a programming language (AutoLISP, the choice to be considered negligible) working in conjunction with the coordinate mapping in transforming the entities. This is recognized as a symbol representing a symbol in terms of equations, functions, and rules. Both of these are geometric entities representing the spatial definition of form in a Euclidean space (x,y,z). Another third involves the use of "skeletons" (Alias) which are symbols representing the form in a manner capable of transferring kinematic relations (determined by the human) into the actual form. Again then we have a symbol (skeletons) representing a symbol (the entities of the model) which is then transformed by a symbol (programming language containing rules for inverse kinematics). The difference here is then the intuitive visualization provided to the designer in understanding a representation of the transformation in terms of a smooth space as opposed to discrete terms. What I am questioning here is the use of euclidean geometry in visual problem-solving, (which is concerned with the metric (measurable) properties of the elements) as not the most appropriate to describe the geometrical properties of vision, which as we have seen utilizes an object-oriented projective geometry. What follows are two examples of problem-solving by means of a generative approach in two differing design spaces.



0650 :: GENERATIVE IN DISCRETE SPACE

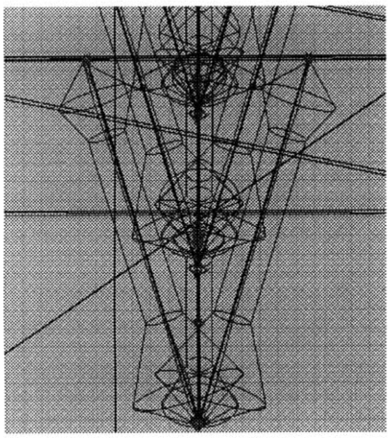


Top: Selected Variations
Side, From Top: Initial state, system of folding and resultant state

Fig.650a-d

In approaching the following generative solutions, I found it necessary to understand the specific methods of the rules for the design of a particular structure, and to develop a formal language of spatial order. Then allow to computer to play the role of generator, enhancing the practical imagining and generative limitations of the designer, whereby the role of the human lies in that of evaluation. In the example of generating variations of the folding door I first modelled one door (although I was already familiar with the operation of the transformation from another architects' design it was difficult to discern what the resultant 3-d form would be as relative to the particulars of each) consisting of parallel lines. (fig.650b) The lines were then cut into half and the bottom half displaced to an open state of the door.(fig.650c) Next, each line was rotated to a point in space as relative to the displacement and the individual lengths of each line. The point in space was determined geometrically by drawing circles around the radius of each line and rotating the lines to the intersection of the circles. (fig.650d) There were of course other methods for solving this particular problem, but such was chosen after many attempts to find a solution which would not work when the rotation of the two lines was beyond the possible rotation of either member. For example when one circle lies completely within the other (which is the case when the displacement is greater than twice the length of the top line) The geometric operations were then put into an AutoLISP (programming language) macro leaving the alternatives for inputting differing curves (cuts) and displacements (distance of which the door is opened). When I found a number of forms I thought were interesting (about 20) I then articulated these into solid forms to be rendered, and then selected a number from those for further articulation. (fig.650a)

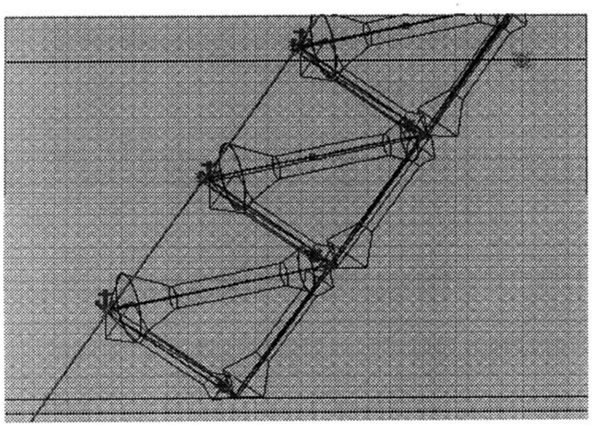
0660 :: GENERATIVE IN SMOOTH SPACE

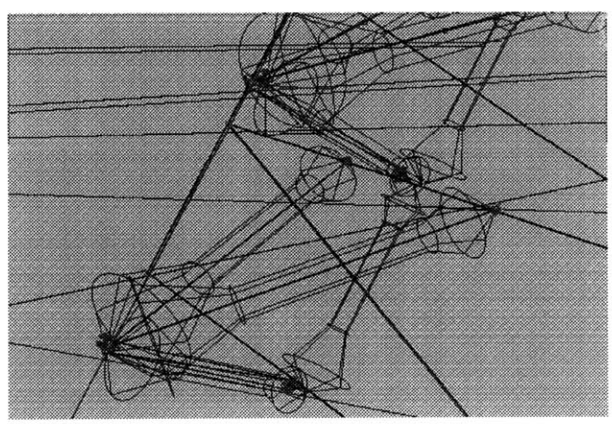


Inverse Kinematics: Problem-sollving in "smooth" space

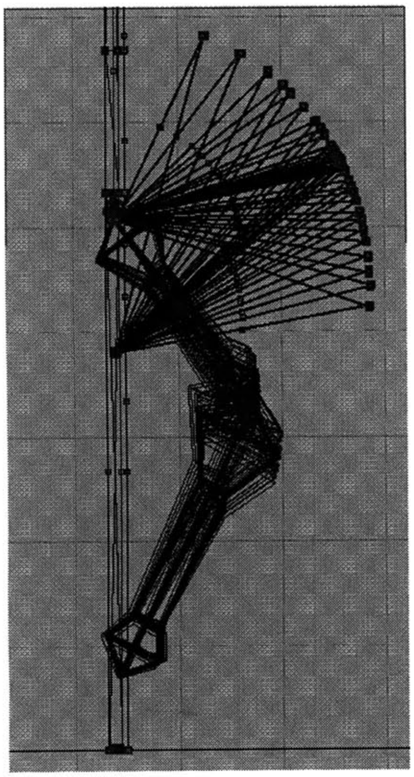
Fig.620a

The above example illustrates the way we typically go about solving problems of the sort in CAD, whereby one has an initial state, a transformation occurs and one then has a resultant state or shape This exercise un-intentionally articulates very clearly my problem with such a methodology utilized in solving problems involving motion, as the specific operations required for the transformation did not emulate the transformation of the object it represented. Specifically, the point where the two members are connected lies upon an arc which is the radius of the top member. The point is that I became aware of this fact only after animating several of models with inverse kinematics (Alias) Previously my understaning of the object was that of the initial state and the resultant state. If the transformation is smooth, one ought to have an understanding of the transformation facilitated through CAD which allows an understanding of the form in the space between the two states. Smooth space is directional rather than dimensional or metric. The typical means for problem-solving, and the one I utilized in the macro defines the points, while the understanding I ought to have facilitated while designing is the line between the points





Tools



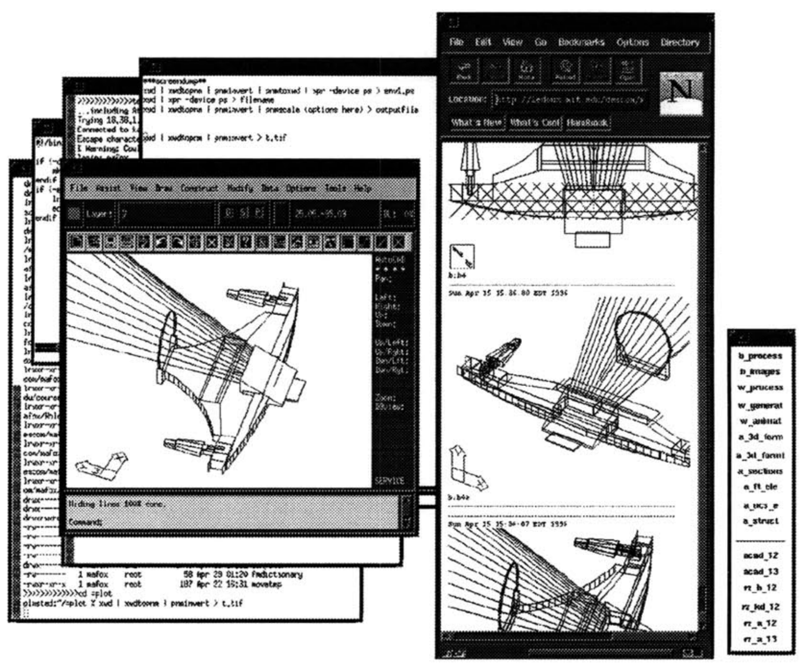
Inverse Kinematics: Problem-sollving in "smooth" space

Fig.620d

Although this chapter necessarily lies here in the overall structure of this paper, it's importance is really quite central to this discourse on the affordances of computation to the design process. The integration of computation into the process of designing lies beyond the mere utilization of any particular software or combinatorial use of software. It lies in an understanding of software as malleable to idiosyncratic designing needs; in computation easily facilitating individual tool-making, not architects becoming technical experts. Such an understanding of the affordances of a computational environment comes from the utilization of such an environment as a testing bed, as an artificial system. Tools are then built through an understanding of an environment not only to emulate human actions but to facilitate novel ones. The design process of the architect in a computational environment lies in a precarious state of affairs, whereby the tools affect the process and the process in turn affect the tools. The tools I argue then, develop new heuristics, the methodologies can in turn be tracked and more aptly facilitated. The tools and the design, on the generalized level as well as the specific then, evolve together. When I speak of the tools as malleable entities I infer that when a problem occurs or a mental limitation is encountered; a new tool is developed to facilitate that limitation or solve the problematic, the construction and utilization of the new tools then become substantial and undeniable heuristics. The importance here lies in the role of idiosyncratic toolmaking within the process; of tool evolving with the design. When we are designing with a tool or tools the heuristics of the process are thereby directed through the affordances and limitations of the tool(s) When the tools evolve with the design the heuristics are facilitated by the tools, and not necessarily limited by their parameters. Intent then is directed or guided by the tools in the former, and facilitated by or directing the tool in the latter. Methodologies then, (existing outside of the parameters of a particular symbolically structured software utilized in modelling) become very difficult to record I mention this only as a rather pessimistic insight on the ability to record our methods at the general level, for optimism still reigns on the future ability of structured computational tools to assist our understanding of particular design "operations".

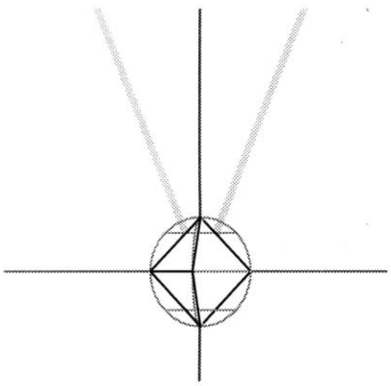
0710 :: THE ENVIRONMENT

I will explore here the specifics of a few of the "tools" which were developed in order to facilitate my process. Some are built from scratch, some reconstituted from friends and other software, some I consider tools but which are merely the combinatorial use of several existing pieces of software and finally some are considered tools merely in that they are existing tools exploited in ways for which they were not intended. I make no pretenses here, nor apologies; for the point is, when I encounter a mental limitation (be it with respect to memory, visual imaging, or generating variations), I develop something, anything to assist me with the limitation. Such an evolution of design and tools has become non-negligible with respect to my process.



Computational Environment
Exploring the use of several tools in a personalized "environment"*

Fig.220.

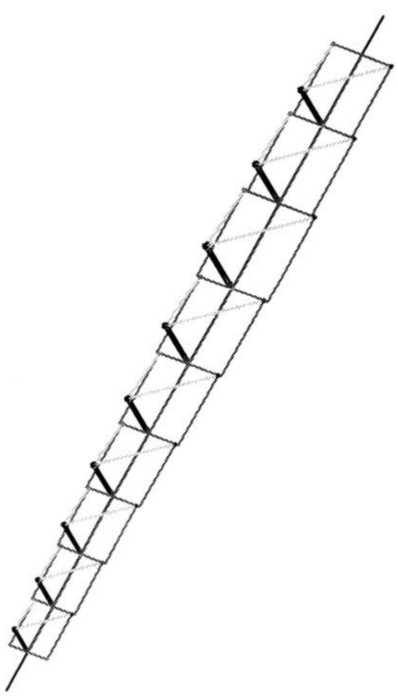


The image on the previous page is typical of my computational working environment. On the left side of the "environment" is the actual modelling software (Autocad r.13) and in the center is a WWW browser exploited as a record-keeping reference for the visual retrieval of data information as well as organized past design "states". To the far right is a rudimentary control panel for the re-sizing of windows and taking iconographic reference "snapshots" of the model. The icons then serve as a reference for retrieval, along with text, of the "active" information within the modelling software.

0711 :: Visual Retrieval of Hierarchical Data

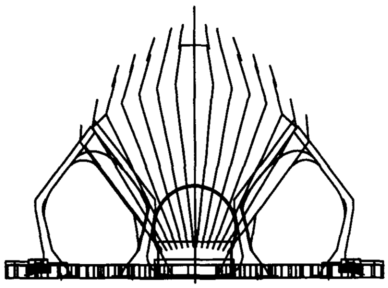
Visualizal Retrieval of Heiarchical data
Iconographic references to "active" information within the model

Fig.711a-b

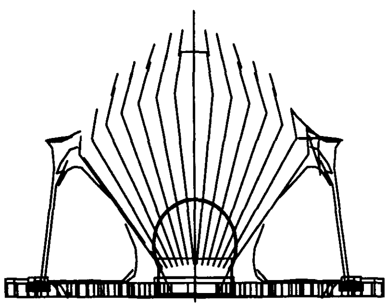


I developed here a "tool" in the above environment for creating iconographic reference images for the visual retrieval of hierarchically structured "active" data information within the model. This was created in order to facilitate my limitation in intuitively retrieving and understanding the inherent hierarchical relationships of stored information within the model. In the software utilized (AutoCAD) one is allowed to use "blocks" which can be seen as analogous to variables. Blocks allow any numbers of primitives to be grouped under a single name whereby any change in that named group can then update all instances of the block within the model. Furthermore blocks may be embedded within blocks whereby often very complex hierarchic structures exist within the model. A complex model may have one hundred or more blocks with a myriad of relations among them. For me this tool was made simply to afford myself a visual recollection of the blocks (through the icons) with simple listings of their hierarchic relations. As a new block overrides a self-referentially up-dated one, they are flagged with times and dates. The top image is represenative of a hub tagged **b:hub1**. Image 711-b represents one structural system of which the hub is a part, it is then signified as **b: (sp1(pa1-pa11(hub1 rod_h rod_p rod_v(hub_2))))** ucs: spinep.

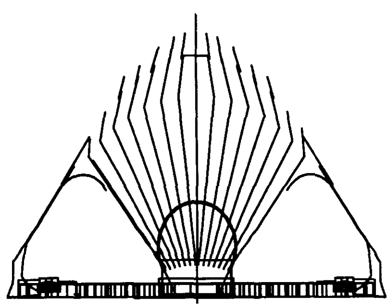
0712 :: Visual Retrieval of Past design variations



Here I exploit the same environment to a different end, specifically for the organized iconographic reference to past design variations existing as "active" information. This came about as simply a self-referential tools to aid myself in recalling past states of the model. A few weeks later it was apparent that the linearity of the storage was not very helpful and that a personal organized system would be better. Everything that seemed marginally important or of potential future use was then saved stored associatively. For instance if I "took a wrong road" exploring variations of an elevation, these would be all stored in one place as icons and the "active" information would still be potentially retrievable within the model. When a person would come to my workplace and criticize my design, they could scroll through past states, and if their criticism seemed valid the information could be retrieved and pursued further. It actually became quite useful in explaining intent which perhaps the present state of the design during the "desk-crit" failed to make explicit.



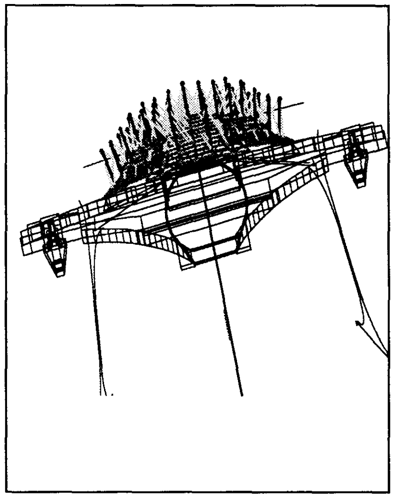
0720 :: MANIPULATION

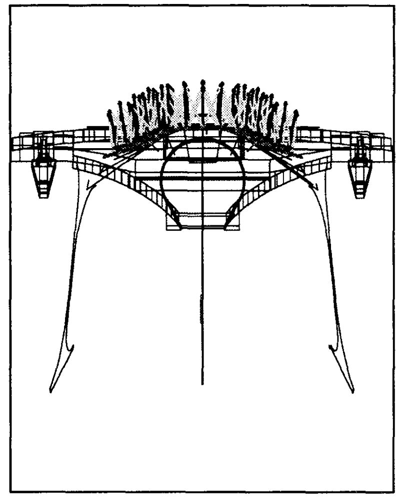


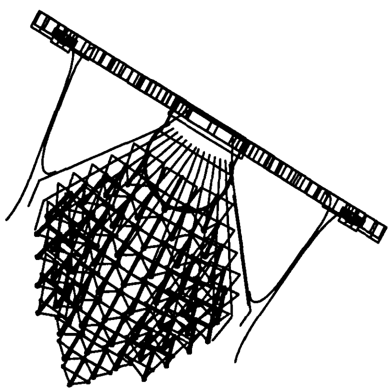
Visualization Tool
Iconified reference to past variations as "active" information withing the modeling environment
Fig.720 a-e

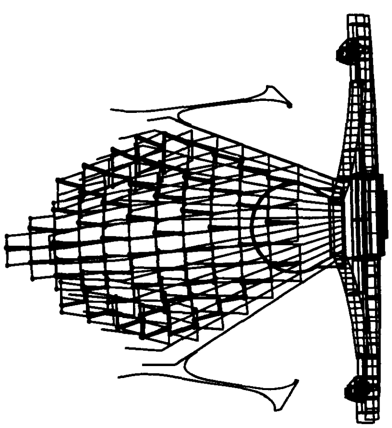
This "tool" is predicated on the assumption that architects often engage in drawing not to record an idea, but to help generate it. This "seeing something in something else" is the essence of imaging, and consequently the act of drawing in the design process of architecture. Often "getting-stuck" in the process simply requires seeing that which already exists in a new way in order to move on. We have seen already in 0650 an exploration one generative role of computation in the design process. The previous example was one whereby parameters of exploration were strictly defined and the solutions generated nearly inclusive within those parameters. While the results may have been surprising or enlightening they were strictly controlled to the extent that they could in fact be predicted with effort. The role which I exploit here lies in the act of visualizing a model in un-predicted ways-nothing more, nothing less. In fact I have not really even created anything here; but simply manipulated an existing tool (through

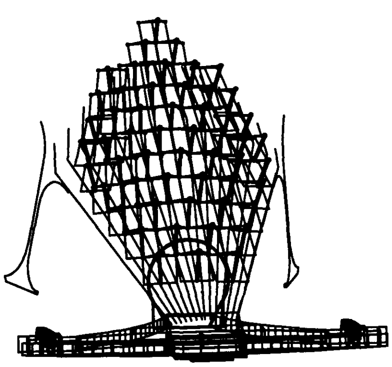
Visualization Tool
Macro for generating random views of
3-d model
Fig.720 a-e











AutoLISP) for the act of visualizing. The notion for the tool here arose out of an accident; whereby I had accidentally put my view while modelling in plan to an unknown coordinate system determined by an entity within the modelling space. What I found myself viewing was a rather compelling view of my plan (actually the entire 3-d model) in a distorted isometric view. I then stored this viewpoint onto the a web-browser and compared it to, and adjusted the actual plan which I had drawn in the modelling program. In a complex model there can sometimes be several hundred "user coordinate systems" (AutoCAD) which is the drawing plane parallel to an entity in the euclidean modelling space. The simple macro allows the user to pick "randomly", (it is not really random as the user is picking, however the results are nearly impossible to discern in this method) whereby each of the coordinate systems as relative to the entities are stored and played back to the designer as ways of seeing their model. If one is found to be compelling, or possibly of use at a later stage in the process, it can be stored as a "block" (grouping the entity (model) at that particular state) and iconifying the image onto the web browser as a "reference" for later retrieval of the actual "active" information in the particular point of view which it was stored. Images (fig.720a-e) show several examples saved as "references" in this manner. Below are two more examples from the same model at a later stage in the process:

Process-Structure-Tools: A Summation

This paper is a discourse into the relationship between the process, computational tools and the role which symbolic structure can play in both. I argue the relationship is dialectic, whereby the tools we utilize in design develop new heuristics, the methodologies in turn, if reflectively understood, can be more aptly facilitated through the development of new tools, and so on and so forth. The tools and the process then evolve together.

The ways in which we think visually in designing is a process derived through a medium of images; of images as we have seen, encoded symbolically, and utilized in the ways we are re-presenting information to ourselves through drawing . The generation and transformation of forms and structures I argue is predicated by an understanding of spaces through imaging. We have seen the ways in which our understanding of forms and spaces is visually structured and articulated by means of symbolic systems, and how limitations in our mental understanding and manipulating capabilities necessitate a re-presentational process of three-dimensional imagery to the visual system. Furthermore, that this representational process is predicated upon the existence of an idiosyncratically designed internal "library" of diagram-like representations, structured in the ways in which we perceive and store information from the perceived (experienced) natural world around us. I have explored the ways in which this structure can be developed and articulated into practically useful terms for it's utility in the development of future tools to facilitate such methodologies of designing. Whereby such a CAD model(system) is capable of inclusive recognition and the representation(shapes) are able to inform back to the designer. Secondly, I argue how an idiosyncratic interpretation of notational symbols, through facilitating a constructive reflection into design processes, can afford one insight into deciphering those aspects of symbolic content which contribute to it's functioning as per one's intent. In other words, the designer with a sufficient understanding of the properties and functions of symbol systems is allowed to create designs which function in an effective manner; works that are replete, expressive and allow for multiple readings. It can allow one insight into what questions to ask oneself and others in the process of designing.

My vehicle for understanding the process has been the exploitation of three kinetic design investigations for the isolated "operations" they display My approach lies in making explicit (through reflection and documentation) my process "through" the exploitation of a near-hit/ near-miss tool (environment) up to it's limitations and extending it (inclusive of speculation) in ways I could only understand through my experiences use of that tool. I explore several methodologies for problem-solving within the computational environment, including several generative roles of computation within the process and it's relativity to visualization and novel heuristics afforded by the tools. In exploring forms in terms of intuitive and visually constructive terms afforded by such tools, I challenge the use of strictly euclidean geometry in visual problem-solving, (which is concerned with the metric (measurable) properties of the elements) as not the most appropriate to describe the geometrical properties of vision.

Perhaps, most important are the ways in which the computational tools influence the processes utilized in designing, and consequently, can have a profound effect upon that which is actually designed. The integration of computation into the process of designing lies beyond the mere utilization of any particular software or combinatorial use of software. It lies in an understanding of software as malleable to idiosyncratic designing needs; in computation easily facilitating individual tool-making. The computational tools I argue, develop new heuristics, the methodologies can in turn be tracked and more aptly facilitated through novel tools. The tools and the design, on the generalized level as well as the specific ought to evolve together. When the tools are utilized as malleable entities (in that when a problem occurs or a mental limitation is encountered, a new tool is developed to facilitate that limitation or solve the problematic) the construction and utilization of the new tools then become substantial and undeniable heuristics. The importance here lies in the role of idiosyncratic toolmaking within the process; of tools evolving with the design. When we are designing with a tool(s) the heuristics of the process are thereby directed through the affordances and limitations of the tool(s) When the tools evolve with the design the heuristics are facilitated by the tools, and not necessarily limited by their parameters. Process then is *directed* or guided by the tools in the former, and facilitated by or *directing* the development (both in the general and the specific) of the tools in the latter.

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