# DIGITAL GRAFT

## Towards a Non-Homogenous Materiality

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# Abstract


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Submitted to the Department of Architecture on August 19, 2004 in partial fulfillment of the requirements for the Degree of Master of Science in Architecture Studies.

Digital methodologies have radically shifted our conception of the design process, as well as our understanding of geometry in terms of flexible relationships instead of finite positions in space. However, the material tectonic that digital means imply has not yet been explored on the basis of the new possibilities disclosed by these very same tools. Tectonic investigations have almost exclusively focused on construction techniques and primarily on the optimisation of methods that preceded the appearance of digital tools. I would argue, that computer generated architecture might imply a new understanding of matter and mass. So far, the materialization of formal expressions instigated by such processes are primarily based on techniques of assembly, which do not negotiate the advanced levels of material complexity that the tools put forward.

This thesis lies on the premise of investigating modes to address an emergent rather than imposed materiality of distributions, instigated by computer-generated processes. Methodologically, this thesis has a twofold task. The former is to interrogate an alternate prism of construction history, which does not shed emphasis on geometry, but rather on mass and matter, paraphrasing Michel Serres. The latter task is to launch design experiments that respond to an alternate, emerging perception of material densities, constellations and coagulations. Through a series of digital case studies it becomes both a "theoretical" and "technical" probe of a materiality with local differences exploring non-homogeneous ways of distributing matter in space. Three material strategies -thread, component and substance - will be presented in an attempt to address modes of interrogating a reciprocal relationship between material distribution and form development. Through this approach, space can be perceived not as distributed geometries, but rather as a composite graft responding locally to flows of programmatic and environmental parameters.


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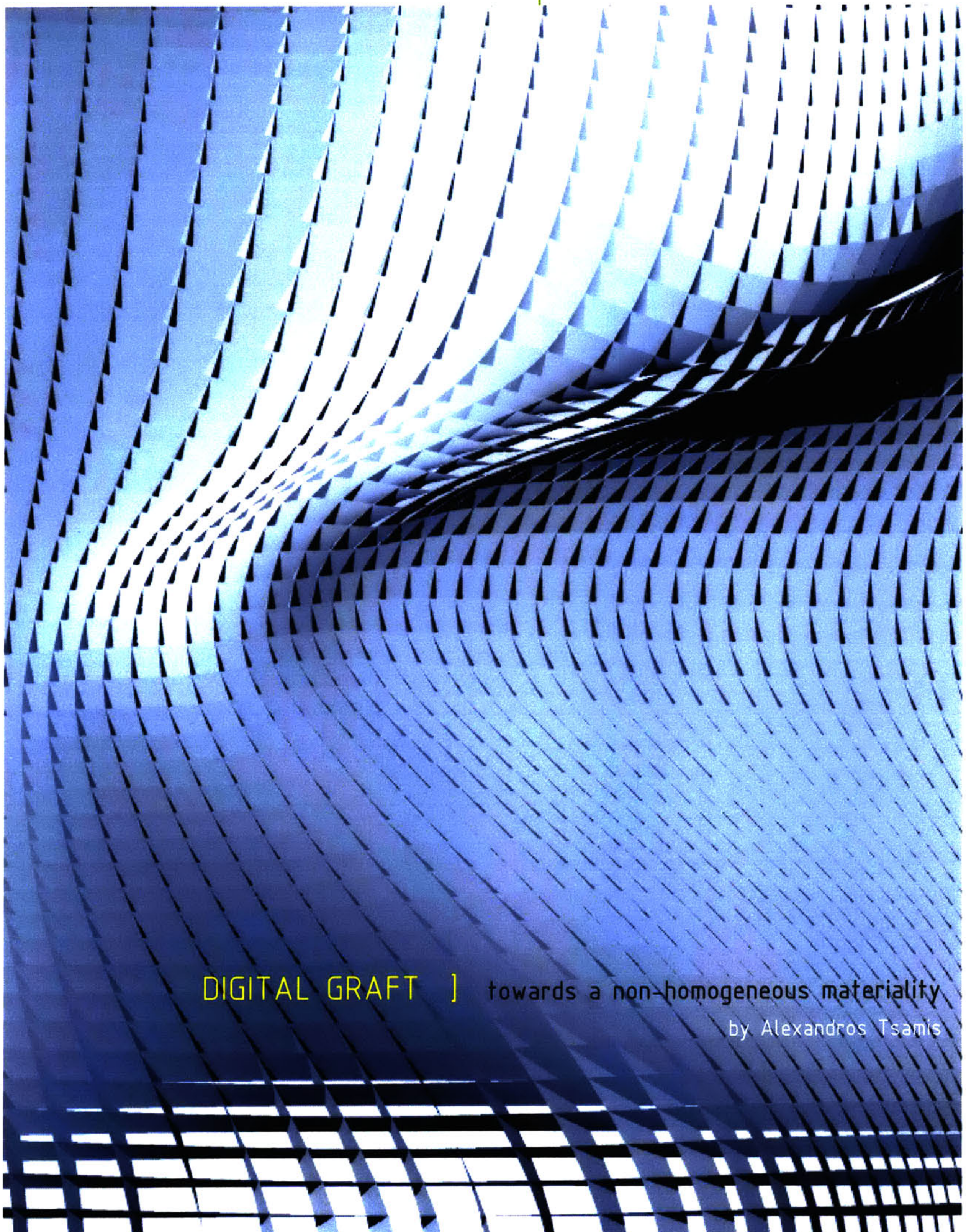
Last but not least, I would like to dedicate this thesis to Lydia kallipoliti -my Lydia- the 'half or more than half' of my architectural education and my partner in all.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Matter >> the unformed, unorganised, nonstratified or destratified body and all its flows: subatomic and submolecular particles, pure intensities, prevital and prephysical free intensities. (referring to Hjelmslev' s net of the notions of matter, content and expression, form and substance)

Gilles Deleuze, Felix Guattari, A Thousand Plateaus. Capitalism & Schizophrenia (Minneapolis: University of Minnesota Press, 1996)

# Chapter 01 : Introduction

There is no easy way to elaborate in what precise manner the design process has been shifted through the use of digital media. Hesitating to probe directly into a deep analysis of this issue, one can attest without a doubt that the last decade has wallowed in the formally spectacular. By this term, I do not refer to conceptual novelty that emerged from the use of digital media; I am rather referring to the finesse and formal acuteness that design has portrayed.

If curvilinearity lies at the core of this discourse, one can trace significant examples of architects throughout the century and even before, that have strived for alternate formal expressions of cavities and slopes, curves and indefinite shape. Ionel Schein (figure 1) and Frederick Kiesler (figures 2,3) comprise prime explorers in this stream of thought, through their daring and subversive explorations in the plasticity of matter and the breaking of its conventional boundaries. Along with formal explorations, the Surrealists in the 1930s, project a vision of an 'intra-uterine architecture', a term conceived by Tristan Tzara. This vision encompasses curvilinearity in its entire kingdom, in the form of cavities and caves, but most importantly associates it with prenatal desires and the space of the womb that is by default inscribed into the desires of the subconscious. On this theme, I am quoting Anthony Vidler who characteristically remarks: "an intra-uterine architecture was thus conceived as a radical

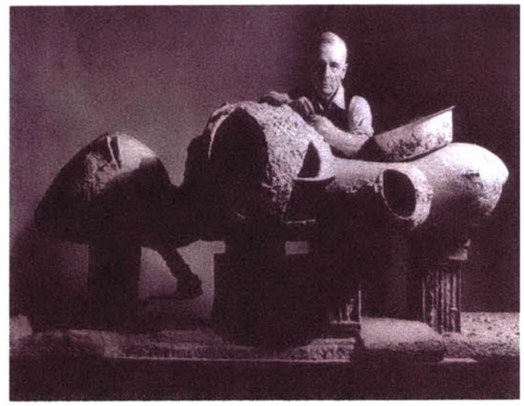


figure 2 >> Frederik Kiesler with model of endless house


figure 2 >> Projet pour une bibliothèque mobile, 1957


figure 3 >> *La Cabine hôtelière, 1956*

criticism of the house of Le Corbusier and Meisian rationalism... Against the horizontal extensions and implied dissolution of public and private of the Domino model, Tzara posed the maternal and sheltering images of uterine constructions which, from the cave to the grotto to the tent, comprised the fundamental forms of human habitation: From the cave (for man inhabits the earth, the 'mother'), through the Eskimo yurt, the intermediary form between the grotto and the tent (remarkable example of uterine construction which one enters through cavities with vaginal forms) through to the conical or half-spherical hut furnished at its entrance with a post of sacred character, the dwelling symbolizes prenatal comfort.[1] Entered through cavities of 'vaginal form', these conical or half-spherical houses were dark, tactile and soft. They imitated the self-constructed shelters of childhood". [2] In this sense, the discourse of curvilinearity has been historically linked to searches for primal origins and the transgression of rationality embedded in creative praxis.

It is important to depict the origins of 'mystical' form before entering the realm of the digital; not only in order to associate digital tools and their effects to their predecessors in 'form making', but also to establish a territory that preceded them and use it as a tool to seek where the difference lies. Readily available tools in 3d modelling environments such as 'lofting' are main participants in the creation of what I previously referred to as formally spectacular. A first parameter that

1. Anthony Vidler in "Homes for Cyborgs" refers to Tristan Tzara, "D'un Certain Automatism du Gout", Minotaure, 3-4, December 1933, p.81-84.

2. Anthony Vidler, "Homes for Cyborgs" in Otagonno; Prosthesis, No.96, 1990.

distinguishes the digital form from the historic precedents is the elaborate definition that can now be accomplished. Kiesler and Schein, as well as the Surrealists, were undoubtedly subversive thinkers and explorers; nevertheless, their results were not always equivalent to the depth of their thought. And so, they remained in a realm of 'otherness' from the main production stream. This condition has indefinitely changed now. 'Digital form' does fascinate us and draws conjecture. In this sense, curvilinearity is overtly not a nascent condition; it has acquired a cultural potency via the use of digital tools.

At the inception of the 90s decade, this tendency was put together in an encompassing umbrella by Greg Lynn, through the launching of a discourse on 'smoothness' and on the basis of the philosophical background by Deleuze and Guattari. Lynn suggests that through the introduction of digital technologies in the architectural praxis, a major shift has occurred. The architectural object is no longer conceived as the synthesis of separate, distinct and opposing elements but as a smooth entity that incorporates local differences within one unified body. (figure 4) He articulates that "the smooth spaces described by these continuous yet differentiated systems result from curvilinear sensibilities that are capable of complex deformations in response to programmatic, structural, economical, aesthetic, political and contextual influences"[3]. Underlying this statement, there is a reaction targeted towards the movement of 'deconstruction' and its conceptual

figure 4 >> Greg Lynn. Ark of the world

3. Greg Lynn, Folds, Bodies and Blobs (La Lettre Volee, 1998), p.115.

paraphernalia of oppositions, conflicts and disparate entities that come together as antithetical parts. Lynn proposes the integration of differences and conflicts in unified bodies and he channels his statement to the realm of the 'real' through the use of digital tools. Curved smooth form is the by-product of this discourse, because the ground-breaking features of smoothness lie elsewhere; both in the shift in the conception of the design process as well as the acknowledgement of a base matter of local differences embedded in the expression of smoothness. These arguments comprise additional parameters that distinguish the digital form from the historic precedents.

Although Greg Lynn, talks about unified systems and smoothing of differences, he refutes the idea of architecture as a construct with a holistic logic, or as an overall matrix that embodies the 'organism' where all parts are integrally related. He states: "This whole architectural concept ignores the intricate local behaviors of matter and their contribution to the composition of bodies. An attention to the matter out of which bodies are composed suggests a reformulation of the concept of the whole. An acknowledgement of base matter does not necessarily lead to a transgression of the concept of the body itself (as has been the recent reaction to the repression of differences by the logic of the whole) but could engender a more open and dynamic conceptualization of how bodies are composed. Bodies can emerge through local intricate connections, alliances, aggregations and affiliations of base matter. These bodies cannot be educed to any single, general, universal or ideal organization as the result from the complex indications of disparate systems"[4]. In this sense, although Lynn's position is intransigent to the formal disjunctions of 'deconstruction', he is in no sense looking backwards to modernist ideals and pursuits. His prodding into the 'inside' of the body of matter and the consequent focus on local relationships and aggregations, controvert the idea of wholeness in the products of architectural design, which was a major quest and pursuit in modernism. On this topic, he notes that modernism has attempted to "repress conflict"[5] through the umbrella of wholeness. Therefore, Lynn's stasis marks the inception of an 'unorganisized' reality of base matter through a bottom-up understanding, where the position of each part is not directed by an overall schema. This model of thought functions on the basis of a Hegelian notion, where the emergent properties belong to the parts as well as the whole.

Moving on from the discourse of base matter, the final parameter that distinguishes the digital form from the historic precedents is the shift in the conception of the design process, which yields variable results as a procedural phenomenon. Latent in the formal expression of curved forms is the process from which they were derivative. In many cases, products are instants of a parametric expression that exceeds formal definition. They are the outcomes of a process in motion that expands finite production to a range of variable results.

4. Greg Lynn, Folds, Bodies and Blobs (La Lettre Volee, 1998), p.135-136

5. Greg Lynn, "Architectural Curvilinearity. The Folded, the Pliant and the Supple" in Guiseppa Di Christina (Ed) Architectural Design: Architecture and Science (Great Britain: Willey Academy, 2001), p.26.

Parametric variability derives from the injection of calculation as a component of design thought and praxis and is a direct offspring of digital media. As Berbard Cache notes in 1998 "Objects are no longer designed, but instead calculated" [6]. According to this quote, a line for instance is defined by its analogous equation f(x)=ax+b, instead from its positioning in the Cartesian space, where a (x,y,z) and b (k,l,m) are fixed and singular locations in the three-dimensional space. This reallocation has impacts on diverse levels of the design sphere. Aggregations and accumulations become an important part of reading a body of information and density of matter regains tremendous respect in conceptualizing architectural space.

6. Bernard Cache, Earth moves: Furnishing of Territories (Cambridge MA: MIT Press, 1998), p.88.

Along these lines lies the eminent discussion revolving around topology. "Topology also called the 'geometry of the rubber sheet' admits all possible transformations of a figure drawn on a rubber sheet when the sheet is manipulated in every possible way without tears or rents. A topological transformation, or homoeomorphism, of one figure into another is determined by a by-univocal and bi-continuous correspondence between the points of the respective figures. Topological transformations are the more general continuous transformations that maintain the geometrical properties of the connection and the vicinity of the points of the figure (so that near points continue to be near and far-off points continue to be far away). Thus topology considers objects as elastic bodies liable to continuous transformations that change their form; and figures that can be transformed into one another by means of process of continuous transformation, avoiding cuts and tears, are topologically equivalent. This means that from the topological point of view there is no difference between a circumference and an ellipse, a triangle and a square, just as there is no difference between a sphere, a cube, a cylinder and a cone. By virtue of this, we can conceive figures as the products of the transformation of other figures. Topological geometry is therefore a flexible and dynamic system that is able of curving, folding or twisting by means of continuous transformation. Accordingly, the pliant and curvilinear architectures are understood and practiced as being the result of processes of manipulation and deformation of form itself, by means of continuous non-linear transformations. "[7] Topology is an intrinsic attribute of digital media that sheds emphasis on the relationships between elements instead of their finite, singular definitions. A NURB surface (within a 3d modelling software) for instance, is by default topologically defined; a possible relocation of any control point throughout the surface affects the position of its neighbouring points, which are redefined respectively. It is a surface defined by equations and relationships, rather than a singular form projected on the screen.

A characteristic example of the open-ended expression of topological transformation is a design experiment by Mark Burry entitled 'Our World' (figure5 )- The context for this experiment is a cubic virtual environment, at the core of which Burry has placed the three axes that normatively define

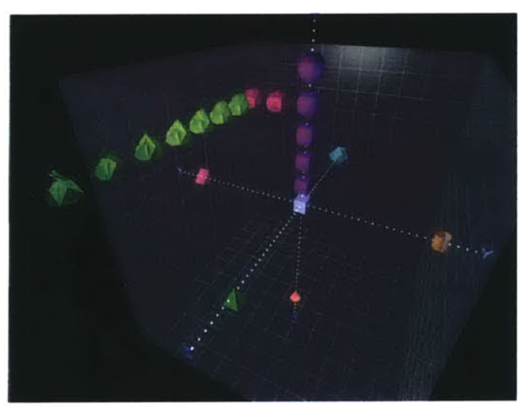


Figure 5 >> Mark Burry. A view of the general layout of 'Our World' three-dimensional space x,y,z. The axes intersect in an orthogonal manner according to the Euclidean definition of space. At the end of each pole of the axes, there is a geometric primitive, more specifically a sphere, a cone, a cylinder, a pyramid etc, whereas at the intersection of the system there is a cube. At the inception of the project, the focus was on the geometric description of each volume in such a way so that it could transform into the other. Therefore the traditional definition of a cube by 12 edges or 6 sides for instance would not be sufficient for its transformation into a cone. New principles of formal definitions would have to be inscribed in each element as to enable it to shift into the next one (figure 6).

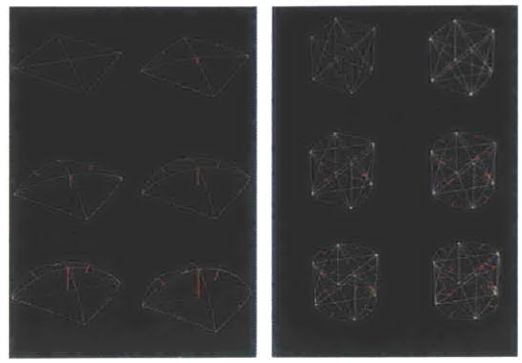


Figure 6 >> Mark Burry. Cube to Sphere & Cube to Cylinder Surface Definition diagrams

On this same theme of embedded information in surface definition, "Markos Novak appropriately remarks that 'a cube is not less topological than a blob".[8] What matters in topology is the information that is encoded into an object, its germinal capacity to shift state of being; the current form is merely an incidence in time, or the intersection of time to the latent potential of the topological form. As Burry describes in his project, the initial scope was to embed the necessary information in the geometric primitives that each state of transformation would require. "The task is simple: to work towards a mutual understanding of the topologies of various Phileban forms (cubes, spheres, pyramids etc.) so that we can computationally adjust the spatial characteristics of their respected geographies in order to represent transitional states -the

8. Giuseppa Di Christina, "The Topological Tendency in Architecture" in Guiseppa Di Christina (Ed) Architectural Design: Architecture and Science (Great Britain: Willey Academy, 2001), p.7.

morphing of one into the other" [9]. For Burry though, the interest of the project did not reside in the orchestrated morphs along the linear axes, meaning along the planned transformation from one geometric primitive to the other. Instead it resided in the potential exuded if one would follow a bizarre trajectory of morphing within the virtual environment of 'Our Word'. An example of such a trajectory would be to begin morphing a cube towards a sphere and before it actually acquires all of the characteristics of the sphere, to begin morphing it into a prism and then into a cone and so on and so forth. The outcome of these hybrid trails provide entirely unpredictable volumes and yield a complexity that is directly derivative of straightforward elements. Burry identifies the space delineated outside of the prescribed axes as "outer space"[10] and consequently the forms comprise the by-products of this alternate reality.

Moving onto another project that exemplifies parametric thinking and topological expression of form, Kas Osterhuis begins from a contradistinctive incentive; mass customized housing through the web. The scope for the specific project entitled 'Variomatics' (figure 7) was to offer "a new interactive approach to catalogue housing. The client manipulates his house's using the images on the website. The elastic geometry of Variomatic is linked to a database, where the surfaces, volumes and costs are calculated. After having shaped his/ her own Variomatic house, the client can order a scale model or a set of drawings or can directly

9. Mark Burry, "Beyond Animation", Architectural Design (AD), Vol. 71, No.2, (London: John Wiley & Sons Limited, April 2001), p 9.

10. ibid. p 12.

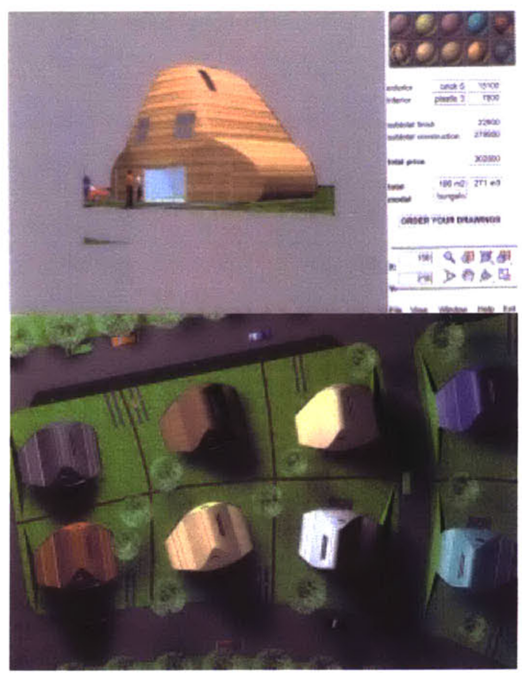



Figure 7 >> - Variomatic Housing. Kas Osterhuis & Ilona Lenard apply for building permission if he/she already owns a plot" [11]. In this case, the topological, parametric definition of form is directly applicable to the market, offering new links between conception and production. Emphasis lies here on user preferences and the appeal of an open system to the consumer world. The uniqueness of the occurring housing results is also advertised as an additional positive feature of the system. As mentioned, "this new concept for a catalogue house is elastic in all directions. In height; depth; and width. The clients define the overall dimensions of the house, the place where the kitchen should be or a solar water heater. They can moreover choose among many materials and colours to finish the volumes: reed, wood, metal, tiles, PVC" [12]. Nevertheless, this very last citation on the selection of a definitive pool of materials and their direct appliance onto surfaces that have already been settled brings to the foreground an issue for architectural design and the concurrent use of digital tools; the issue of materiality which is not parametrically defined as form is. In fact, material and form are mostly disjunctive operations in the digital realm. The discussion on formal complexity and variability is endless, whereas a discussion on the materiality emerging from the use of digital tools has not yet been instigated. In most cases, materials in 3d modelling environments are merely offered as a selection for 'pasting' and remain independent from the logic of formation of objects. On the basis though of the parametric potential and inscription of properties that digital tools support, a basic

11. Kas Osterhuis & Ilona Lenard, "Variomatic SM" in Marie-Ange Brayer & Beatrice Simonot (Eds), ArchiLab's Future House: Radical Experiments in Living Space (New York: Thames & Hudson, 2002), p.182.

12.ibid

question arises; why is the material of Variomatic a wallpaper on the mass customized house? Can there be an alternate way to deal with materiality, allied to procedural definition of from making?

The 'Raybould House' project by Sulan Kolatan and Bill McDonald comprises another example that broaches the inquiry of emergent material definition through the use of digital media (figure 8,9). The house is essentially composed of a unified surface that blends the building with the landscape and simultaneously organizes the interior space. The envelope becomes a mediator between diverse conditions becoming from an interior partition to a structural component. The same surface becomes a wall a ceiling a bath tub and a staircase. This decision defies most deeply embedded postulations of construction and necessitates new fabrication and construction techniques to be set into practice. The plans involved the fabrication of templates, cut in plywood at 1:1 CNC machine and erected on site. Once assembled, they will form a skeleton for the overall building envelope. Spray-on foam will be applied to the rib frame matrix. An aluminized polyurethane skin will be applied to the exterior, while the interior shell will be finished in a smooth cementious acrylic mix.

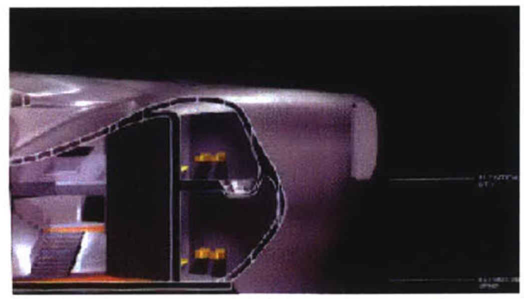


figure 8 >> kolatan / Mcdonald. Reibould house

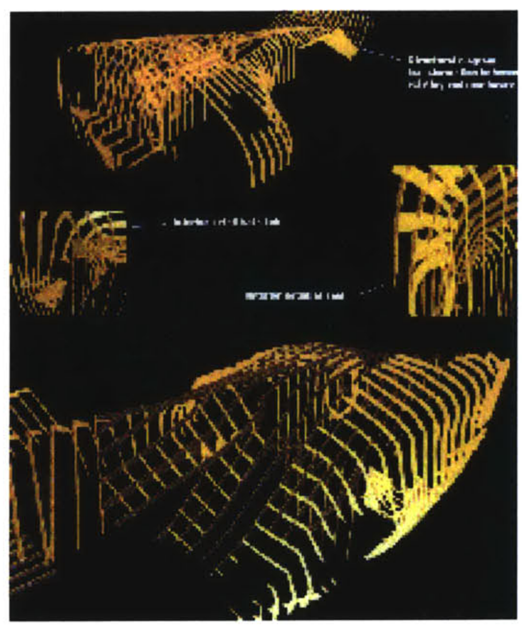


figure 9 >> kolatan / Mcdonald. Reibould house

The question that the 'Raybould House' poses directly is what does it mean to conceive of a super-surface that incorporates within its unified body the properties of a wall, a window, a ceiling and a bathtub? The technique of spraying is certainly not a new tactic; many explorations in the 70s, in a time of 'utopia of materialism' have deployed techniques of spraying as a tool for inexpensive fabrication. What is radically different in this case is the emergent material of a body with varying attributes and the fabrication that it implies for further contemplation. In light of this study, if one revisits our current fabrication methodologies for intricate formal explorations, such as the ones derivative from the use of digital media, it is quite overt that they comprise a set of external specifications imposed on the objects. In more than many cases, a component based exterior system is enforced, at the implementation phase. "We presently process a variety of materials, cut them up into shapes and then fix them together to create the built environment for our particular needs. The majority of design recourses are directed into trying to solve the technical problems brought about by the bringing together of different building components, whether they be structural, finishes, or service equipment of varying magnitude. However the advancement of material science is revealing a new construction process initiated at atomic level. Instead of cutting and stitching a patchwork of structural and non-structural elements in the hope that they will work in harmony, the atomic revolution will provide us with the means of creating building enclosures by the means of manipulating the molecular matrix and the atomic ingredients to the required structural and environmental specifications"[13].

According to Deleuze and Guattari matter is "the unformed, unorganised, nonstratified or destratified

13. Battle & McCarthy, "Multi-Source Synthesis. Atomic Architecture", Architectural Design (AD), Vol.65, No.1/2, (London: Academy Group Ltd, 1995), p.III.

body and all its flows: subatomic and sub-molecular particles, pure intensities, prevital and prephysical free intensities" [14]. Grasping onto this comprehension of material entities and chemical compositions, Greg Lynn portrays complexity as a tool for synthesis and conception of the design process. He depicts the architectural potential of 'viscous mixtures' and mentions: "The two characteristics of smooth mixtures are that they are composed of disparate unrelated items and that these free intensities become intricated by an external force exerted upon them jointly. Intrications are intricate connections... They affiliate local elements with one another by negotiating interstitial rather than internal connections. The heterogeneous elements within a mixture have no proper relation to one another" [15].

So far, the interpretations of these ideas have revolved around urban complexity and local behaviors as related to the realm of the city. By transferring this notion into a micro-scale, it is possible to conceive of material under similar terms, if reconsidering the forces that may have an affect on materials in this scale. On the basis of the notions of mixtures, alloys, entropic material landscapes and so forth, one imagines a material archipelagos of diversity, pigments and constellations. My inquiry lies on the absence of such an expression; on the hiding of the composite nature of elements and information behind 'sharp plastic wraps'. If Bernard Cache advocates the fusion of landscape all the way to the scale of the furniture, what does this insinuate for the occurring

14. Deleuze & Guattari refer to Hjelmslev's net for the notions of matter, content expression, form and substance. In Gilles Deleuze & Felix Guattari, A Thousand Plateaus. Capitalism & Schizophrenia (Minneapolis: University of Minnesota Press, 1996).

15. Greg Lynn, "Architectural Curvilinearity. The Folded, the Pliant and the Supple" in Guiseppa Di Christina (Ed) Architectural Design: Architecture and Science (Great Britain: Willey Academy, 2001), p.26.

material of such a fusion?

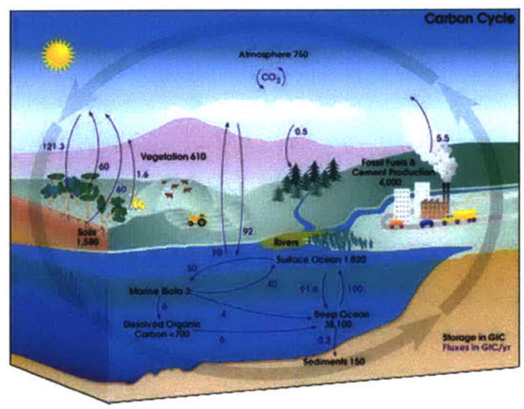
By conceiving matter as a densities and constellations of materialized information, rather than as distinct components, new possibilities are disclosed. The possibilities of a parametric material expression in absolute correlation with the procedural thinking of the design process lies at the core of my discourse in this thesis. My intention is to explore the techniques of non-assembly, to investigate modes of distributing matter in space in an attempt to position the contemporary architectural discourse with its implied materiality. Consequently, this thesis revolves around a question: Can there be a topological expression of materiality allied with all disparate forces in the creative praxis?

## Chapter 02 : Material Perspective.

### Material in transition

If there is a territory that can comprise sufficient ground for an exploration of topological materiality, this territory is the encompassing field of morphogenetic phenomena. In nature, material composition and geometric configuration are concurrently generated and transformed in a constant loop.

A simple example would be to look at the phase transition of water into its three states; vapor, liquid and solid. The transition of state is not accompanied by an alteration in water's molecular composition; after all, it is always comprised of two molecules of hydrogen and one molecule of oxygen ($H_2O$). Instead, what changes is the environment around it that forces the molecules to either compact in a dense mass or to barely connect to each other. Another example is carbon, which participates during its formation in an endless loop of changing state (figure 10). When carbon is located deep inside the earth, according to the compression that comes as a result of layers of earth pilling up over time, it appears in four states: amorphous, graphite, diamond and Fullerenes[16]. Carbon's material 'instance' or variant is not derivative of different elemental composition. Rather, it relies solely on the conditions that surround its geological formation. And although, material properties and exterior conditions are of primary importance, when we look at a section of an underground geological formation, our fascination derives from tracing the geometries and contours of materials in categories. Our visual




(figure 10) >> Carbon Cycle

16.http://en.wikipedia.org/wiki/Main_Page.

perception is constructed in such a way as to follow the things that are of same consistency, although the principle behind this very same formation is that of local intricacy and constant transformation.

Another, more complex example, yet indicative of the convolute mechanics of the form-material relationship, is the formation of the snow crystal (figure 11). "Its genesis is dynamic and can be seen situated initially at the convergence of three distinct fluxes: mica and mineral particles; a moisture saturated field; and a thermal flow of heat exchange. One does not know in advance when or where such a crystal will begin to nucleate or form, but one knows it will emerge -apparently spontaneously- from a flux of convergence of flows, not in a prepared form or state."[17] Kwinter's fascination with the snow crystal does not merely derive from the complexity of its formation. Rather, what he finds compelling is that despite its partially predetermined, regular crystalloid form, no two specific crystals are ever the same. As he suggests, "each is different because it maintains its sensitivity both to time and to its complex milieu. Its morphogenetic principle is active and always incomplete (i.e., evolving)"[18]. In this sense, our general understanding of a crystal as a rigid tetrahedral lattice of hydrogen and oxygen, which determines the even formation of hexagonal plates cannot encompass the entire spectrum of its fundamental nature. The crystal's interaction with its environment during its formation process causes "certain regions of the hexagonal matrix to catch more than their share of the external weather

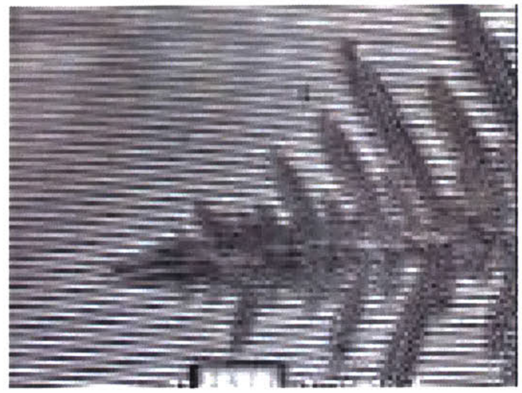


Figure 11 >> free crystal growth

17. Stanford Kwinter, Architectures of Time, Towards a Theory of the Event in Modernist Culture (Cambridge MA: MIT Press, 2002), p.26.

18. ibid

conditions"[19]. The crystal's local adaptation to mica and mineral particles exceeds its former conception as a fixed symmetrical entity with stable consistency. In this sense it lies at a bizarre intersection of being self-defined and simultaneously emergent from the complex convolutions of the external milieu; it is a body of variable properties not only due to its geometrical configuration but also due to its material composition. (figure 12)

At a closer examination of the aforementioned examples, we can conclude that in order for nature to achieve such spectacular local intricacies it employs two or more constituent elements in myriads of 'irrational' combinations. By the term irrational I mean, that the latent combinatorial logic is not headed towards utopia or perfection, instead it sets in motion numerous trivial and simple rules that are performed effortlessly, without meaning, without the implication of general axioms and hierarchies. Precisely on this issue, the French philosopher Francois Dagognet refers to nature as a 'blind bricoleur' and unfolds his argument in the following seminal passage. "Nature has not been natural, in the sense of pure and untouched by human works, for millennia. More provocatively, he asserts that nature's malleability demonstrates an invitation to the 'artificial'. Nature is a blind bricoleur, an elementary logic of combinations, yielding an infinity of potential differences. These differences are not prefigured by final causes, and there is no latent perfection-seeking homeostasis. If the word 'nature' is to retain a meaning, it must signify an uninhibited

19. Stanford Kwinter, Architectures of Time, Towards a Theory of the Event in Modernist Culture (Cambridge MA: MIT Press, 2002), p.26.

Figure 12 >> free crystal growth

polyphenomenality of display"[20].

## Non-homogenous material

The material analogue of an artificial combinatorial logic is that of composite materials. The analogy derives not only from the fact that composites are combinations of more than two elements, but also from the fact that the properties of the final product are substantially different from the individual properties of the parts. More specifically, "the result is a new substance whose properties are different and superior to those of the original elements but where the mixed elements retain their individual characteristics"[21]. In practice, a contemporary composite material is consisted in most cases of a combination of two principal elements: reinforcement and matrix. The Reinforcement provides high strength, high stiffness and plays the principal role of load carrying. The matrix provides a surrounding medium for the reinforcement, distributes the load carrying forces evenly and protects the reinforcement from environmental damages, such as elevated temperature and humidity (figure 13).

Composite materials do not comprise a new territory of exploration. In fact they are of prehistoric origin, as they were extensively used by nomadic populations in their shelters, transportation vehicles and weaponry, composed of mixtures of straw, mud and other local materials. The black hat (figure 14)

20. Paul Rabinow, "Artificiality and Enlightnment: From Sociobiology to Biosociality" in Jonathan Crary & Sanford Kwinter (Eds), Incorporations. Zone (Series);6 (New York, NY: Zone, MIT Press, 1992), p. 249.

21. Johan Bettum, "Skin Deep. Polymer Composite Materials in Architecture", Architectural Design, Vol.72 No.1, Ali Rahim (Ed.), (London: Willey Academy, London, 2002), p.72.

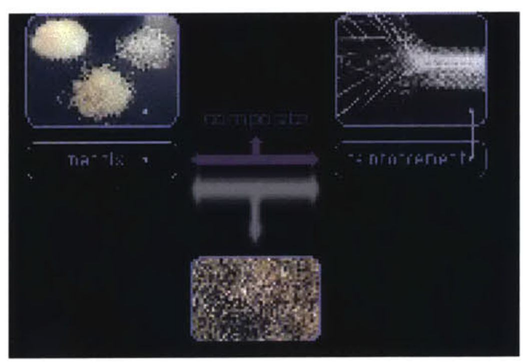


figure 13 >> matrix and reinforcement of a polymer composite is a typical example of nomadic habitat, constructed out of fabric hair from goats, sheep and camels. The cloth provides shade and absorbs the heat to disperse it in the space that is enclosed. Hair can also provide insulation against the cold[22].

One of the main reasons for the deployment of composites at such an early stage in history was the intense relocation of populations that accordingly necessitated all structures to be as light as possible in order for their transportation to be efficient. Lightweight structures are inexorably linked to the use of composite materials; because of their synergistic logic they do not necessitate the deployment of heavier and stronger materials. The intrinsic character of fusion in composites augments their vigour and competence and allows for the materialization of lightweight structures.

Nonetheless, besides parameters associated to the efficiency of lightweight structures, there are other interpretations on why composites were deployed by nomadic populations. A prominent conjecture is that the craft of the structures embodied principles driven by the surrounding environment. As David Kronenburg notes "the nature of nomadic and migratory people's relationship with the lands they inhabited can also be examined in order to develop our understanding of one of the crucial factors in creating new environments: the creation of a sense of place. These people had an intimate understanding of their place in the landscape which extends to their relationships between their buildings and even to the layout of their interior spaces"[23].

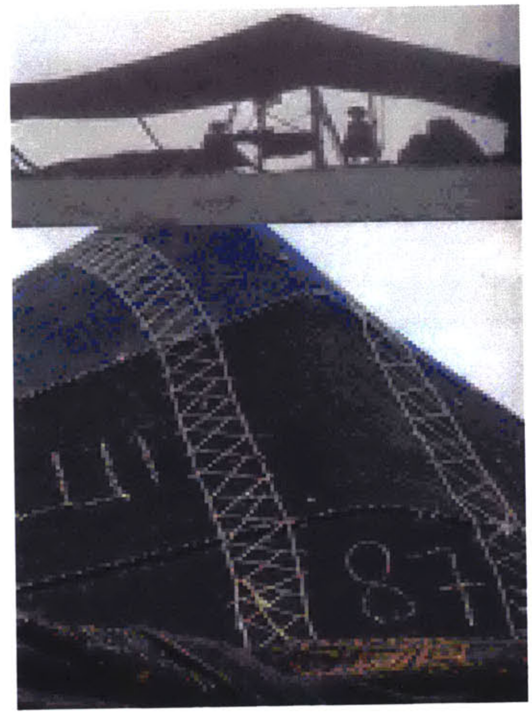


figure 14 >> The Black Hat

22.Adriaan Beukers & Ed Van Hinte, "Lightweight Structures", in Architectural Design (AD), Vol.72 No.1, (London: Willey Academy, London, 2002) p.102.

As time went by, people settled and started using other materials such as brick and metals for weaponry. In the 20th century, the use of metals reached its climax. From the 1960s the use of advanced composite materials saw a rapid increase to meet the demand for lower structural weight. After World War II, US manufacturers began producing fiberglass and polyester resin composites. The automotive industry first introduced composites into vehicle bodies in the early 1950's. Because of the highly desirable lightweight, corrosion resistance and high strength characteristics in composites, research emphasis went into improving the materials science and manufacturing process.[24] Adrian Beuker and Ed Van Hinte, on their publication for minimum energy structures (1997), argued that "energy consumption can be fundamentally reduced just by reducing the weight of a structure[25].

This vivid reoccurrence of composite materials is now associated with highly advanced manufacturing techniques, fabricated precisely to meet predefined conditions. "A property of materials that has not been mentioned yet is their ability to be tailored according to special needs. By manipulating mutual directions of fibres, elastic behaviour can be controlled. It is possible to design a structure that changes its shape in an 'abnormal' way under the influence of forces in order to perform a certain function... The principle of elastic tailoring is also used in X-29 first strike fighter by Northrop Grumman. It is a canard airplane (figure 15) and

23. Robert Kronenburg, Houses in Motion. The Genesis, History and Development of the Portable Building (Great Britain: Wiley-Academy, 1995), p.11.

24. Benjamin Tang, "Fiber Reinforced Polymer Composites. Applications in the United States" in www.fhwa.dot.gov/bridge/frp/frp197.htm.

25. Adriaan Beukers & Ed Van Hinte, "Lightweight Structures" in Architectural Design (AD), Vol.72, No.1, (London: Willey Academy, 2002) p.102.

its specialty is that the arrow of the wings points backwards. Because of this the fighter is more efficient and more manoeuvrable" [26].

Moving backwards from the high end of technology to the description of a prehistoric precedent, the similarities in the logic of material manipulation are overt and distinctive: "The baidarka kayak meshes small pieces of bone into a wooden superstructure in the strategic zones, requiring maximum flexibility... Its combination of hardness and flexibility, due to micro-insertions of specialized materials within the composite, reflects the current challenge for the development of micro-templating."[27] (The 'baidarka kayak' is analyzed extensively in chapter 03).

At first, it is curious how prehistoric examples such as the skin of the baidarka kayak, are indicative of an advanced materiality that can form intricate relationships at a micro-scale, responding to external conditions. Indeed, the micro-insertions of specialized materials within the composite skin of the kayak, as well as its localized adaptive resilience, counter the flows of the river's currents. By embedding within the mass of the kayak's skin localized material densities of soft bone, a system of breaks is formulated, which enables the kayak to optimise its itinerary along the river.

It seems that prior to the introduction of human rational into construction processes, the craftsman's intuitive action was to embody the functions of nature, thus transfusing into his constructs the logic

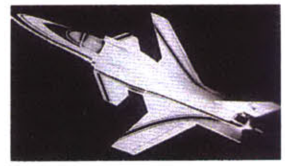


figure 15 >> the x-29 airplane

26. Adriaan Beukers & Ed van Hinte, Lightness (Rotterdam: 010 Publishers, 2001), p.60.

27. Anna Dyson, "Recombinant Assemblies" in Architectural Design .AD, Vol.72 No.5, (London: Willey Academy, 2002), p.62.

of a responsive organism, one that is not defined by its ultimate separation from its environment. In this way, the prehistoric understanding of materiality is very close conceptually to the most avant-garde digital methodologies.

The X-29 and the baidarka kayak function on the same prime logic of local material manipulation in order to respond to external conditions. This historic linkage is not merely an intuitive one; As one can see in the diagram that illustrates the evolution of materials in time (figure 16), composites were widely used in prehistory, from around 10,000 BC to 500 AC. After 1960s and under the umbrella of cheap energy, via the discourse of lightness, they find a renewed significance for a completely different cause.

The gap in between is distinguishable and is possibly due to the infusion of a deterministic rational within the construction process, throughout history, creating an irreversible paradigm of homogeneous component assemblages. The question of why should this be the unique interpretation of matter has not been set on the table. At this point, construction cannot be conceived of otherwise.

However, within the past twenty years the advent of genetic modes of production and unparalleled advancement in computation imply similar tectonic investigations such as those of the baidarka kayak paradigm.

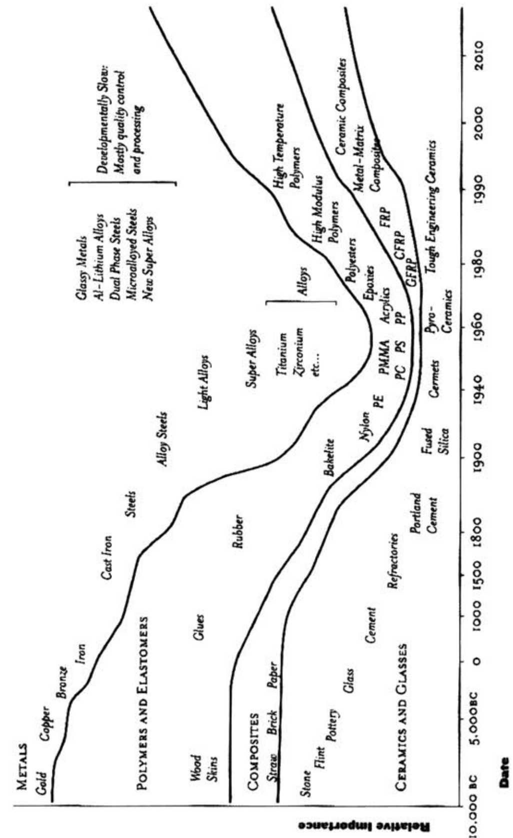


figure 16 >> Evolution of materials

"One of the keys of bio-performance is the micro-compositing of more than one material. Two or more must be employed (for example a layer of chalk separated by a layer of proteins) as natural systems, blur boundaries at multiple scales within composite structures to facilitate symbiotic performance behaviour, as well as possibilities for adaptive recombination" [28].

28. Anna Dyson, "Recombinant Assemblies" in Architectural Design .AD, Vol.72 No.5, (London: Willey Academy, 2002), p.62.

Clearly, we are witnessing the emergence of a distancing from mechanical modes of production, or in other words systems that cannot be described through stitching and assembling of incongruous parts by enforcing onto them joints and struts. On the reverse side of the stream of thought allied with additive processes, theories of emergence, allied with the engagement of unpredictable phenomena, have intensely preoccupied diverse disciplines such as computation and material science in architecture. According to John Holland, "emergence occurs only when the activity of the parts do not simply sum to give the activity of the whole"[29].

29. John Holland, Emergence: From Chaos to Order, (Cambridge, MA: Perseus Books, 1998), p.14.

The translation of this emerging cultural logic into its material counterpart sheds emphasis on material systems and distributions that form local alliances and connections, making it feasible to create components that can be structural at certain points while non-structural at others, opaque and translucent, rigid and soft. In this sense, composite materials depict more than a logic of crude combinations and disclose the potential of the notion of non-homogeneity, geared towards both enhanced performance and to an alternate perception of material distribution. A non-homogeneous materiality is defined at this point as a body of local differences with diverse properties along its range and will constitute a core investigation for the design experiments coming in the next chapters.

## Form VS material

Composite, non-homogeneous materials depict a comprehension of synthesis in the material level, conceived conceptually in equal terms like formal configurations are conceived within the course of the design praxis. Nevertheless, the relationship of material and form historically has not normatively been a relationship of correlations and intertwining interrogations. More than frequently material is a crude application on idealized forms, an exterior enforced logic or a 'final touch'. Moreover through the modernist prism, materials were utilized to symbolize generic beliefs, such as clarity, lightness, openness. This emblematic function constitutes an additional separation of material and form, since the selection of materials was not in direct dialogue with the specific expression of each architectural proposal, but was used to depict other values beyond the instance of each case. At this point, one has to acknowledge that there were instances throughout history that the relationship between material and form has been vividly investigated for its generative potential. Approximately in the 60s and at the inception of the 70s there were two concurrent movements in art and architecture originating from open material explorations; critical regionalism and arte povera. The former arises as a reactionary statement to the subjugating homogeneity of the International Style that defies the particularities of location and place. It consequently launches the direct application of found materials and local building traditions to the recipes of the modern movement in various different expressions according to the project's local. The latter movement of Arte Povera commences as a reactionary statement to the representational traditions in Italy, deeply rooted in conception of art as painting. Arte Povera seeks interchanging ways to produce art, where materiality unfolds a discourse of its own and form is emergent (figures 17,18). The interactivity of work and material comprises a major characteristic of this movement. Between the two movements, there are no established connections, as they are assumed to root from distinct points of departure. Nonetheless, their parallel emergence in time though, along with the proximity of the geographic territories in which they emerged implies the birth of a cultural material conundrum along the region of the Mediterranean in the 60s-70s.

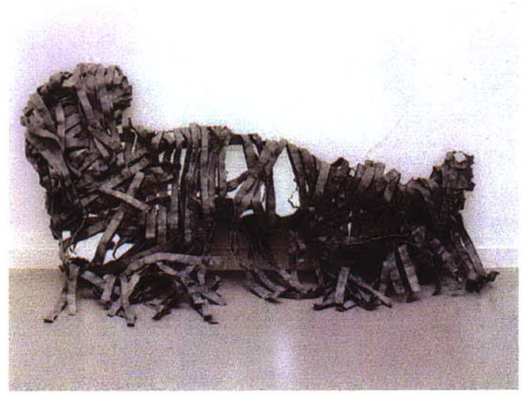


figure 17 >> Luciano Fabro. "speculum Italiae" (The mirror of Italy) 1971

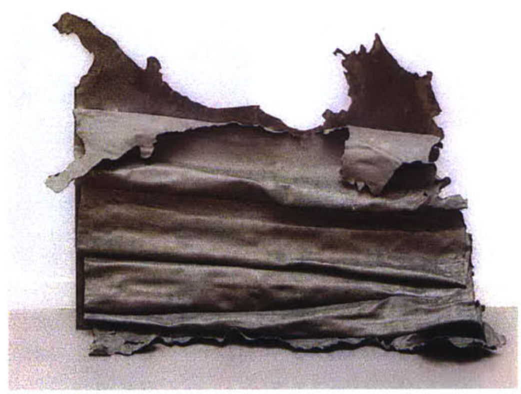


figure 18>> Luciano Fabro. "De Italia" (About Italy) 1971

If the previous quests involved direct material explorations, we currently have available a variety of digital tools, which we can use in a generative way not only to prescribe form, but also to yield elaborate material distributions. With the use of these tools instinctive methods of composing materials in local relationships and alliances can be planned and be set in motion. In the coming chapters, the intent is to commence an investigation on how computational techniques can be used to give impetus to a non-homogeneous material expression as an integral part of the design process from its initial stages of conception. A major concern is to seek alternative modes of addressing materiality through computational parameters, which do not ally with post-rationalization techniques. Instead, the search will focus on informing formal expression during the design process. One does not suggest here, to begin conceiving of architecture solely through systems that begin from an internal logic. Louis Khan's suggestion that architectural design is an act of palindrome from the inside to the outside and backwards is still valid to my understanding for many years to come. My suggestion lies elsewhere. By informing our thought processes with local rules, as well as rules that concern the whole, we can reveal generative potential that we could not have conceived of otherwise. If we go with the flow of a partial lack of control in our designs and invest in various interscalar understandings of design, we can potentially yield new concepts of materiality. This materiality could become something like the music of Ioannis Xenakis, which he describes his 'statistical music' as an acoustical event that cannot be broken down to its constituent elements[30].

30. S. Allen, "Contextual Tactics & Field Conditions", Points+Lines. Diagrams and Projects for the City.

# chapter o3 >> case studies

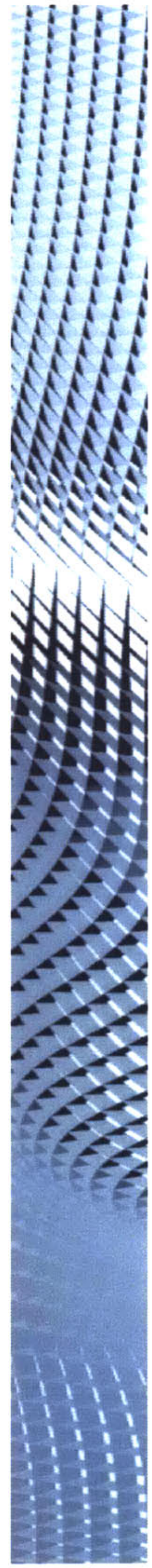
The following examples demonstrate different instances in which material properties in objects are addressed in a non-homogenous manner. The precedents are retrieved from various areas of creative expression such as craft, product design, art and architecture.
According to the techniques used in each of the precedents, a matrix was created divided in three major categories: *substance* , *component* and *thread.*

*Substance* refers to 'raw' material properties, meaning properties that are directly derivative from the intrinsic nature of material such as its transparency, color and elasticity. In this category, the connections between different materials occur mostly in the realm of chemical interactions, rather than external bonds and connections. Non-homogenous effects are the outcomes of potent fusions and material layering in various scales of reference. A liquid form of plastic, for instance, falls into this category.

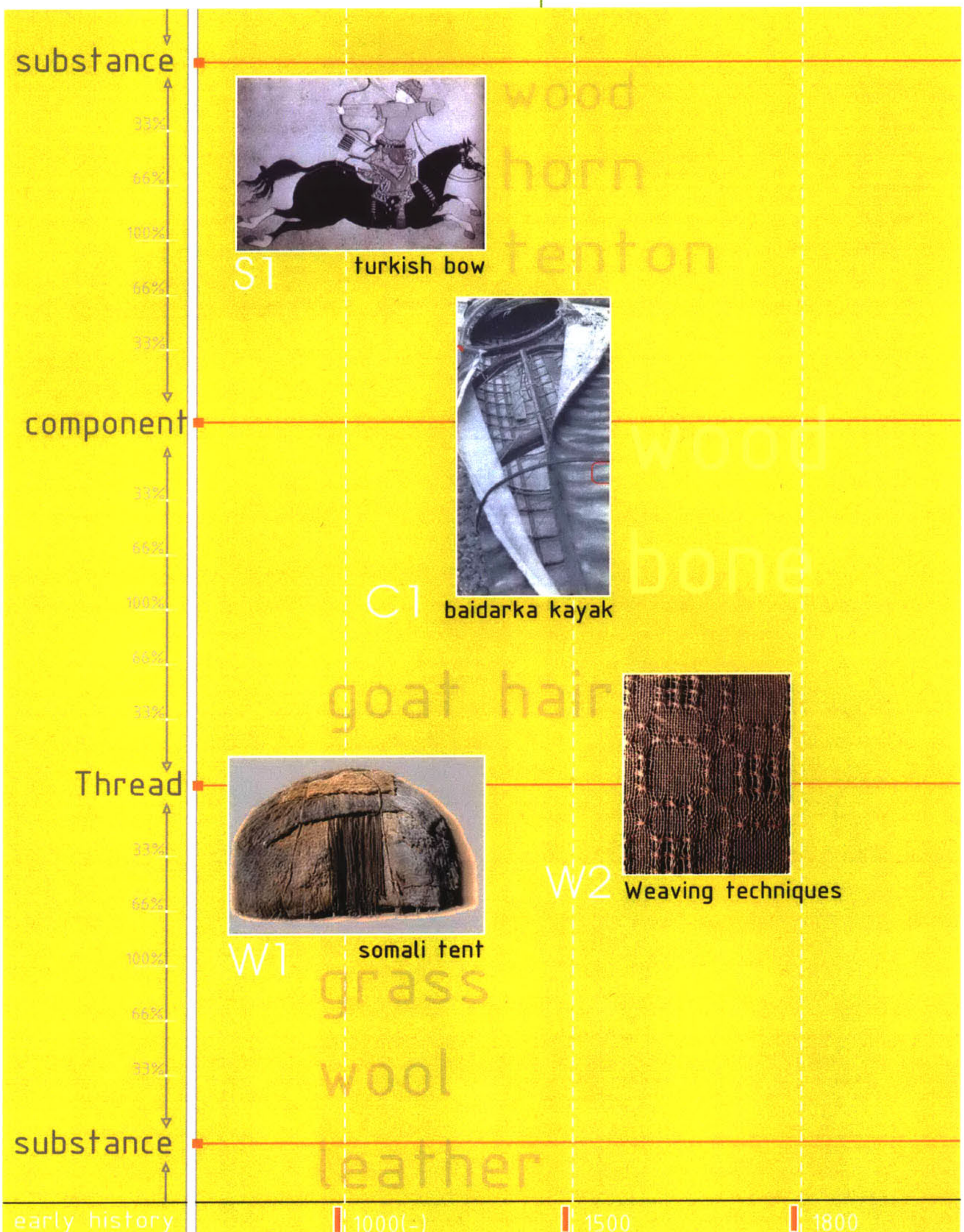
*Component* refers to techniques of distributing a basic unit along various geometric configurations. In this case, the specific geometry of the element is predetermined and remains in most cases unaltered; what varies significantly is the positioning of one unit in relationship to the others. The non-homogeneous effect, emerges through a combinatorial logic of component distributions. As a result, complexity is more related to the overall pattern rather than the individual intricacy of each element. A Byzantine brick, for instance, falls into this category.

*Thread* refers to the intertwining connective logic between linear yarn-like components. The word "thread" is a generic geometric term describing a material having very long length compared with its cross-sectional dimensions: possessing a very high aspect ratio. Although a thread as an entity being employed in construction could also be characterized as a component in a linear form, the effects of its linearity are so overwhelming that one could claim that it losses its individuality as a component when becoming part of a larger web. In this case, complexity can potentially emerge as a result of the manipulation of one single component. When threads converge and overlap, they are usually not traceable as units within the network of induced relationships.

The boundaries between the three material deployment techniques are not considered fixed and in many cases precedents are resultants of overlapping territories. The three aforementioned techniques are considered 'boundary conditions', which enable me to classify the objects and the techniques being used.



This matrix becomes a map of investigation and a pool of germinal ideas for the development of this thesis.


substance
33%
66%
100%
66%
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component
33%
66%
100%
66%
33%
Thread
33%
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100%
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33%
substance
S1
turkish bow
wood
horn
tenton
C1
baidarka kayak
wood
bone
goat hair
W1
somali tent
W2
Weaving techniques
grass
wool
leather
early history
1000(-)
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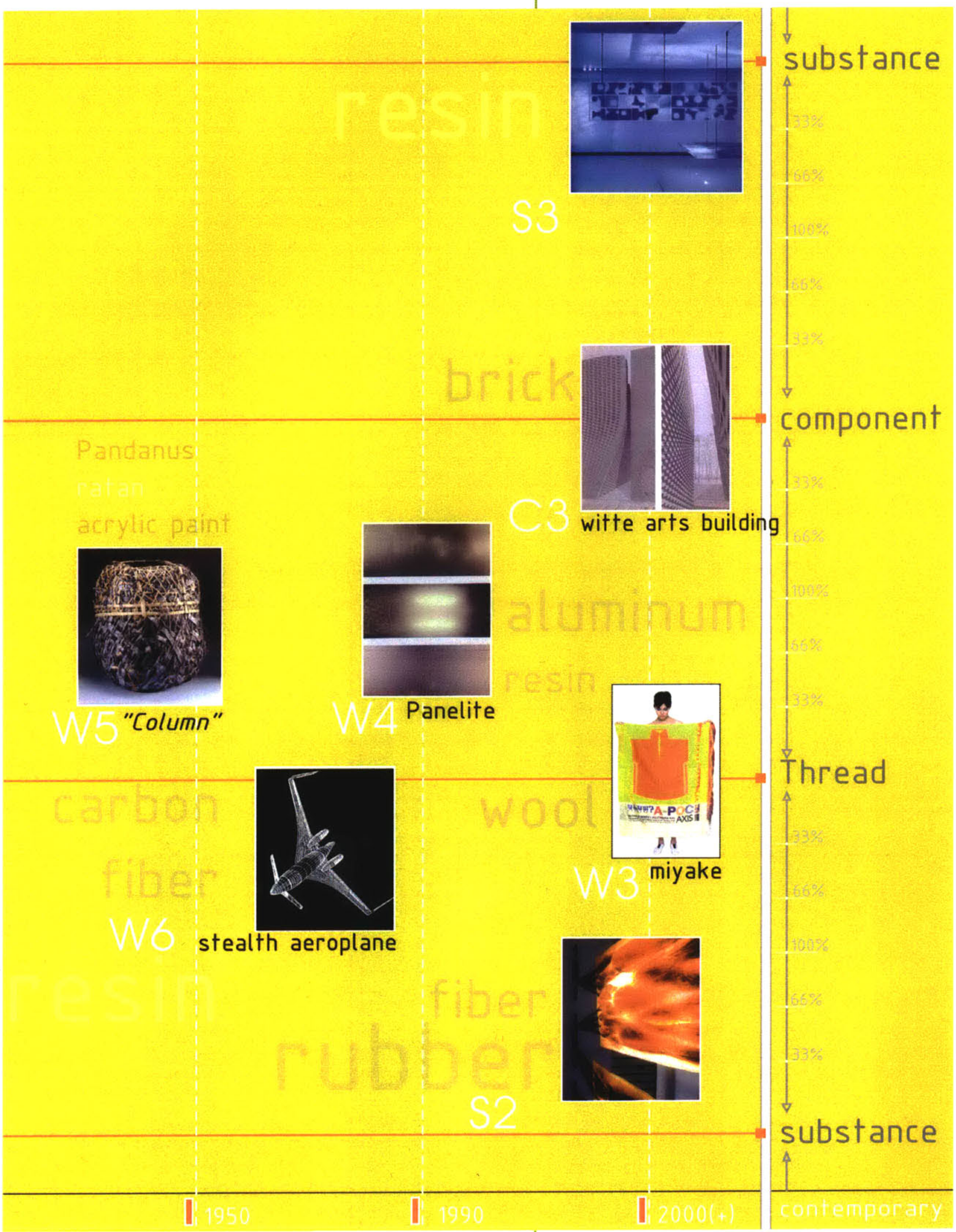

substance
resin
S3
brick
component
Pandanus
ratan
acrylic paint
C3 witte arts building
aluminum
resin
W5 "Column"
W4 Panelite
Thread
carbon
fiber
wool
W3 miyake
W6 stealth aeroplane
resin
fiber
rubber
S2
substance
1950
1990
2000(+)
contemporary

## C1: baiarka kayak

"The baidarka kayak (figure 19) meshes small pieces of bone into a wooden superstructure in strategic zones requiring maximum flexibility..."[31]

It would be quite an elusive task to locate historically the origin of the baidarka kayak. Its first recordings are traced in the 1580s by a Russian expedition group, which campaigned across Siberia and reached the American Aleutian chain. The kayak has retrieved its name from the Russian word "baidara'", which was used to describe an open, skin-covered vessel.

The baidarka demonstrates a unique feature that distinguishes it from other kayaks. Since it was made in the Alaskan area, where wood is scarce, it could not be carved out of a single bark. On the contrary, it was constructed out of a ribbed, wooden, frame, which was wrapped with animal skin, usually taken from seals.

The ingenuity of the kayak lies on the Aleutian inventiveness to insert small pieces of animal bone in strategic places of the wooden frame, usually in the front part of the boat, in order to control its behavior in the water. The Aleutians observed that increasing the kayak's elasticity, augmented its capacity to absorb the impact of waves, as they hit the boat. As a consequence, the resistance on the paddler was significantly reduced. [32]

31. Anna Dyson, " Recombinant Assemblies" in Architectural Design (AD) ,Vol. 72, No 5 September / October 2002, p.60.

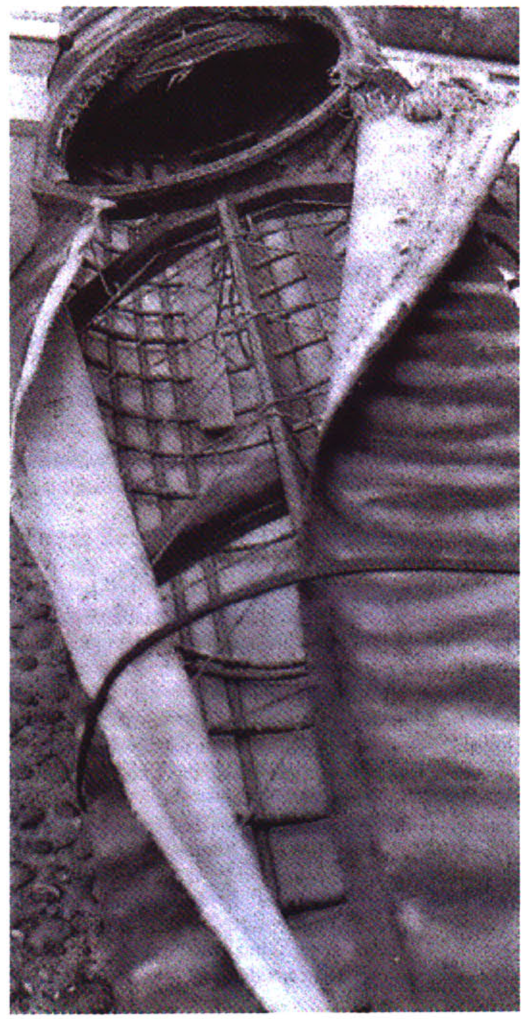


figure 19 >> the Baidarka kayak

32. George Dyson, Baidarka. The Kayak, (Alaska Northwest Books, 1986)

This technique of micro-insertions becomes an early example of a composite material with non-homogenous properties, since the synergy of bone, wood and leather, contribute to locally vary the boat's rigidity along its length. An exterior performance parameter, such as the floating behavior of the boat on waves, becomes the incentive to manipulate not only its shape (as it happens in the design of all boats), but also its locally adjusted material composition.

"The technique of composing the Baidarka kayak "... makes an interesting performative comparison with the most 'high-tech' carbon fiber composite models. For all its apparent flexibility, the carbon-fiber craft is a homogenous structural solution that exhibits non of the localized adaptive resilience that the ancient prototype exhibits. "[33]

33. Anna Dyson, " Recombinant Assemblies" in Architectural Design (AD) , Vol. 72, No 5 September / October 2002, p. 60.

## S1: turkish bow

34. Adriaan Beukers, Ed van Hinte , Light-ness, (Rotterdam, 010 publishers, 2001), p.86

In his 'History of Warfare' John Keegan observes that the bow can be seen as the first machine, since it employed moving parts and translated muscular into mechanical energy.[34]

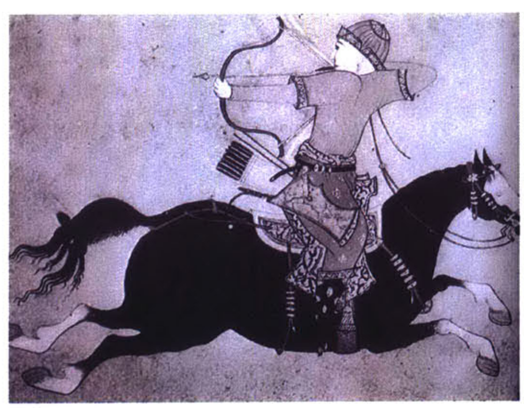


figure 20 >> the turkish bow

The Turkish bow (figure 20), which dates as early as 5000 years ago, is one of the first composite bows and "is consisted of a slender strip of wood - or a laminate of more than one - to which were glued on the outer side (belly) lengths of elastic animal tendons and on the inner side (back) strips of compressible animal horn, usually that of the bison. The glues, compounded of boiled-down cattle tendons and skin mixed with smaller amounts reduced from the bones and skin of fish, might take more than a year to dry and had to be applied under precisely controlled conditions of temperature and humidity."[35]

As the bow had to become lighter, shorter and at the same time stronger it is curious how advanced the craftsmanship became at such an early stage. Taking a closer look at the different sections along the bow's length (figure 21), one can observe that materials are layered in different thickness. In order to store as mush energy as possible, but at the same time be light enough to carry and easy enough to bend, the craftsmen varied the thickness of the deployed materials in order to locally control the stiffness and the elasticity of the bow. In order to decrease the size of the bow while retaining its range capacity, the central part became stiffer than the limbs; in this way, the bow's core became more flexible, yet strong enough to achieve the same throw breadth as that of larger in length bows.
Similar techniques are being used for the production of contemporary high capacity carbon fiber recurve bows.(figure) In such studies, stress analysis software is being used to estimate the local stress-strain behavior along the length of the bow. This technique is implemented in order to determine the direction of fibers and the layers of epoxy that would be used in any given part of the bow [36].

35. Adriaan Beukers, Ed van Hinte , Light-ness, (Rotterdam, 010 publishers, 2001), p.86

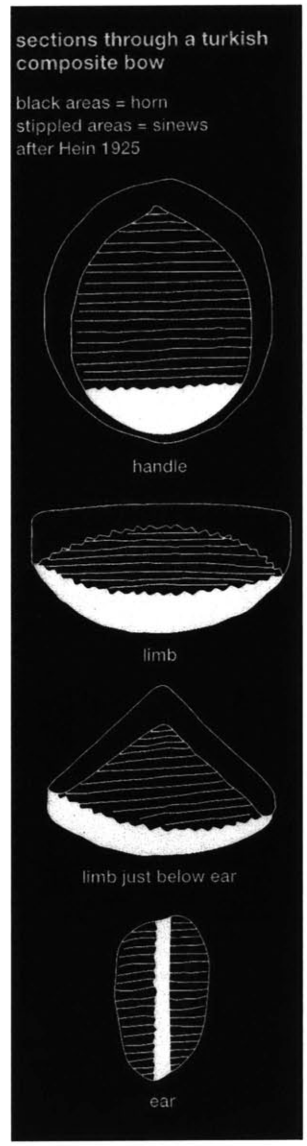


figure 21 >> sections of the turkish bow

36. Losee Jason, Prof. Graig Weeks, "The Composite Recurve Bow" in : http://www.engr.iupui.edu/me/courses/recurvebowfinalpres.ppt. Fall 2000

## W1: the somali tent

Ten thousand years ago, nomadic populations intensely used lightweight structures and composite materials[7] in order to facilitate the relocation and transportation of their communities to better climatic conditions. Modes of constructing their lightweight tent systems, as well as the optimum synergistic logic of materials were embedded in their culture.
In the case of the Somali tribe in Africa, the prefabricated and portable nomadic house known as Aqal (figures 22, 23, 24), is a readily erected and dismantled hemispherical dome, 1.5 - 2.3 meters in height and is constructed of three component parts:

1. semicircular shaped poles that give it its strength and form.
2. vertical poles used for reinforcement.
3. and layers of woven mats made of grass acacia fibres and animal hair used for covering and decoration.

All three are tied together as an intricate web to form a strong impermeable package. [38] The intricacy becomes evident at a closer examination of the tent fabric and its material composition logic. Due to the natural materials' properties, the weaved panels are capable of adjusting to the humidity of the atmosphere. The natural materials that are used in the Aqal shrink when they are wet, so in winter the tent is protected by the closely woven fabric. In dry periods, the same fabric often sags, and as

figure 22 >> the somali tent

38. Description and images found in : www.rit.edu/~africa/somali/somaliAqalPg1.shtml

a consequence the weave pattern loosens, creating voids along the fabric and allowing a breeze to enter. Therefore, whenever the climate is dry the tent becomes more porous because of the materials' natural contraction and when it is raining it becomes waterproof. By controlling the thickness of the tent skin through the layering of the different woven pieces, one can conclude that the skin becomes more or less rigid (rigid in areas where the skin connects to the frame) and at the same time more or less permeable from air and humidity according to thickness and seasonal changes.

In the case of the Agal, the significance of the fabric's synthesis lies beneath the distribution of material and resides as well in their intrinsic properties to respond effectively under various external climatic conditions. In this sense, the characteristic of non-homogeneous material distribution is in effect in a dual manner; first by the positioning of materials along the fabric and second by the selection of natural materials yielding specific responsive behaviours that improve the performance of the shell.

This portable house is of female construction and execution. It is the gift of the mother and female side of the bride's family, and each female has the responsibility of mounting and demounting her house for each move, maintaining and repairing its component parts, and eventually providing additional portable houses for her own daughters or womenfolk.[39]
(It does take a woman to devise such an intricate design-construction logic!)

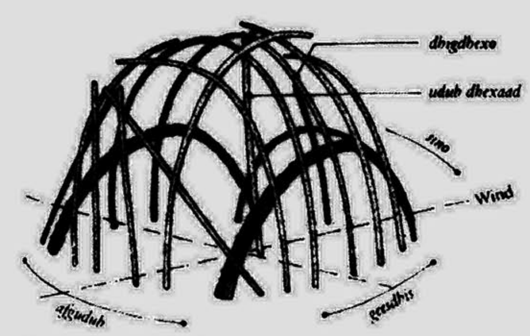


figure 23 >> Agal frame

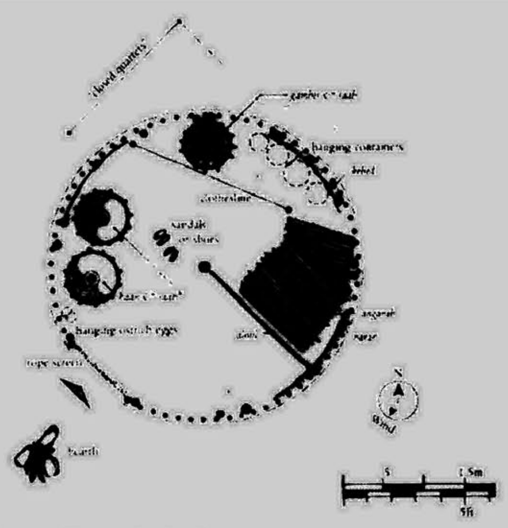


figure 24 >> Agal plan

39. Description and images found in : www.rit.edu/~africa/somali/somaliAqalPg1.shtml

## W2: weaving techniques

This section will not focus on a specific precedent; rather it will attempt to illustrate the general principles of weaving that originated in ancient times.
The essential characteristic of weaving is its prime logic based on a grid that is divided in two directions. The former direction is called warp and is comprised of long threads attached to a loom; the latter is called woof (or weft) and runs crosswise, interlacing with the warp. The classification of woven fabrics occurs on the basis of the type of overlay between the warp and the woof, or in other words according to the manner in which warp and weft cross each other. The three fundamental types of weaves are the plain, twill, and satin. Crossbreeding between typologies has generated many hybrid weaving techniques that lie between the major categories.

While a major driving force for the development of weaving patterns is the production of appealing visual effects or patterns, weaving differs significantly from other decorative methods such as the placement or printing of visual imagery on objects. Weaving is conceptually separated from any techniques of layering or addition of decorative components. On the contrary, it advocates a genuine conjunction between the material used and the effect it produces; it does not attempt to illustrate or simulate a visual effect through the external imposition of images or foreign patterns. Patterns and effects are emergent from the methods that are being applied and the structural relationships of the warp and woof operations. In this sense, weaving and the distribution of material becomes significantly relevant to a current discussion related to digital media on seeking ways to express a materiality that is not imposed on geometric modeling.

In parallel to the argument of a combined perception of material and visual effect, primitive weaving techniques, also portray a non-homogenous understanding of material distribution. The two 'renegade' techniques that will be presented as follows, indicate necessary actions that need to be performed in case the emerging pattern begins working against the weaving's underlying grid.

Woof substitution is commonly used to create complex solid and linear patterns. Two yarns of different color and maybe texture are threaded together as a pair. With each shot of crosswise yarn, one of the pair is chosen to create the pattern, and the other pushed to the back of the weave. In the specific example illustrated (figure 25) "When not being used in the design, each weft-substitution yarn floats on the back. The large chevrons (v shaped stripes) in this piece present an exception. Because it is impractical to float yarns across such wide spaces, most weavers reverse them, to weave back and forth in those broad areas."[40]

Knotting: The following technique demonstrates a method with which the generally imposed weaving grid can be overridden in order to achieve smoother transitions in embedded patterns during the production of a fabric. "They have been used extensively by Chinese, Kurdish, Saryk, Yomut and occasional other weavers."[41] Essentially, individual

40. Marla Mallett "A Baluch Bag" in http://www.marlamallett.com/up-three.htm

41. ibid

figure 25 >> Baluch Bag

full or half knots are inserted between the regular woof and weft grid cells in order to push, hide or exaggerate them (figure 26). As a result smoother curves are achieved and extra colors are inserted. For further information please refer to the http://www.marlamallett.com/up-three.htm

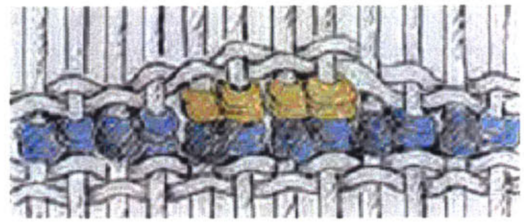


figure 26 >> Knotting technique

## W6: stealth airplane

Recent developments in the aviation industry have led to the construction of airplanes manufactured entirely of composite materials. " Making composite structures is more complex than manufacturing most metal structures. To make a composite structure, the composite material, in tape or fabric form, is laid out and put in a mold under heat and pressure. The resin matrix material flows and when the heat is removed, it solidifies. It can be formed into various shapes. In some cases, the fibers are wound tightly to increase strength. One useful feature of composites is that they can be layered, with the fibers in each layer running in a different direction. This allows materials engineers to design structures that behave in certain ways. For instance, they can design a structure that will bend in one direction, but not another. "[42]

42. Dwayne A. Day, "Composites and Advanced Materials" in http://www.centennialofflight.gov/essay/Evolution_of_Technology/composites/Tech40.htm

In comparison to pure materials and assemblies, composite materials present the advantage of yielding a certain kind of performance orchestrated to respond to fluctuating external circumstances, such as the different forces that will be exerted in different parts of the aircraft during flight (figure 27). Therefore, a major property of a composite

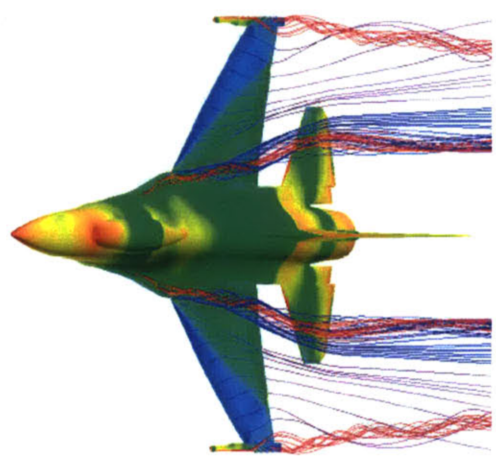


figure 27 >> Pressures and streamlines obtained from a computational aeroelastic maneuver simulation material is its ability to be tailored according to special needs. By manipulating mutual directions of fibers, elastic behavior, for example, could be controlled.

In the case of the stealth B2 bomber (figure 28), a primary manufacturing concern is the enhancement of the stealth capability, meaning the aircraft's invisibility to radars, which can be achieved through the reduction of its parts. The wing should be produced mostly as singular component that requires minimum assembly. Given its monolithic fabrication, in order to control the main body's elasticity and enable it to adapt its shape to the flight speed, the fibers in the composite material are layered locally in multiple directions and densities. Consequently, certain areas of the wing are more elastic than others.

Construction wise, such a technique signifies a breakthrough; it demonstrates a manner in which non homogenous material distribution is strategically allied with the performance of the aircraft and even further than that a performance calculated in detail through the specifications local resilience.

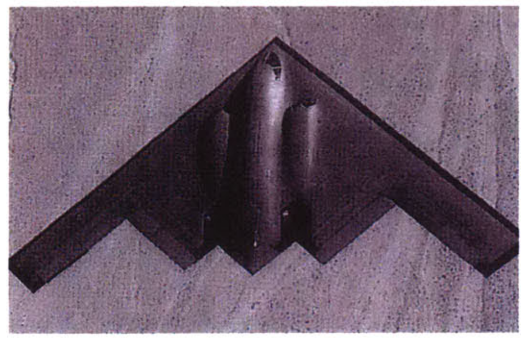


figure 28 >> stealth b2 bomber

## C3: OFFICE DA Tongxian Arts Center Beijing China (principals: Monica Ponce de Leon and Nader Tehrani)

In a generic description of the implicit intentions underlying the work of Office DA, Monica Ponce de Leon and Nader Tehrani, declare: " Our agenda attempts to establish a new relationship between constructional systems, program and the surface they produce : the visible deformations on the body of the building are, at once, the result of

43. Monica Ponce de Leon and Nader Tehrani, " Versioning: Connubial Reciprocities of Surface and Space " in Architectural Design (AD) , Vol. 72, No 5 September / October 2002, p. 28.

programmatic pressures that guide the form, and also the result of geometric and syntactic laws permitted by particular units of construction..."[43]

In the case of the Tongxian Center, the architects are conceptually considering the building in its original state as one solid brick block or as they state it: " ... as if it was vacuum formed into shape.."[44]. Their attempt is to register on its skin the effects exerted by local, interior and exterior, technical parameters such as light, drainage and circulation, and allow them to become factors of local deformations. A deformation is accordingly defined, not only through the revelation of a geometric disorder, but also through the material composition of the envelope.

On the basis of these lines of thought, the unit to be implemented in a geometric configuration and the geometry itself, are simultaneous and interrelating investigations; investigations that can be formed and reformed in the process of making. In this case, although the material unit is constantly the same (i.e. brick), the way it is combined with its neighbours generates a non homogenous effect. In an attempt to locally shift from one spatial condition to the next, the architects manipulate the Flemish bond in a manner that produces areas of thick massive wall and areas of lightweight porous skin constantly registering the change of activity in the interior.(figure 29) In their understanding through this project they "...have attempted to project a relationship between the skin and structure that is mutually dependent, correspondent and integral.

44. Monica Ponce de Leon and Nader Tehrani, " Versioning: Connubial Reciprocities of Surface and Space " in Architectural Design (AD) , Vol. 72, No 5 September / October 2002, p. 28.

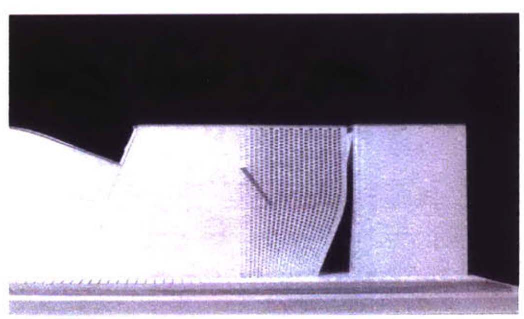


figure 29 >> Tongxian Arts Center Beijing China (principals: Monica Ponce de Leon and Nader Tehrani)

The stretchers and headers of a Flemish bond are manipulated as a vehicle to compress and expand not only wall surfaces, but also the very spaces they define. Spatial construction and surfacial manipulation are constructed as part and parcel of the same interdependent set of determinants"[45].

45. Monica Ponce de Leon and Nader Tehrani, " Versioning: Connubial Reciprocities of Surface and Space " in Architectural Design (AD) , Vol. 72, No 5 September / October 2002, p. 28.

## S2: a new approach to rubber

This project is part of the broader context of student research conducted at Harvard university, exploring the theme of new construction and material techniques in architecture.

The specific project (figure 30) that I will be referring to entails the investigation of the relationship between compressive and tensile elements in composite materials. Driven by the intention to yield a parallel aesthetic performance derivative from the material synthesis of the composite, the project uses as matrix of the composite a semi-transparent material, in order to reveal the inner reinforcement pattern. The material composition of the case study is rubber for the matrix and PVC coated fiberglass screen mesh over bars for the reinforcement[46]. Although the layers of reinforcement in a composite material are conventionally used to strengthen it and augment its performance, this case exemplifies that the intricacy of reinforcement patterns can be put in effect for alternate causes , such as the creation of dense and loose areas of material.

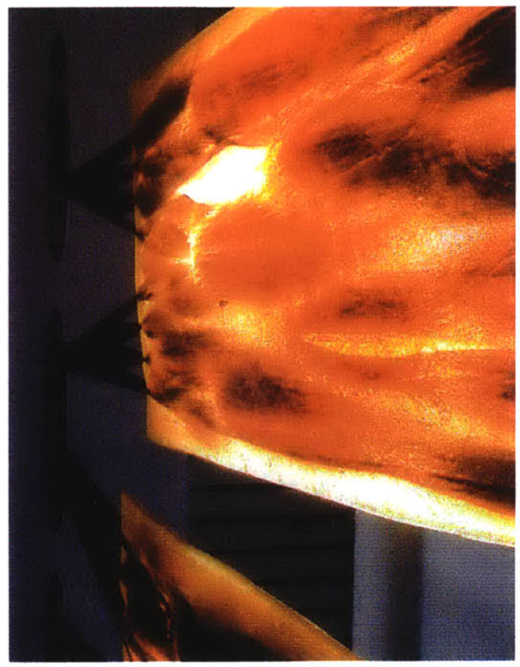


figure 30 >> composite rubber panel

46. Nader Tehrani, Kristen Giannattasio, Heather Walss, John May, Richard Lee, "edge" in Immaterial / Ultramaterial , architecture design and materials, (New York, George Brazillier Inc. 2002), p. 5.

During early studies, it was observed that according to rubber's thickness its elasticity fluctuated. When rubber was cast in thin sheets it became very elastic almost like fabric and when it was cast thicker it maintained a certain rigidity. This led to an early exploration of casting rubber pieces with a variable thickness. A mold was produced from a surface (figure 31) that was modelled in Rhinoceros 3d software and was then fabricated out of Styrofoam with a CNC milling machine. After the casting process, the resultant material had areas where it was more elastic and at the same time more transparent and areas where it became more rigid and more opaque. The aforementioned attribute combined with the local tailoring of the reinforcement, suggested a material that would contain into its body attributes of "structure" and "skin"[47], attributes of window and attributes of wall, maintaining yet its autonomy.

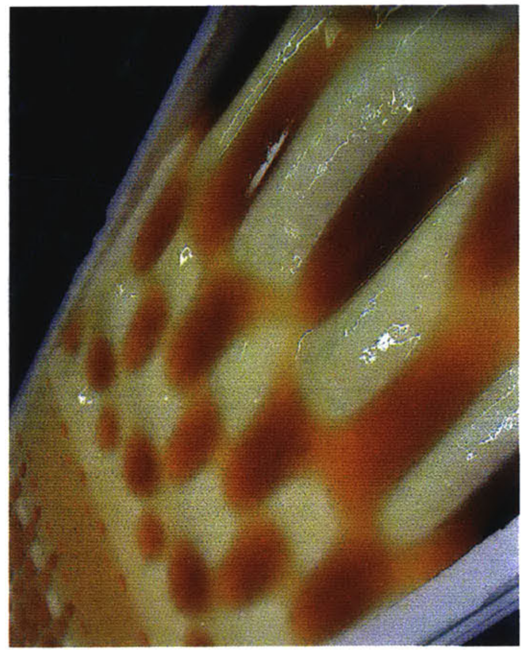


figure 31 >> casting process

47. As it is being understood in a traditional cut up of a building on its constituent parts. Foundation, Structure, Skin, Interior Partitions, Furniture. Based on a categorization by Stewart Brand (How Buildings Learn)

## W5: "column"

The example illustrated is an art piece created by Lillian Elliot, born in 1930. Elliot is currently being exhibited in the American Craft Museum in New York.

The piece (figure 32) entitled "Column" is made of pandanus, rattan and acrylic paints. As editor Martina Margetts comments: " The apparently random structure and texture of Elliot's piece is a deceptively 'primitive' work with a controlled technique."[48]

In this case study the weaving strategy apparently defies the basic principle of weft and woof grid. The complex texture seems to emerge out of an interweaving of "threads" with different rigidity, size and colour in multiple directions. Since no explanation is offered, the amount of control in this process cannot be determined.

## S3 : ninety-eight percent nothing

This project is part of a research conducted at Harvard university and encompasses new fabrication and material techniques for architecture.

The main principle underlying the project (figure 33) is the investigation of alternative construction modes between the elements of a window and a wall. A window is conventionally perceived as an incision or a 'hole' on a wall that is comprised of one unified material. Moreover, a third component of assembly plays the role of negotiating the wall material and the window material. This project lies on the premise that one could embody the attributes of wall window and joint into one entity, one unified body.
The project was initiated by defining in a 3d modelling environment, a three dimensional NURB surface (figure 34) that would later become a mold, through a numerically controlled milling machine. On this mold, resin would be cast. The constantly variable depth of the produced surface enabled the casting process to take place in stages. The surface

figure 32 >> Lillian Elliot, "column"

figure 33 >> ninety-eight persent nothing was divided horizontally into topographical zones, allowing resin of different colours and transparency to be cast in layers according to the correspondent topography.

The result was a panel that contained along its body variable structural, thermal but mainly optical properties. Ron Witte comments that " the most significant implications of the Ninety-eight Percent Nothing Project lay in our understanding of material assembly.... Our research into variant sameness replaced a three material system with a single material/multigeometry system. Instead of substituting one material for another, changes in transparency, structural capacity and thermal efficiency were produced by altering the chemical matrix of a single material."[49]

This is a key project that initiated a major part of the current thesis. The question posed after this analysis is : "how can one design such a window-wall relationship?" Is it possible to actually input into a design process parameters that would define areas of 'window(ness)' and 'wall(ness)'? Can a non-homogenous resin panel, like the one analysed above, be outlined in a 3d modelling environment topologically in terms of its material?

49. Ron Witte with Billie Faircloth, Judith Hodge, Suzanne Kim, and Clover Lee, "substance" in Immaterial / Ultramaterial , architecture design and materials, (New York, George Brazillier Inc. 2002), p. 46.

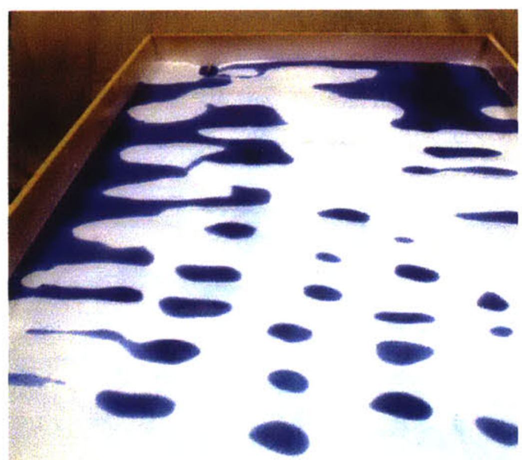


figure 34 >> ninety-eight persent nothing, casting process.

## W4: PANELITE

"Panelite is a material development agency for architecture, founded in 1997 by three architects Emmanuelle Bourlier, Christian B. Mitman, and Andreas Froech. After having searched the market for the right translucent material for a project, the architects were not entirely satisfied with their findings and decided to develop the material themselves. The company's present structure is based on the initial crossover between architecture and material production."[50]

Typically, a honeycomb panel is consisted of two major components, a core and a facing; the core is the honeycomb pattern that is embedded between the two facings. A subversive characteristic of honeycomb panels, as opposed to other materials with embedded patterns, is their optical perception that is non-homogeneous. Contrasting regular perforated or weaved metal meshes, an aluminium honeycomb core is often more 'elusive' due to is fabrication process. Essentially, several aluminium sheets are layered one on top of the other and glue is laid between them (usually with a numerically controlled machine) usually in a hexagonal regular pattern . The layers are then pulled apart, causing the metal to extrude, resulting into the three-dimensional structure of the aluminium core (figure 35).

As Panelite architects have observed, a slight misalignment during the extrusion process causes

50. Emmanuelle Bourlier, Christian B Mitman, and Andreas Froech "Material Effect" in Architectural Design (AD) Vol. 75 No. 5. (London International House, Ealing Broadway Centre). p.35

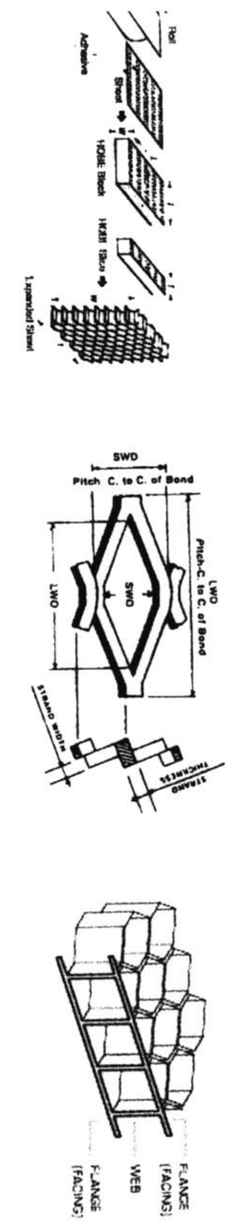



figure 35 >> honeycomb core fabrication process some of the cells of the core to either shrink or expand resulting into an optical lapsus. For this reason, the material's ideal repetitiveness seems to be locally disrupted and a number of unpredictable variants emerge (figure). This incidence or fault of the fabrication system is used and celebrated by Panelite for its optical potential. The architects encase these 'fallacious' cores in transparent facings in order to expose the perceptible differences in their pattern.[51]

This project became directly a point of departure for my own series of computation experiments described later in this thesis. Would it be possible to input into the design process an orchestrated lapsus? Which would be the parameters that control a possible local densification of cell units? What would that densification mean?

51. Emmanuelle Bourlier, Christian B Mitman, and Andreas Froech "Material Effect" in Architectural Design (AD) Vol. 75 No. 5. (London International House, Ealing Broadway Centre). p.35

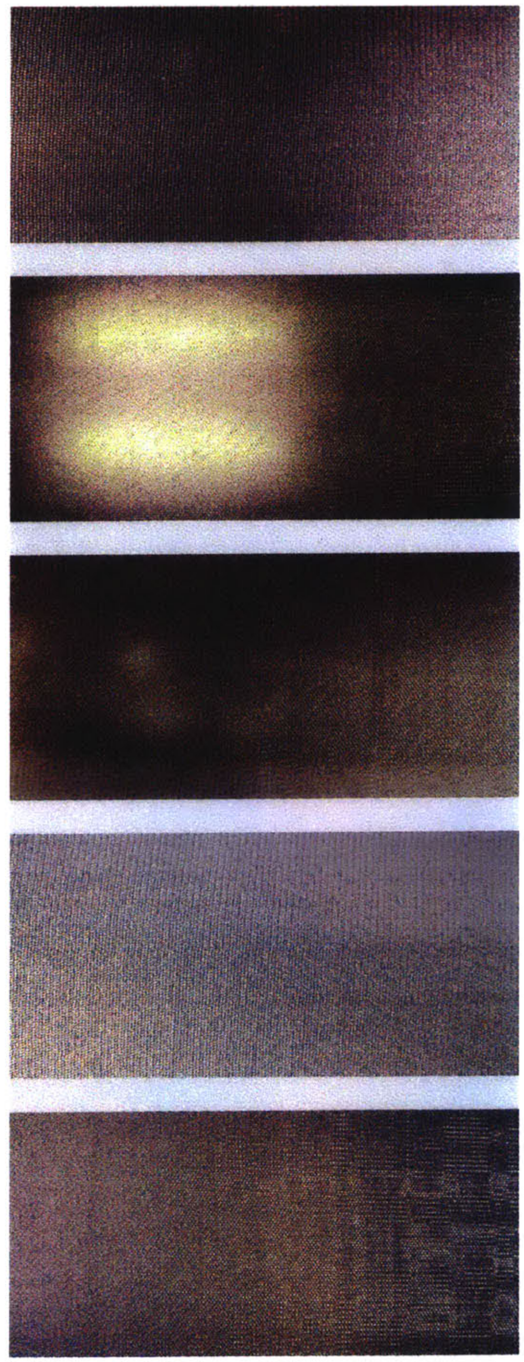


figure 36 >> panelite honeycomb panels

## W3: SEAMLESS

A-POC (A - Piece Of Cloth), the new collection series of Issey Miyake, began as an experiment in the mid-90's and has turned into an independent line in 1999. Through this project, Miyake challenges the most deeply rooted assumptions in cloth making, which entail weaving a fabric, cutting it in pieces and sawing the pieces together to produce the final cloth. Miyake on the other hand, proposes a seamless production (figure 37) through which the clothes would be weaved directly as one unified entity using a computer controlled machine. The technology involved in this process is unique in the design industry and necessitates an 'intelligent' weaving machine. " Computer - controlled levers move the warp threads into the up or down position according to the digitised pattern instructions, and an automated shuttle pulls the weft thread through a dizzying 200 times a minute... the key to the hole process is the digital Jacquard machine overhead, a loom attachment that automates the weaving patterns."[52] Through this process, the designers are able to specify locally the density and the type of the weaved pattern - to make for instance the cuffs of a shirt more elastic than the neck. In other words, the seamless process enables the designer to manipulate in a non-homogenous way the direction and density of the weave, in order to embed into the final object attributes that in any other case would be derivative from an assembly of different parts.

figure 37 >> Issey Miyake, seamless production of cloth

52. Jessie Scanlon " seamless " in Wireless Break the Rules. April 2004, p.167

Any material that can be turned into fibre could potentially be used in an A-POC process. In this sense, the seamless process can be thought of as years ahead of its time in the field of the fashion industry. When transferring the potential of such an understanding of materiality within the arena of our discipline, the project could be considered as millennia ahead of its time. If there is a dream of "material distribution in space for cultural effect"[53], A_POC is a lot closer to this vision than the most contemporary fabrication techniques used in architecture.

53. a brilliant in my opinion definition of architecture that I first heard from Mark Goulthorpe / principal dECOi architects.


figure 38 >> Issey Miyake, A-POC

# Chapter 04 : Experimentation

The following experiments are the outcome of my attempts to address the notion of non-homogenous deployment of material within the digital realm. Although the general categorization with blurred boundaries of the thread, the component and the substance still remains, it should be noted that the coming explorations do not attempt to simulate techniques that belong to the physical world. The case studies were not intended to be used as metaphors. On the contrary, their digital counterparts derive meaning from the digital tool itself and the inherent properties it puts forward. In each of the three categories, several experiments are deployed in an effort to relate a topological understanding of geometry to its 'corresponding' materiality. For each experiment, there is a conscious investigation of the relationship between form and material and both are treated as concurrent understandings of spatial characteristics. In the geometry-material model, feedback between the two is organized in two loops: from geometry to material and from material to geometry. In some cases, a change in geometry results to a change of material definition; in others, a material definition forces a geometry to occur. In any case, both definitions are present and are always interrelated and intertwined.

## 04.1. Thread

Christopher Alexander while attempting to establish a difference between the axiom of a tree and that of the semi-lattice[54], offers an interesting viewpoint on the act of weaving. He considers weaving as a tactic that embeds emergent behavior in terms of materiality, due to the overlapping and consequent interactions of different elements. Indeed, the structure of a tree is significantly different than that of a semi-lattice, since the former can be described via an analytic logic of hierarchical separation of independent elements, whereas the latter discloses complex material behaviours through the overlaying of materials that at certain points derail from their expected behaviours of material strata. In other words, weaving is an essential and one of the few authentic three-dimensional modes of operating in materiality. Although, ancient in terms of origin, weaving truly exemplifies localized behaviours and properties gained for a material or a textile through both overall understandings and local connections that are formulated by the joints of the layered materials. In this sense, weaving is a complex three-dimensional strategy that opens up conceptual conduits for localized resistance and material variation.

The first series of projects that will be presented here, derives from the 'thread' strategy analyzed in the previous chapter. 'Thread' is not used here as

54. Christopher Alexander, Architectural Forum, Vol. 122 No 1, April 1965

an analogy; rather it becomes an attempt to define a digital thread, detached -at least for now- from any parallel in the physical world.

The first experiments were initiated from an investigation on emergent outcomes derivative from the manipulation of the U and V parameters inherent in any given NURB surface. U and V comprise the two directions of the non homogenous grid that is utilized in any 3d modelling environment (i.e. 3d studio max, Rhinoceros, Maya), in order to construct the topology of a surface. These parameters are by default inherent definitions of NURB surfaces and amount to a priori constituents for the translation of formal complexity in the digital realm. The notion of UV can be further understood if we look at the non-homogeneous grid system that is utilized by D'Arcy Thompson, as an externally attached coordinate system in order to define an organic form (figure). According to Thompson, transformation of the initial coordinate system would produce changes or deformations of the inscribed form.[55] In my case, the actual visualization and manipulation of the primary description function of a NURB (i.e. U an V coordinate system) yields material ramifications on a given topology. In other words, the UV coordinate system is used as a scaffold, upon which material can be accessed, distributed and manipulated. Accordingly, material ceases to be applied as a texture map or a 'pasted' image on a given geometry and begins to be parametrically structured, disclosing potential for developing a discourse of intrinsic, inherent non-homogenous

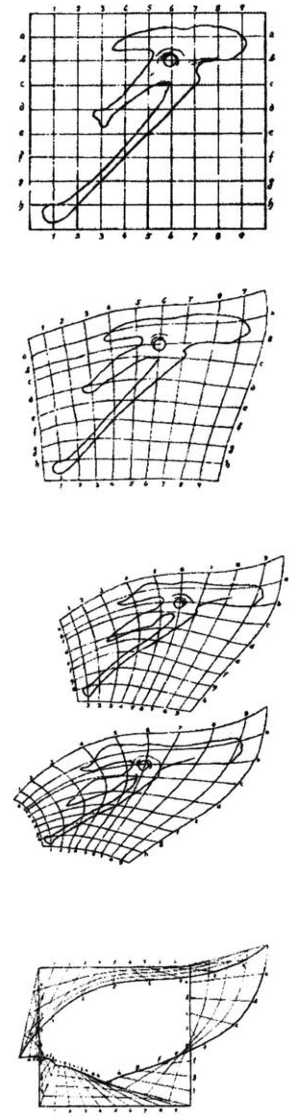


figure 39 >> D'Arcy Thompson. Transformation of organic form through topologically defined grid.

55. Michael Weinstock. "Morphogenesis and the mathematics of emergence" in Architectural Design (AD) Vol 74 No 3 (London, International House Ealing Broadway Centre, May/June 2004 )

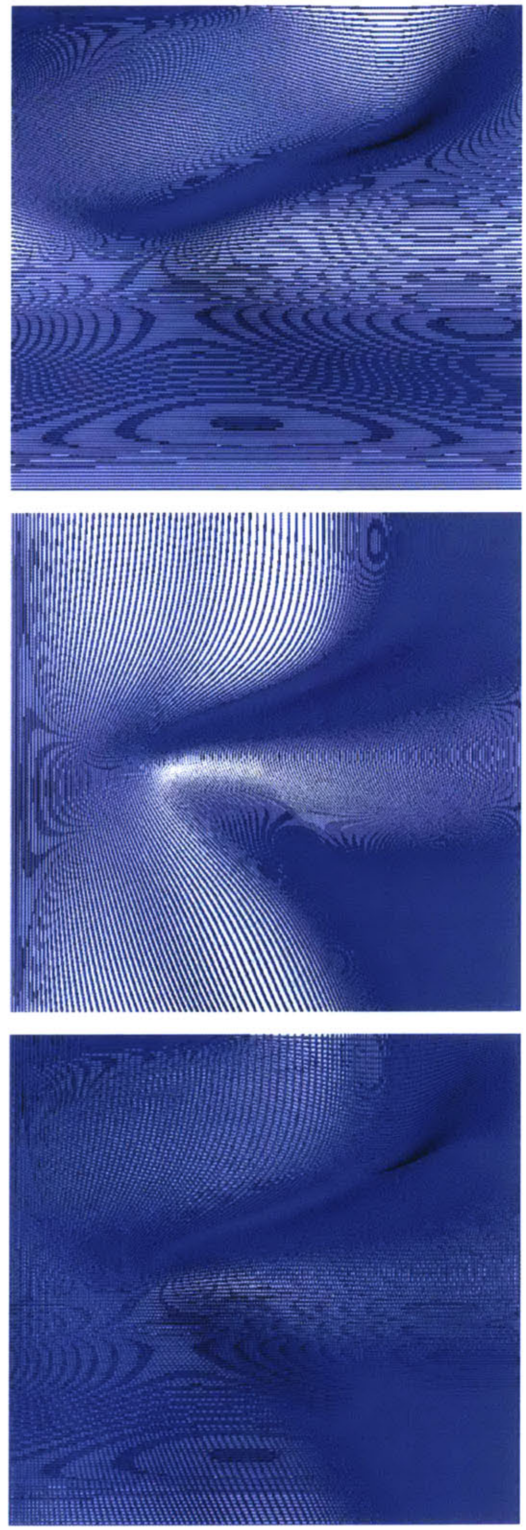
material properties.

Towards the expansion of this discourse, I have developed two different techniques, each subdivided in constituent operations. The former addresses the interlocking directions of the UV coordinate system, as a framework along which linear elements of variable dimensions can be put into effect. The latter addresses the space that occurs between the lines and deals with the void as a quantitative value, instead of a residual space that exclusively occurs as a remainder. Cells, meaning spaces between the U and the V directions, become numerically important in this case and comprise the basic framework for consequent operations.

## Thread Experiment 01: Weaving
## (import geometry >> export material definition)

The steps described in this first process are:

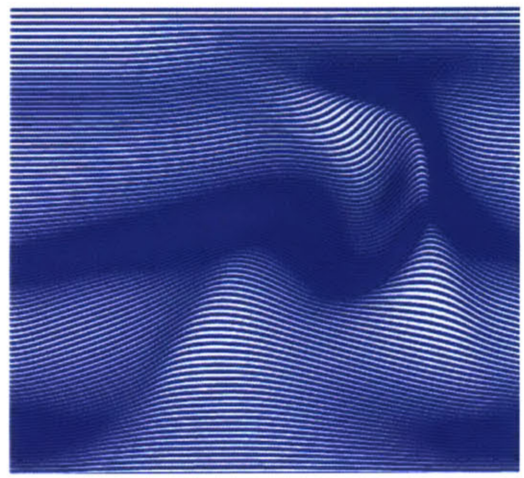
Manually: manipulation of the U-V's relative position on a surface (while maintaining the same geometric configuration), areas of increased density occur.
Scripting: extract the U-V directions of the NURB surface and then access them independently as NURB curves.
Scripting: produce a "thickness" (embedded command in rhinoceros that produces a cylinder using any line as profile) on each of the independent U-V lines.
Scripting: application in U or V or both directions



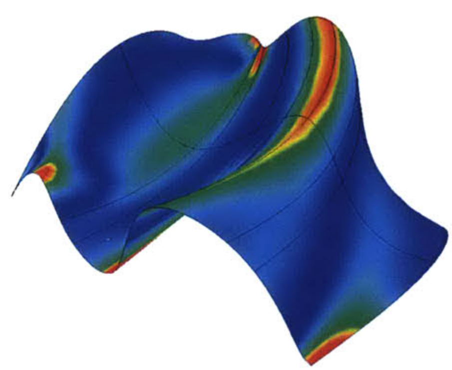
Thread Experiment 01, constant thickness of thread

and production of variants
In this case, material density is an outcome of a specific topological definition; the geometric configuration is considered as given or imported and materiality occurs as a scanning of surfacial intensity and density of information. The previously hidden density in the appearance of a unified NRB surface, is given form and thus materializes into an object. Any formal variation would directly affect its materiality, resulting into a different material configuration. In this initial step, the result was not considered satisfactory since there was no input for this densification, other than the deliberate manipulation of the designer, contradicting in this way the notion of process driven material definition.

As an addition to the first script a second was implemented, which became an attempt to directly link a geometric configuration with its corresponding material expression without any deliberate act. Curvature was selected as a factor that would influence this transformation. As embedded in Rhinoceros, curvature is essentially a parameter that indicates on any given point of a surface the tendency of the neighbouring points to curve relative to the original; it shows how steep or how "fast" a surface cambers at any given point. If we closely look at a curvature analysis of a given NURB surface in Rhinoceros, we realize that when the tool is applied on a curvilinear form, its graphic representation becomes a vivid example of the non homogenous nature of information distributed on



Thread Experiment 01, constant thickness of thread



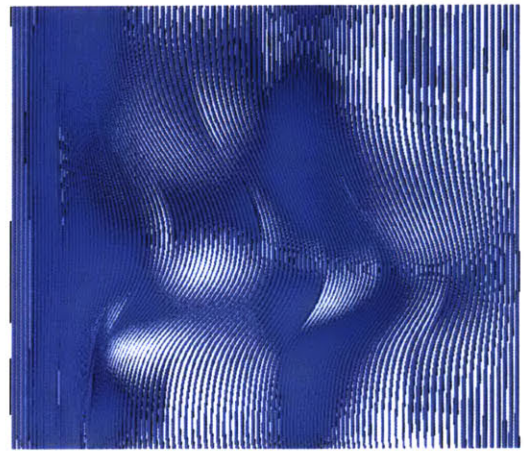
curavture analysis as provided by rhinoceros 3d modelling software such a surface. Consequently, curvature becomes an "indicator" that can potentially be used to inscribe on its corresponding surface a non-homogenous material expression.

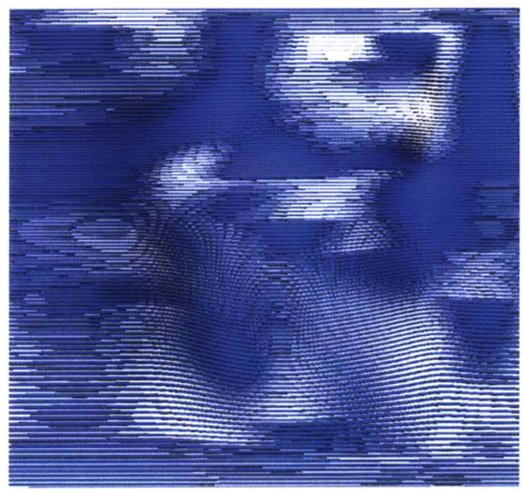
- Manually : manipulation of the U-V's relative position on a surface (while maintaining the same geometric configuration), areas of increased density occur.
- Scripting : extract the U-V directions of the NURB surface and then access them independently as NURB curves.
- Scripting: Produce a "variable thickness" (this time the Rhino command is not directly used. Instead the thickness is constantly varying corresponding to the local curvature ) on each of the independent U-V lines.
- Scripting: application in U or V or both directions and production of variants

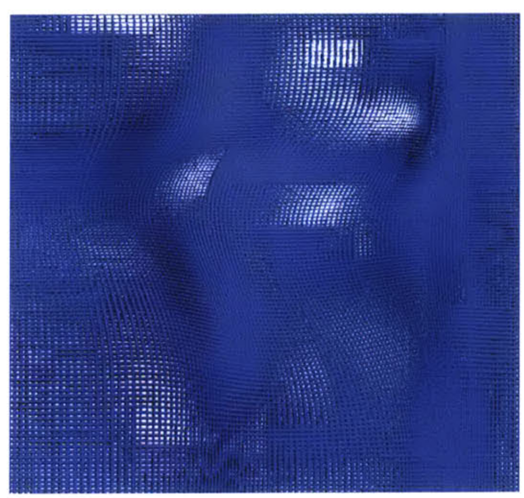
With this second scripting operation, the curvature of the surface was taken into account at designated points and altered locally the diameter of each of the threads produced. High curvature would produce increased diameter and low curvature reduced diameter.

Examining the outcome, one could say that on these surfaces there are areas that appear solid, clogged, reinforced and opaque and areas that are loose, "elastic" and transparent.

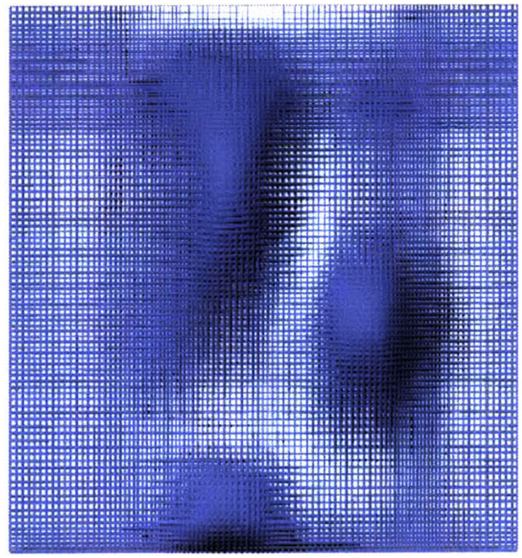
Although the process itself is and must be very



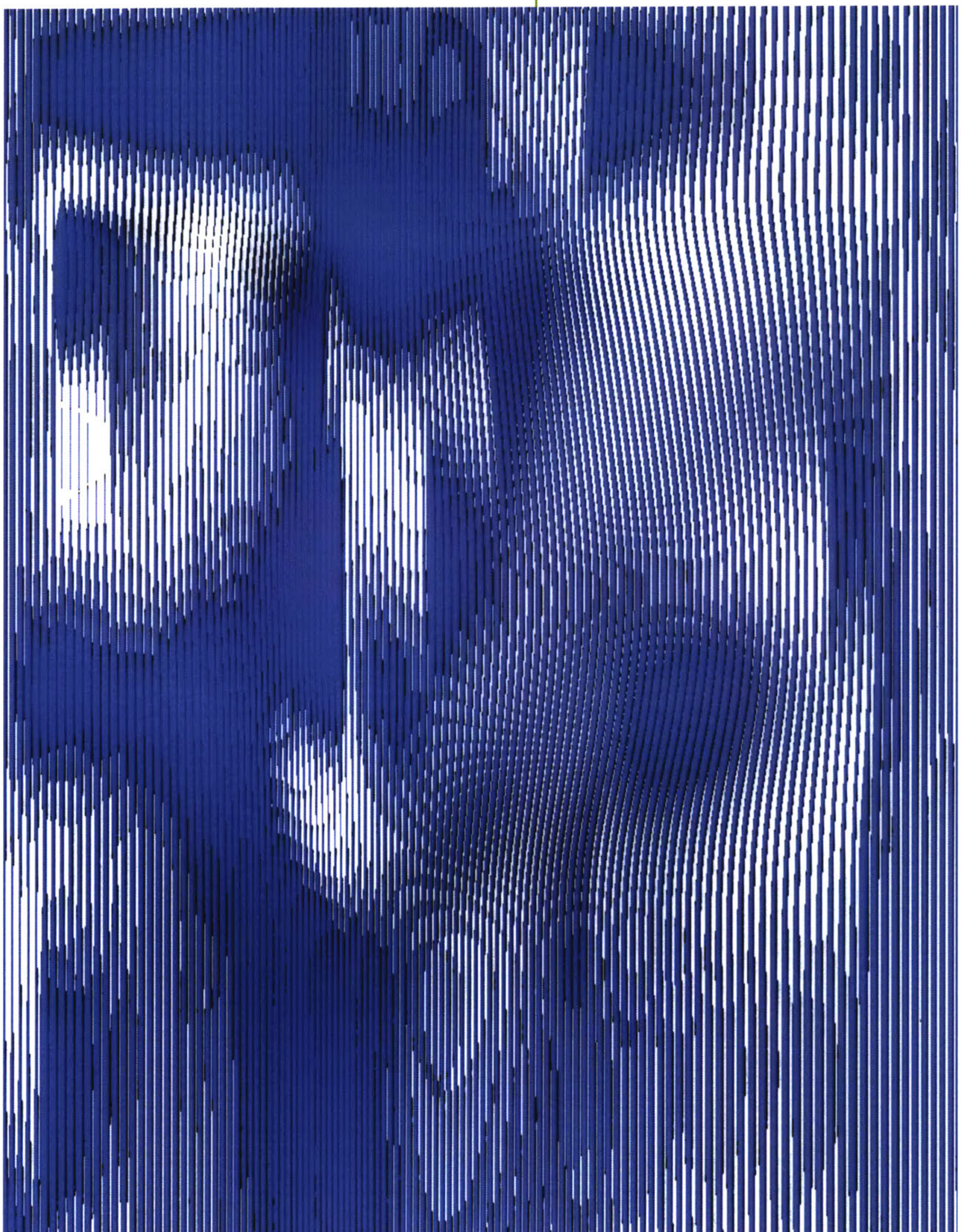


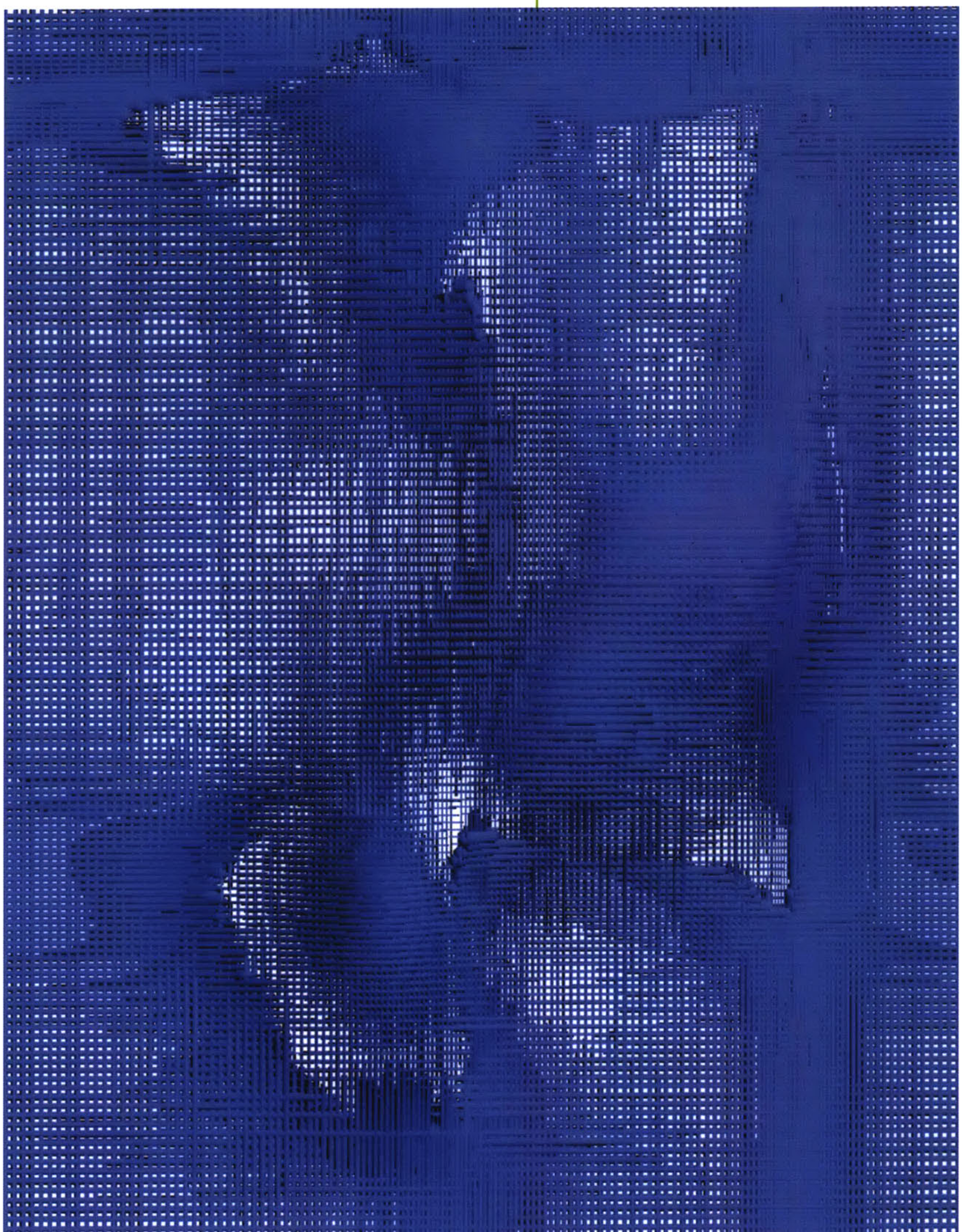


Thread Experiment 01, variable thickness of thread conscious and segregated into simple procedural tasks in order to be translated into a computer language, the same cannot be stated about the resultant material expressions. The project went beyond is initial attempt to define a window - wall relationship or provide insight for a possible structural (Provided that we talk about the reinforcement of a composite material, areas of high curvature would tend to be more dense/stiff than others). solution. Simple operations that regard local rules and behaviours would yield complex textural patterns, transgressing the analytical logic that produced them.

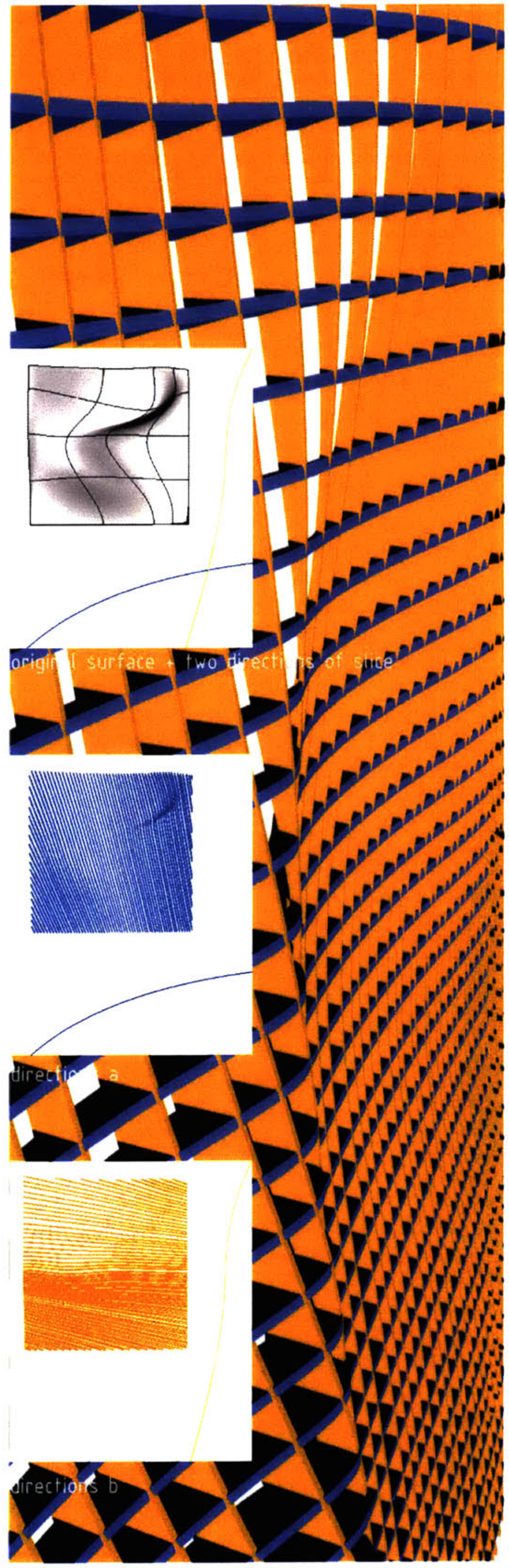


Thread Experiment 01, variable thickness of thread





## Thread Experiment 02: Inter-sectioning (import geometry , control system >> export material expression)

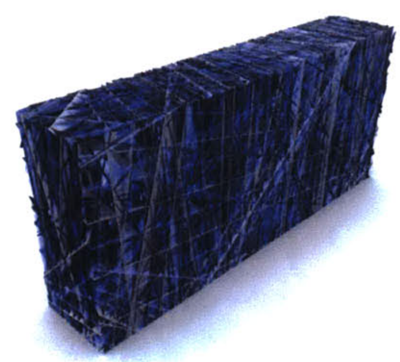


This second attempt takes a completely different approach towards the notion of thread. This time threads are deliberately attached on an object and are not derivative of the geometry of the object itself. However, the "weaving" process is parametrically defined, since it is directly linked to a control system of input NURB curves.

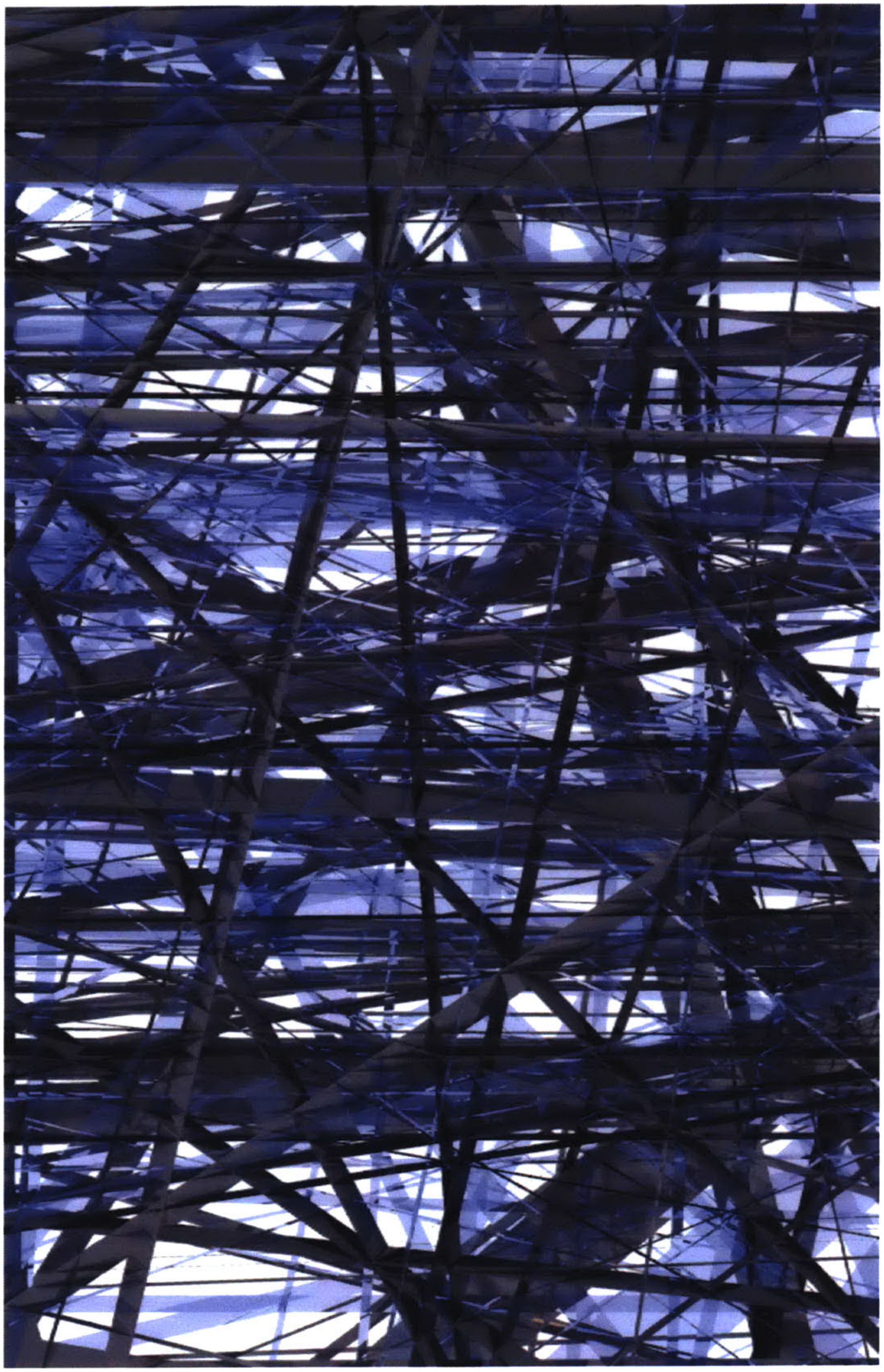
Steps embedded into the script:

- Manually : Definition of a control system for the directions of weave. (a NURB curve deployed in two or three dimensions is used as a guideline or scaffold upon which the direction of the weave is mapped.)
- Scripting: A specific thread occurs as a result of the intersection of a plane drawn perpendicular to the curve at a designated point and the surface on which the thread will occur.

This "sectioning" process can be applied on a surface more than once; each time defining a direction of cut (figures). It could be interpreted as an attempt to define a non homogenous matrix of woofs and wefts in a typical weaving process. The manipulation of the input control curve is directly linked to the resultant density and at the same time the direction of "thread". This process has not reached the desired level of control and therefore cannot be considered successful in terms of its original conception. Nevertheless, it can be interpreted as an expansion of the orthodox contouring process employed in many cases, when there is a necessity to fabricate curvilinear forms. More than frequently these forms are segregated into primary two dimensional sections through a linear and equidistant array of 'ribs', under the auspice of comprehending complexity through its analysis into simple prime elements in an array. However, this exteriorized logic refutes an inherent reading of formal expression.



Thread Experiment 02, extereme sectioning



## Thread Experiment 03: Honeycombing I (import geometry >> export material expression)

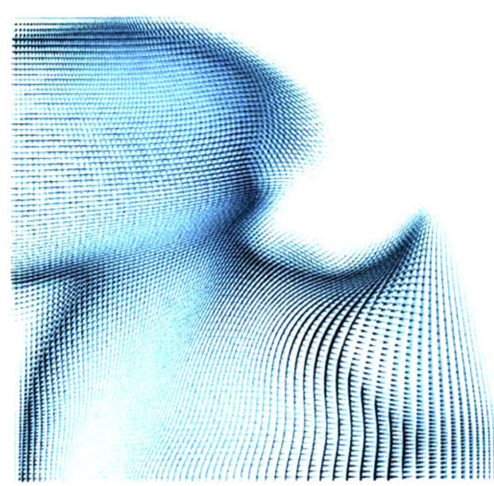
A second set of experiments was initiated as an attempt to expand the lapsus effect disclosed by 'Panelite' architects. My incentive emerged from the honeycomb panel's intrinsic property to locally deform in the course of its production. My intention became to define processes where this incidental deformation could become a cognitive parameter in the design process.

In the first phase of this design experiment, the U and V curves of a surface were used as scaffold for material deployment. The focus though in this case was on the space between the UV curves, in other words the occurring cells; these became elements that could be programmatically manipulated instead of the UV lines themselves.

The process is divided into the following steps:

- Manually : Definition of u and v coordinate system on two NURB surfaces defining a wall with thickness. The thickness can be homogenous or not.
- Scripting: Definition of space between U and V on each of the two surfaces as autonomous cells.

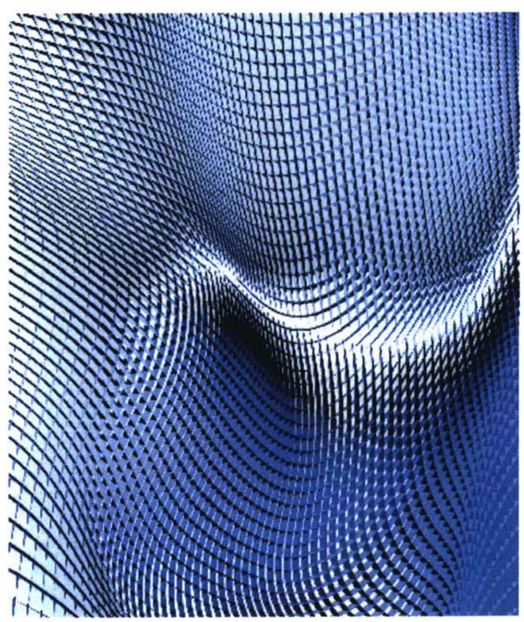
By locally varying the density of the U and V



Thread Experiment 02, honeycombing I

parameters a quadratic core for a honeycomb panel emerges. This honeycomb panel, when produced out of a flat surface, can be directly linked to the "Panelite" fabrication model that is described in the previous chapter. Using a numerically controlled machine for laying the glue between the aluminum sheets (same us laser cutter technology), the panel would not be that far from reality. The lapsus effect this time doesn't occur as an incidence, but rather as a cognitive design principle. But what is the driving force behind this local densification?

To my surprise, an unexpected property emerged during the frenzy production of the honeycomb variants. A slight miss-alignment of the UV coordinates of the two surfaces changed not just the density, but also the orientation of the core's cells. As a result, the honeycomb panel had embedded in it a direction of focus. This 'mistake' was interpreted as a possibility for guiding view through the panels towards specific points of interest. Such a strategy could be directly applicable in exterior envelopes as an optical mediator between exterior and interior. What if the "window" area, instead of offering a panorama, geared vision towards specific focal points?

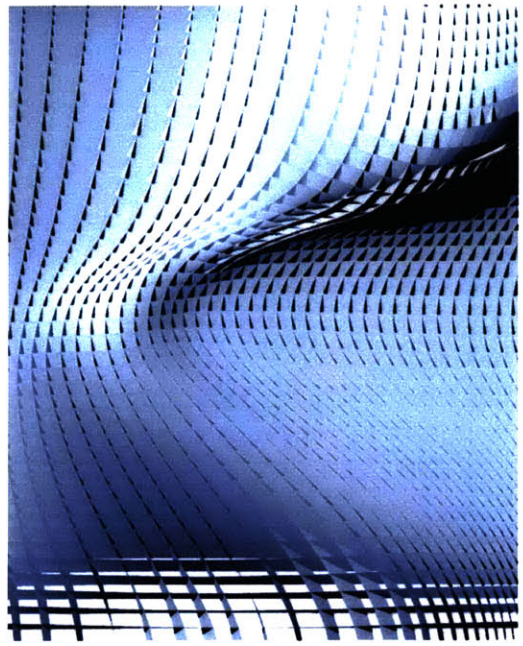

Thread Experiment 02, honeycombing I, mistake!

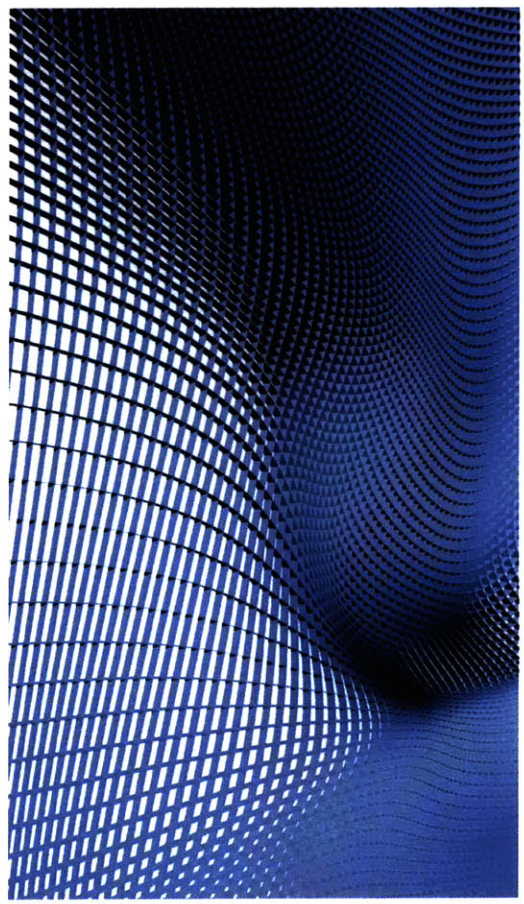
## Thread Experiment 04: Honeycombing II (import geometry and exterior points of interest >> export material expression)

The process is divided into the following steps:

Manually : Definition of U and V coordinate system on a NURB surface defining a wall.
Scripting: Definition of the space between neighboring U and V curves on each of the two surfaces as autonomous entities. The way cells are defined this time is different. Points with (x , y , z coordinates) provide within a specified area of effect input for the direction of cells.
Manually: Moving the points in space alters the honeycomb panel's inherent configuration. The same operation can be applied both in flat and in three-dimensional surfaces.

This example demonstrates the potential of a 'honeycomb' materiality to distribute views at specific areas of a given site. It illustrates an alternative understanding of exterior envelope construction; that of a constantly shifting window which acts as an attractor or repelor of view, a window that engages with the viewer in a dynamic way. Walter Benjamin first articulated the experience of architecture as a continuum of 'starting', 'stopping', 'starting', 'stopping', a movement of seeing that accumulates over a certain interval, in which space and time are



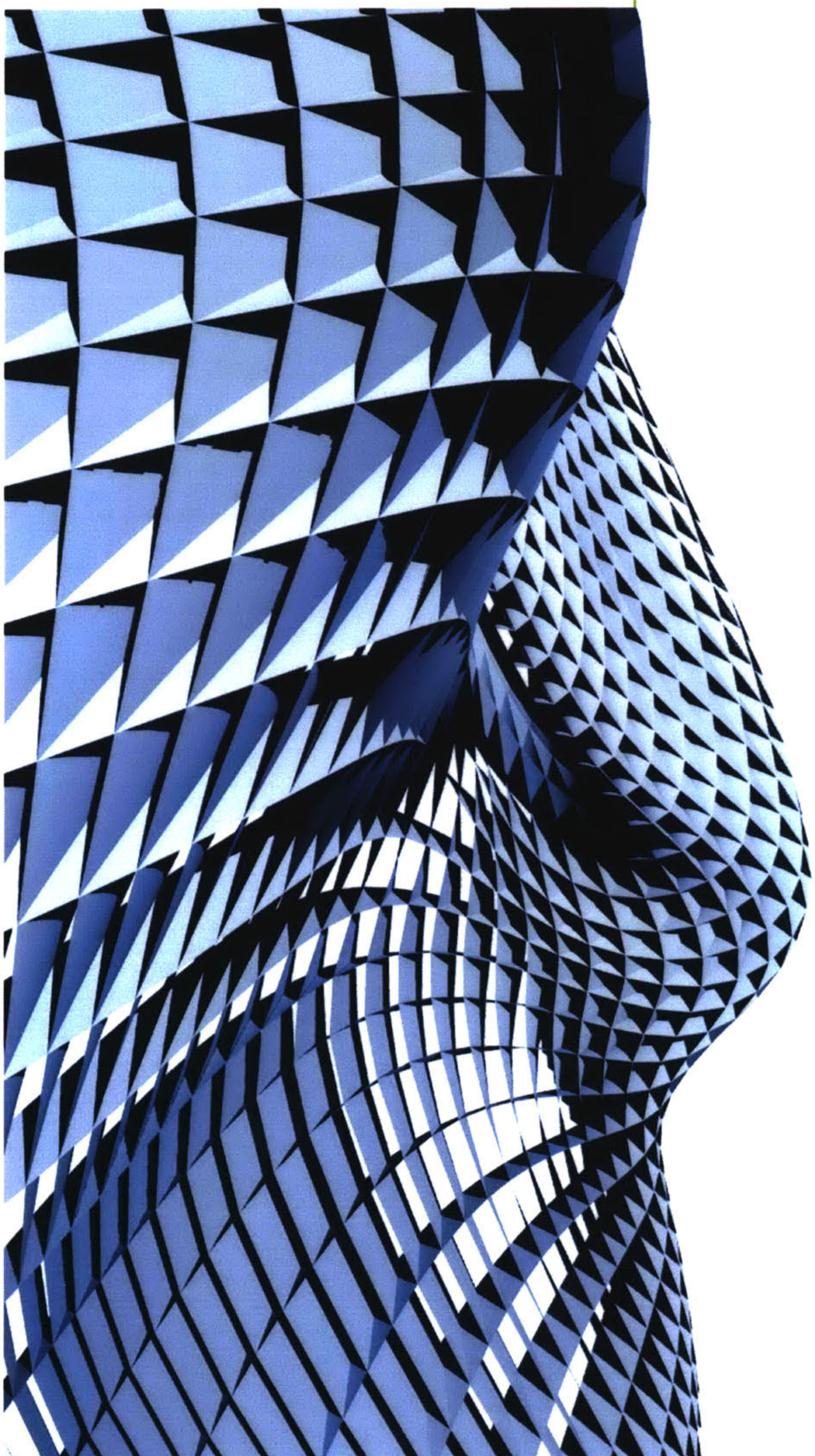


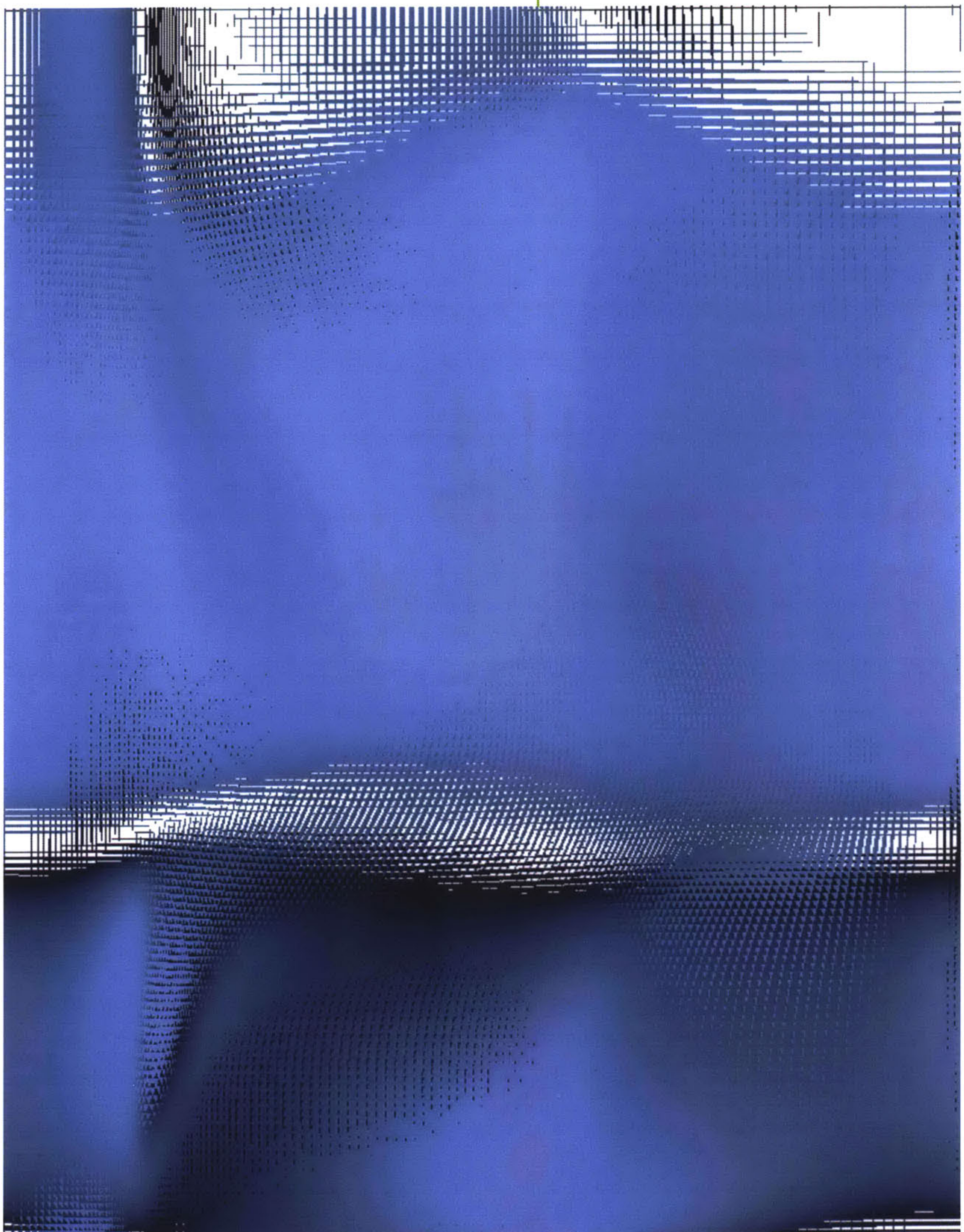
Thread Experiment 02, honeycombing II

traversed and fit together. But architecture, also eludes optical summation since movement corrupts the seeing and seeing corrupts the movement.[56]
What if we were to use the movement of the body through space as a way to 'animate' material?[57] Such an object, when perceived through movement opens and closes, expands and contracts, develops a dynamic relationship with its viewer. What if we manipulated the perception of space in order to temporarily produce a materiality with animate local differences?

56. A. Picon, A. Ponte (Ed.), Architecture and the Sciences. Exchanging Metaphors, Princeton Architectural Press, New York, 2003, p.235.

57. paraphrasing Greg Lynn's 'Animate Form'

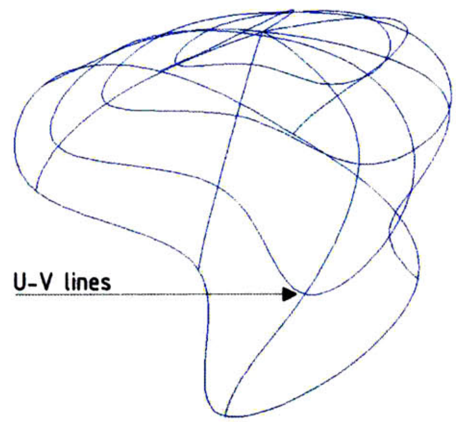


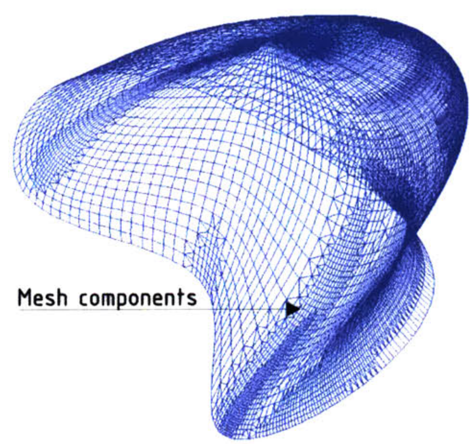


## 04.2. component

### Mesh objects

The second series of projects that will be presented here derives from the 'component' strategy analysed in the previous chapter. A primary interpretation of a component was that of a mesh object, inherent in most of the 3d modelling software. Meshing is a common technique being used to describe a NURB surface out of small, usually triangular or quadratic, pieces that are independently accessed. From now on, we will be using the terms 'NURB mode' and 'MESH mode' when referring to a surface. The difference between the two modes of description lies on the geometric definition that each case entangles. In the former case, a surface is defined as a single unified yet malleable entity, whereas in the latter as a non-homogenous constellation - agglomeration of small pieces, each one different than the other in size and orientation. Consequently, in a "MESH mode", each piece can be evaluated separately and be given a material property regardless of the others. When a transformation occurs from a NURB definition of a surface to a MESH definition of the same surface, its topological characteristics are temporarily eliminated and remain only as traces.




Meshing, as a technique, has been widely used by disciplines that deal with the performance analysis of an object under certain conditions. For example, it has been used as a means to calculate locally the stress that is exerted on a given structural component (figure 40), since it enables the division of an object in areas and the calculation to take place in parts.

Since manipulating and assigning locally material properties, is a major point of interest in my case, 'MESHING' provides a tool for deploying non-homogeneous material properties within a single unified geometric entity.

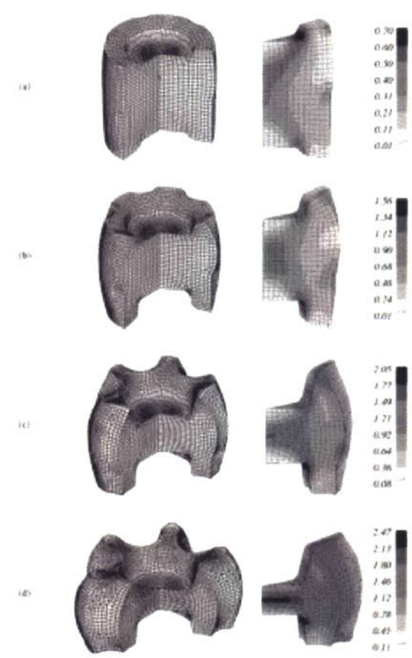


figure 40 >> Configurations of deformed mesh and distribution patterns of the effective strain. Y.K. Lee, Y. Yang.

## Component experiment 01 : Meshing
## (import NURB geometry>> export MESH geometry).

An initial step for this series of experiments was the production of a scripted process, through which a surface would be transformed from the 'NURB mode' to the 'MESH mode'. A key feature for this process would be to keep/store the topological definition of the surface, so that the 'Mesh mode' can be directly linked to the information inscribed in the NURB mode and consequently adapt to any transformation induced in the original NURB surface. This became the primary reason for not using the meshing algorithm already embedded in the 3d modeling environment (Rhinoceros).

A first series of objects was produced from a single NURB surface (figure). This process demonstrates the potential of moving back and forth from a smooth to a tessellated geometric expression in which the constituent components locally adapt to the geometry of the original source surface.

TOLERANCE 0

TOLERANCE 0.5

TOLERANCE 2

TOLERANCE 10

TOLERANCE 25

TOLERANCE 35

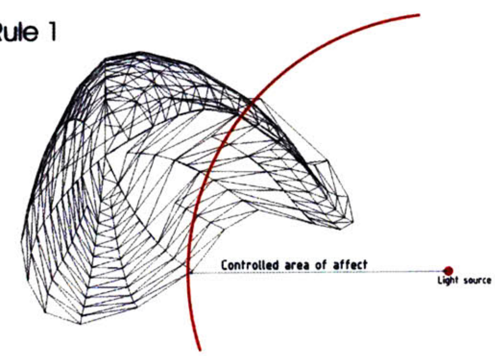
## Component experiment 02 : Window __ Wall (import : geometry, light source >> export : material expression)

Going back to my original preoccupation, meshing was considered a suitable tool for engaging with the design of a window-wall relationship. As it was described in the 'Ninety-Eight Present Nothing' project, the fabrication of a non-homogenous resin panel leads to the following questions: "how can one design such a window-wall relationship?" Is it possible to actually input into a design process parameters that would define areas of 'window(ness)' and 'wall(ness)'? Can a non-homogenous resin panel, like the one analyzed above, be outlined in a 3d modelling environment topologically in terms of its material? In an attempt to approach these issues, a scripted process was designed, in which a wall was considered as a 'repelor' of light and a window as an 'attractor'.

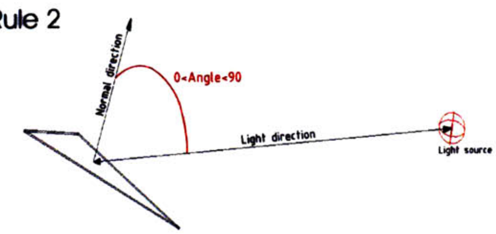
The steps of this process are :

- Scripting: a topologically defined surface was transformed from its 'NURB mode' to its 'MESH mode'
- Manually: a light source is designated as a point with x, y, z coordinates in space. This point could be understood as the specific location of the sun on a given site on a given moment.
- Scripting : a calculation occurs in which each mesh component of the mesh surface

Rule 1



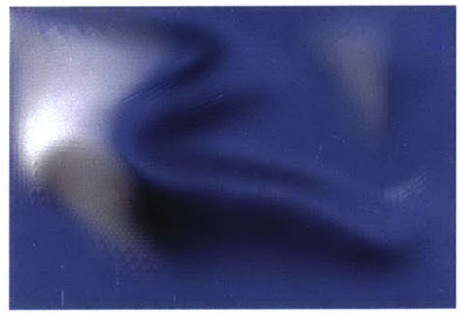

Rule 2

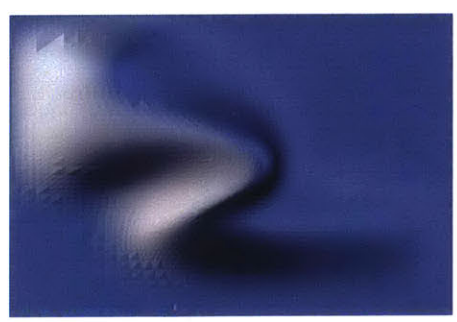


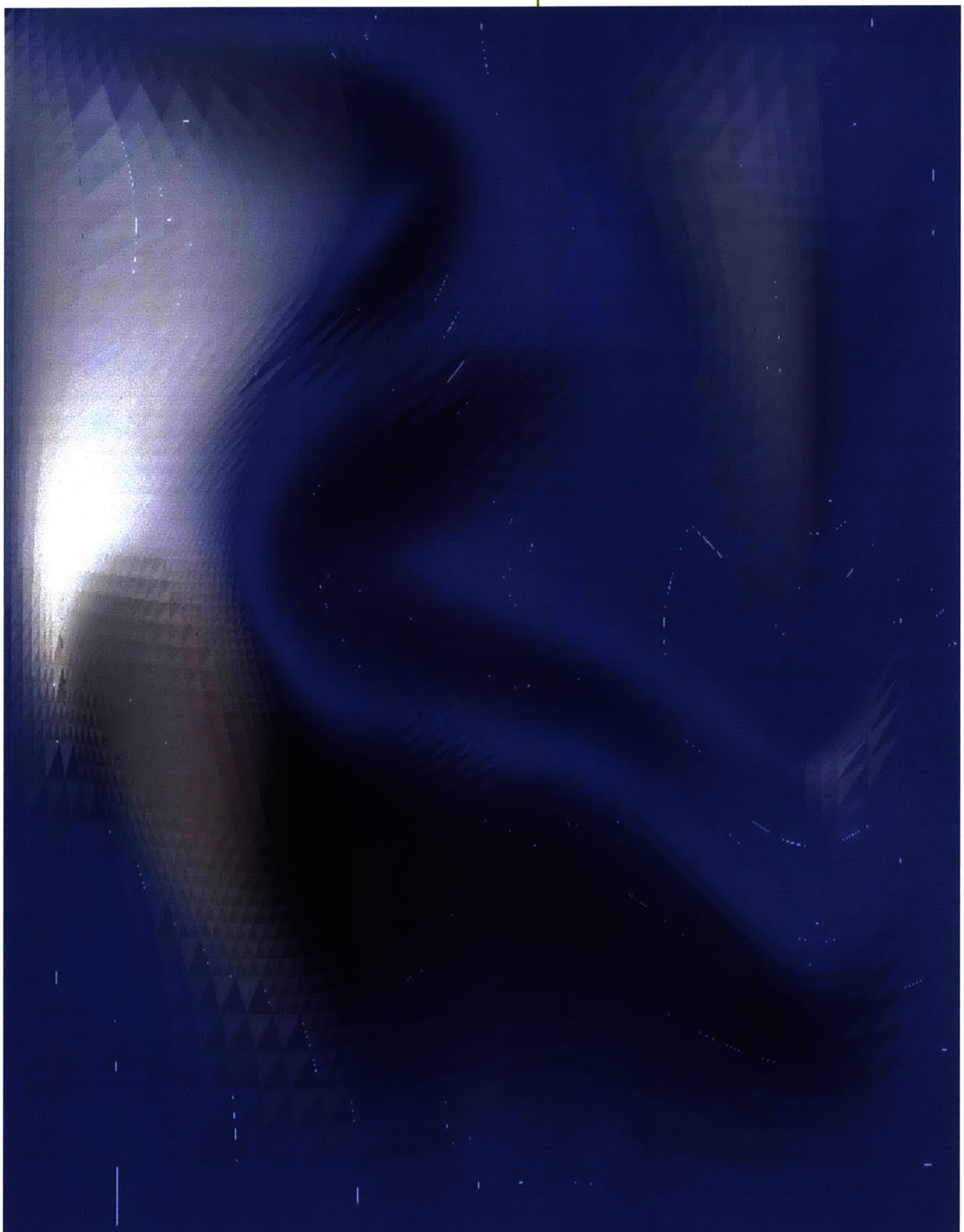

rule diagram for window-wall generation

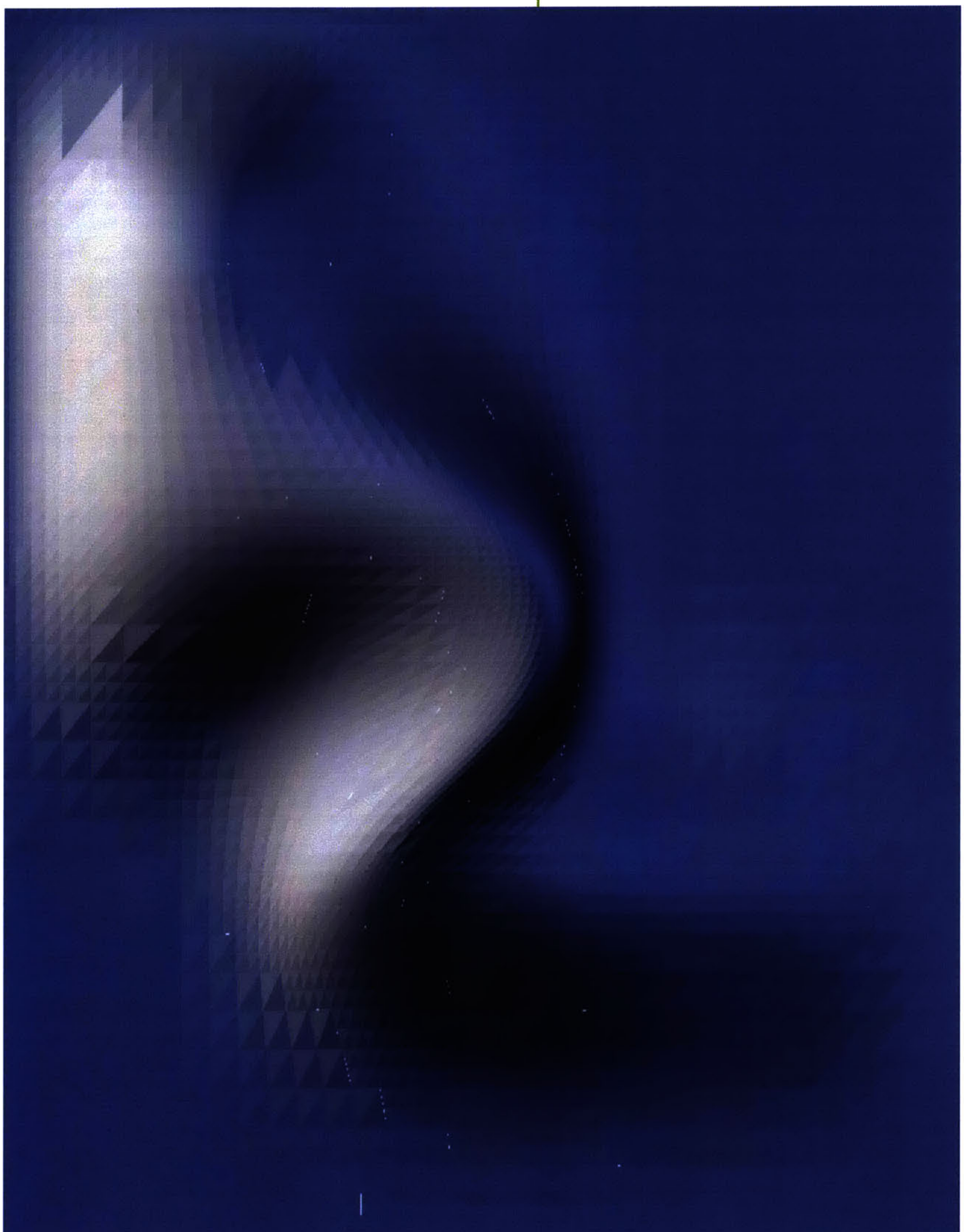
is evaluated according to its position and orientation relative to the position of the light source. An area of affect of the light source is inputted by the designer. This area is a percentage of the total area of the site and It ranges from 0% (meaning no triangle is evaluated) to 100% (meaning all triangles in the geometry are evaluated). (figure) If a triangle is within that area of affect, it obtains some degree of transparency. The level of transparency also ranges from 0% to 100% and depends on the specific orientation of the triangle relative to the position of the sun (the more directly a triangle faces the sun the more transparent it becomes). (figure)

This process describes a possible way to design a window - wall relationship on a given parametrically defined surface. Any possible change in the geometric configuration of the surface effectuates a change in the window - wall definition. Windows and walls are not imposed as exterior elements, but rather are described as formation processes. Furthermore, any change in the relative position of the light source also affects the window configuration. It should be mentioned here that a light source is not necessarily singularly defined as the sun; it could be interpreted as a window agent or a targeted point of view that 'triggers' a window materially manifest.





## Component experiment 03: Variable thickness (Import: material definition >> export: geometry)

This last part of the second series of experiments attempted to address another issue raised in the 'Ninety-Eight Percent Nothing' project. This issue revolved around the inquiry of how we may produce a physical mold that would enable the fabrication of a composite resin panel with variable properties along its body.

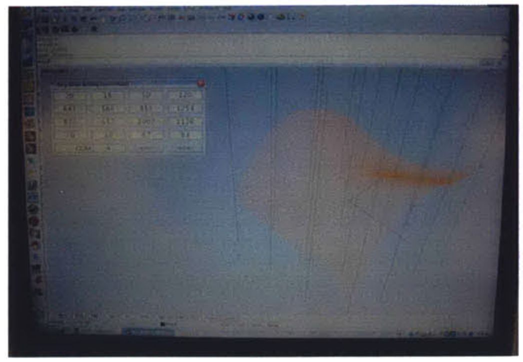
The outcome of the previous Window _ Wall experiment was defining areas of transparency and opaqueness on a single surface without thickness. The following process attempts to give thickness to that surface by locally offsetting the original according to its local transparency.

This process had the following steps:

- Scripting : access each mesh component (i.e. constituent triangles of the mesh surface) and evaluate its level of transparency. Since transparency is ranging from 0% to 100% it becomes a factor for determining the thickness of the surface at the specific point
- Scripting : for each triangle in the original surface, a new triangle is produced at a distance from the original determined by the transparency factor. Areas of high transparency result into thin wall section


production of variable thickness from original window wall definition and areas of low transparency into thick. (figure)

- Scripting : transfer the digital model into a physical mold. (mold_it device)



## Component experiment 04: Mold _ it.

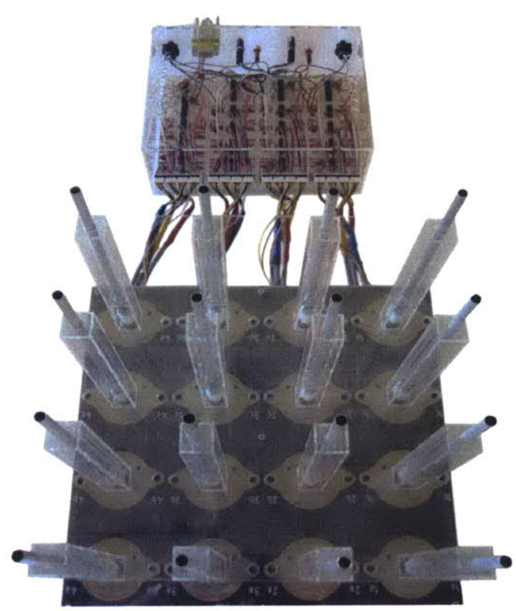
My intention in this experiment was to design an intelligent moulding device, able to reconfigure its shape in order to facilitate the production of physical variations of a single object. In order to achieve this goal, a malleable silicon surface, controlled by stepper motor driven pistons acts as a transformable platform that enables diverse configurations. Based on the movement of the pistons and their stasis at different lengths, the surface constantly readjusts, resulting in the formation of diverse curvilinear cavities.

The "mold it" device is divided into three major components:

01. The main platform consisted of a base, 16 stepper motors, 16 pistons and a silicon surface.

02. A circuit box, handling power and communication between the platform and the pc.

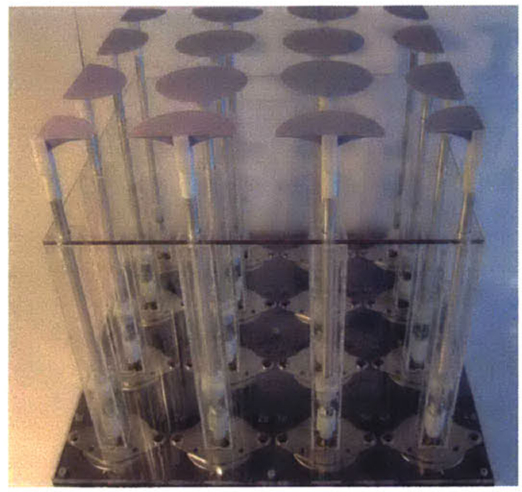
03. A VBScript in Rhinoceros 3.0 which extracts digital information and transforms them into analog movement of the pistons.



mold it device. Alexandros Tsamis with Stelios Dritsas

Through this device multiple moulds could be produced and facilitate the production of a resin panel with variable thickness and transparency.

Although the experiments of 'Variable Thickness' and 'Mold_it' were considered successful in terms of responding to their original conceptions, an additional remark came to the foreground; in some instances of the experiments, material property preceded geometrical configuration. In other words, instead of trying to describe a materiality that corresponds to a formal expression, an already deployed material forces geometry to manifest. The component experiments are intentionally interrupted at this point, as they will be redeployed on the third and final set of experiments, through a new context. The concept of a materiality that precedes form definition will be investigated later in this thesis.



mold it device. Alexandros Tsamis with Stelios Dritsas

# 3. Substance:

## Material distribution

Substance refers to 'raw' material; it becomes an attempt to handle the concept of manipulating material properties in space prior to determining any specific geometric configuration. Substance could be seen as a non homogenous field of material distribution in space.

"A Field condition could be any formal or spatial matrix capable of unifying diverse elements while respecting the identity of each. Field configurations are loosely bound aggregates characterized by porosity and local interconnectivity. Overall shape and extent are highly fluid and less important than the internal relationships of parts, which determine the behavior of the field. Filed conditions are bottom up phenomena, defined not by overarching geometrical schemas but by intricate local connections. Interval, repetition, and seriality are key concepts. Form matters, but not so much the form of things as the form between things" [58].

58. S. Allen, "Contextual Tactics & Field Conditions", Points+Lines. Diagrams and Projects for the City.

Transferring Stan Allen's understanding to a material realm, the conceptual shift from objects to fields is still prominent. To begin with, the emergence of new computer tools with capabilities to blur boundaries between objects and their environments has had a significant impact on our perception of architectural space. Visual representations based on the use of such techniques have created compelling iconic figures that on a first level of analysis, intuitively convince us of such a shift.

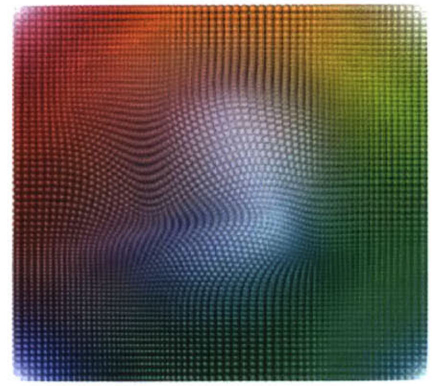
Going beyond the surface of architecture's representation, but again based on the germinal potential of digital methodologies, it becomes clear that the shift is not merely formal. It regards a true dissolution of geometry and its origins on the square and the compass, by shifting the significance from geometric objects to fields of material properties. Objects are no longer the outcome of a manipulation of their geometry, but instead emerge as a spatio-temporal sublimation of fluctuating distributed material. This reallocation has impacts in diverse levels of the design sphere. Aggregations and accumulations become an important part of reading a body of information and density of matter regains tremendous respect in conceptualizing architectural space.

## Voxel space

A voxel in space is the three-dimensional element equivalent to a pixel on a two dimensional image (bitmap). It is essentially a 'place holder' of information in a three dimensional space. A pixel, for the computer, is a generic unit with minimal x , y dimensions that contains information such as the R (red), G (green), B (blue), corresponding to a color of the image at the specific location. The equivalent could be assumed about a voxel, only this time it belongs in space. It is being used here as a key tool to address the notion of 'substance', as a way to describe a field of material properties distributed in space.

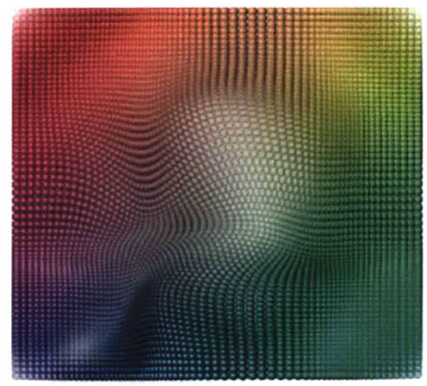
The first part of this set of experiments demonstrates how such a voxel space can be generated by collecting information from a specific geometric context. It is being used here as an initial step in order to engage with such a concept within architectural design and begin to imagine its generative potential.

## Substance experiment 01: Voxelizing (import geometry >> export voxel space.)

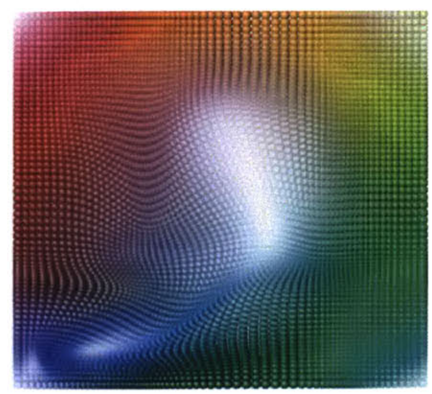


The script written for this section collects information that is inherent within a topologically defined surface and transforms it into a voxelized environment.

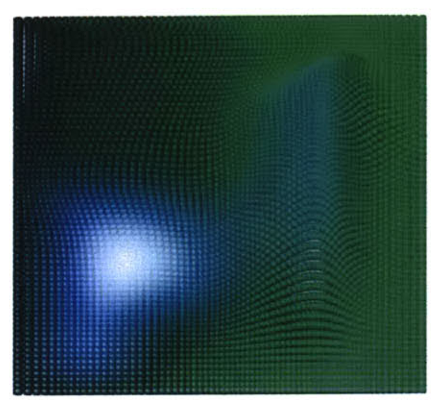
- Scripting : densely sample a surface through U an V intersections collect their x , y , z coordinates and calculate for each one its distance from the 0,0,0 point.

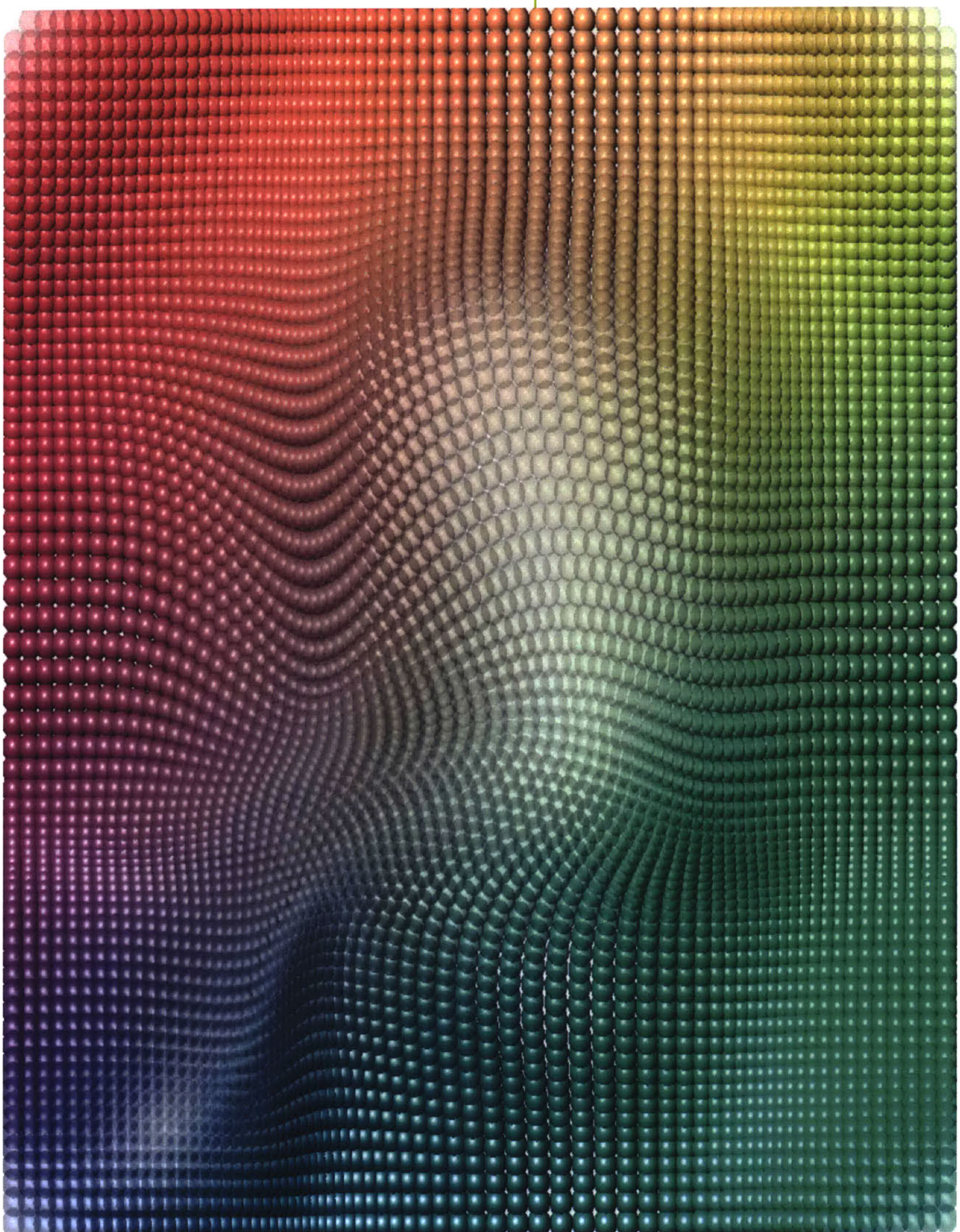


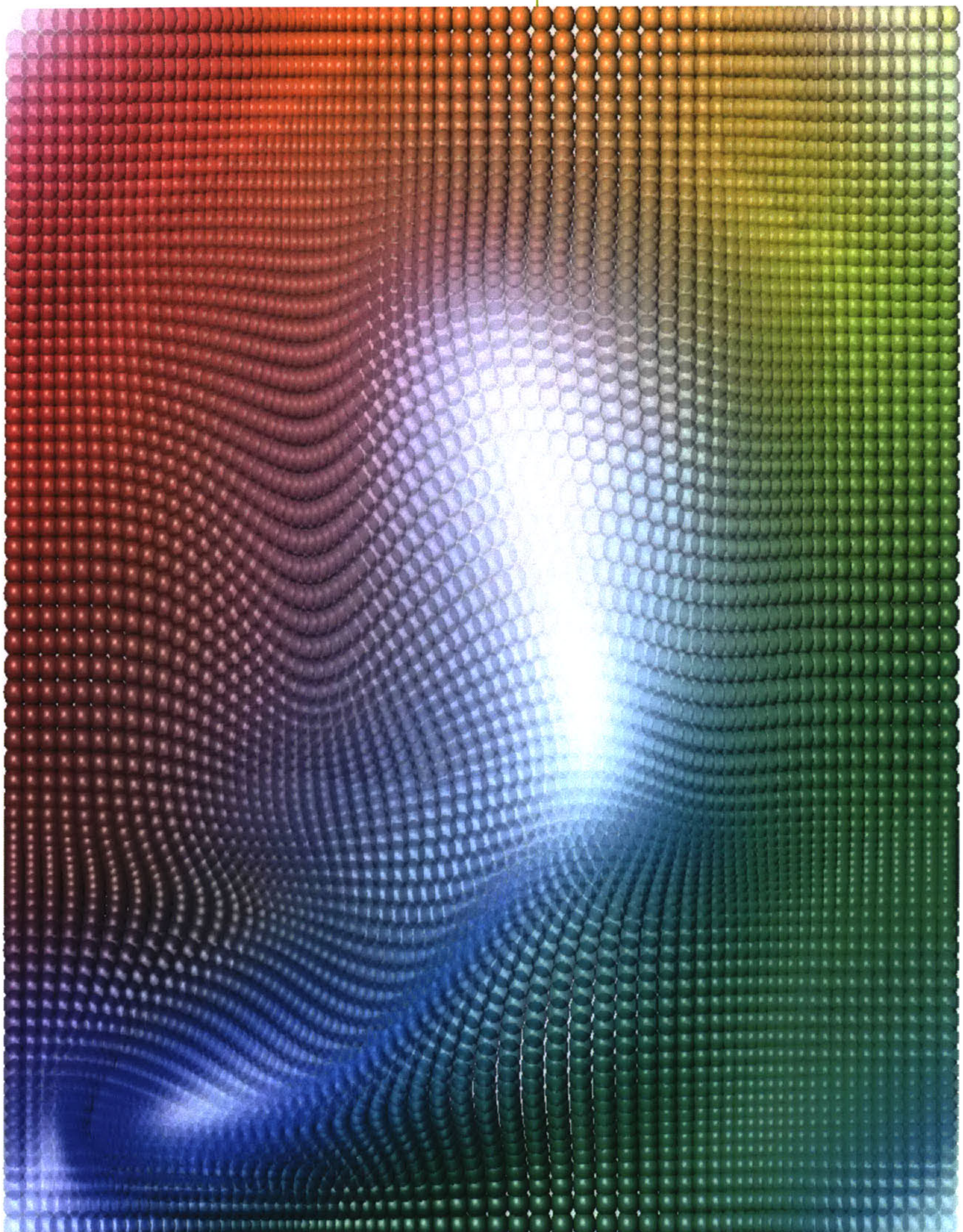
- Scripting : for each of these points make a sphere (a place holder in this case, geometry is generic and of no importance) and assign to it a material with an R,G,B color definition determined by its distance to the 0,0,0 point. Furthermore, assign to it transparency according to its relative z coordinate. The closer the point is to the 0,0,0 point the more it becomes red and the further away the more green. Transparency increases as the z value increases.



This exercise is a demonstration/representation of my perspective on the generation of a voxel space through the extraction of information in a given context. It has no specific meaning or purpose other than evaluating the computation technique being used. For the specific example, a manipulation of the original geometry results in a variation of the voxel definition (figures). When the target context is not







a surface but a volume (lets say a potential site) the same process produces a volumetric distribution by sampling not one, but many, dense layers of that volume (figure).

## Simulation VS Sampling

The analysis of the difference between Simulation of light and Sampling of light as techniques being used for advanced visualization of digital environments, sheds some light to my understanding of the possible exploitation of voxel space as a generative mechanism for the production of 'materially informed' architecture. Through this analysis an attempt is made to understand the nature of a voxel space and how it can gain meaning for our perception of architectural space.

Radiosity, which came in 1984 from Cornell University in a paper titled "Modelling the Interaction of Light Between Diffuse Surfaces" written by Goral, Torrance & Greenberg.[59], is a major proponent of simulation. The idea in radiosity was to imitate energy (light) transference from diffuse surfaces that reflect light equally in all directions. Through this tool, an attempt is made to transfer in a digital context an understanding of the behaviour of light as it performs in a given physical environment. In this case, light is considered an energy beam which hits an object, imbues it with light and then bounces back into the environment, only this time

59. http://www.flipcode.com/tutorials/tut__rad.shtml

its energy is reduced. The same beam bounces again to the next object until it finally fades out. Non-reflective objects absorb more energy and register less light on their surface than reflective ones. (for a deeper understanding of the technical implications behind this process please refer to http://www.flipcode.com/tutorials/tut_rad.shtml and http://freespace.virgin.net/hugo.elias/radiosity/radiosity.htm ). A generic description of the principle behind this process would be that a digital environment is employed to simulate our abstracted perception of the behaviour of light within a given physical environment.

A completely different approach to the same matter was taken by Devebec in 1997 with his paper on "Recovering High Dynamic Range Radiance Maps from Photographs"[60]. His ground-breaking proposal suggests that instead of using simulation as a technique for visualizing digital environments, light information can be extracted from photographic images. Using a series of images of a given physical environment, Devebec proposes a reconstruction within a digital environment, of the existing light conditions. The process is not as simple as getting a picture, and it involves a meticulous gathering of information through a specifically designed device. Cameras are placed around a highly reflective sphere, pictures are taken from multiple points of view of the sphere (figure 41) and then the resulting images are unfolded back to the digital environment. (figure). (for a deeper understanding of the technical implications behind this process

60. Paul E. Debevec and Jitendra Malik. "Recovering high dynamic range radiance maps from photographs". In SIGGRAPH 97, August 1997. p. 369-378,

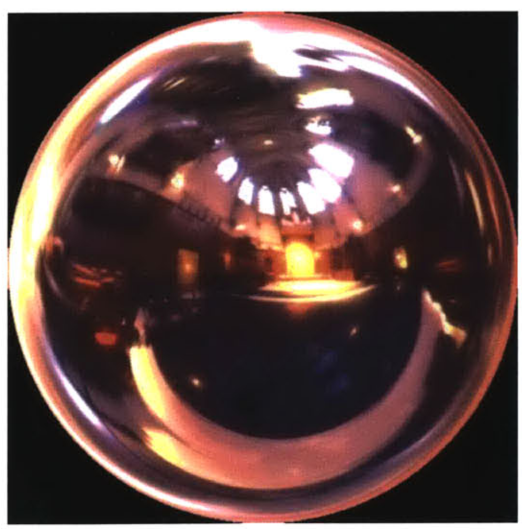


figure 41 >> P. Devebec, device for light messurment please refer to : http://www.debevec.org/HDRShop ) . Through this process Devebec samples a physical context; for example he extracts light information from the context, transfers that information into a digital environment and places a digitally designed object within that environment, predicting the way light would behave on it, as if the object was actually there.

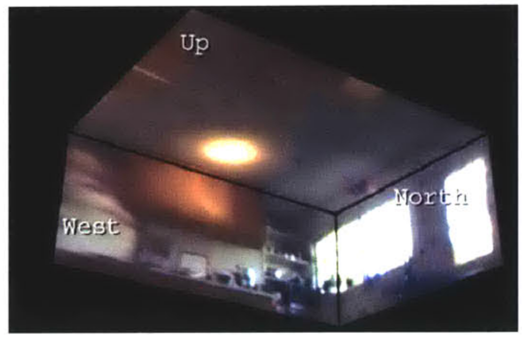



figure 42 >> P. Devebec, unfolding of light information back to a digital environment.

The difference between Simulation and Sampling lies on their basic underlying principle. In the first case, the computer is used to essentially reproduce in an abstract way our generic, global understanding of the physical world. In the latter case, the process determined, accepts the environment with its local intricacies without attempting to rationalize it. It absorbs complexity as such; it does not pretend to understand the reasons behind its formation. Abstraction does not come at the stage of collecting information from the environment; rather, it comes later, in the process of interpreting that information. In this sense, a voxel space could be considered a phase in the design process in which information is gathered in a 'raw' form or as 'raw' material readily available for further manipulation and allocation.

Although far from actualization, the following examples illustrate the potential of exploiting voxel space as a germinal tool that is put forward by the intrinsic nature of the digital realm.

## Substance experiment 03: Chameleon (import geometry and environment >> export material definition)

The chameleon project entangles directly the outcome of the simulation VS sampling analysis. It suggests an alternative mode of operation for describing the relationship between an object and its environment.

For the chameleon, the environment around it is already defined through its perception, and it is there for it to assimilate. Roger Callois in his influential essay "Mimicry and Legendary Psychasthenia" analyzes imitation techniques, arguing that the objective for skin coloring and ornamentation is not crudely a defensive reaction. Imitating mechanisms disappear once the morphological character is acquired. Moreover, predators are not all fooled by homomorphy and homochromy. Other senses besides vision are so highly evolved as to guide predators track their preys. "It would come as no surprise that such creatures have other and more effective ways to protect themselves. Conversely, some species that are inedible and would thus have nothing to fear, are also mimetic"[61]. Callois concludes that this is an "epiphenomenon whose utility appears to be null"[62]. The primary fact for mimetic transformation is fascination. He goes on to advocate that metamorphosis for these species is a type of luxury rather than a function, an erotic display of amalgamation with space, as the subject enters into a psychology of depersonalization -psychasthenia-, by assimilating to its surroundings.[63]

61. Roger Caillois, "Mimicry and Legendary Psychasthenia", October: The first decade. 1976-1986, Cambridge, MA, 1987, p.58

62. ibid

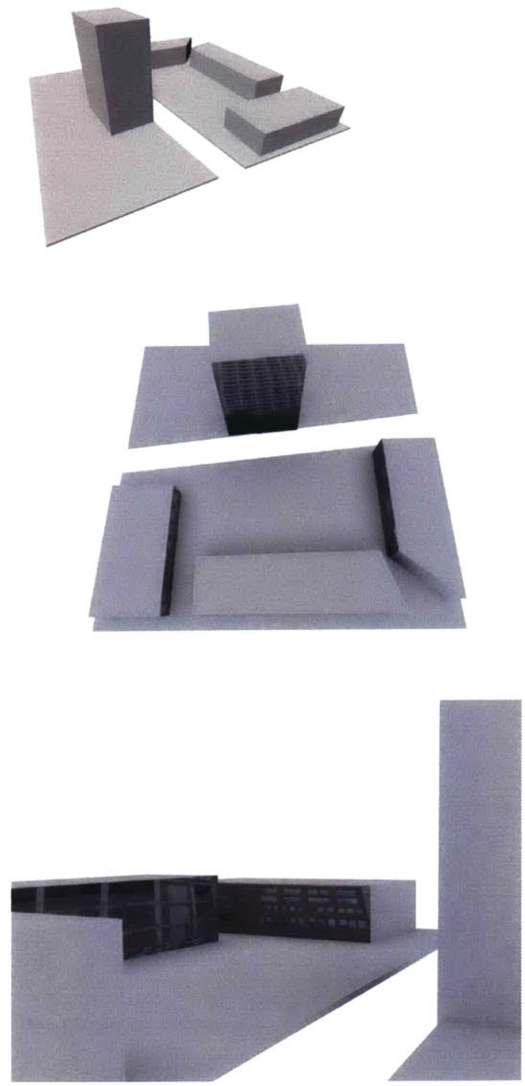
This fascination of the mimetic creatures was expanded into an incentive for a design expression. In my case, objects choose through their material definition to either assimilate or distinguish themselves from their environment. Technically speaking and returning back to voxel space, the chameleon project deploys the following process.

- Manually : take pictures of a site , define within a digital environment its geometric characteristics and visualize its material boundary conditions through an array of the pictures taken. (figure)
- Scripting : sample the given images and deploy material place holders in space through an algorithm that interpolates pixels from the original images (figure).

Interpolation is chosen here as a means to directly impose the existing material boundary condition of the site within its volume. The intention is to describe areas of affect of each material according to proximity. Towards the edges of the site the material properties correspond to those of the environment. The closer one goes to the center, since the material definition is a product of interpolation, the properties start to become unique, distinguished from those of the environment.

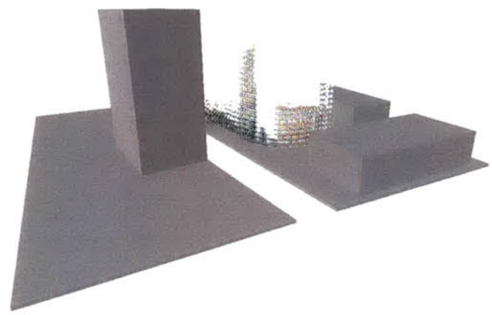
- Manually : insert an object within the already materially defined space.
- Scripting : through the meshing algorithm described in the previous set of experiments,

63. Roger Caillois, "Mimicry and Legendary Psychasthenia", October: The first decade. 1976-1986, Cambridge, MA, 1987, p.70-72



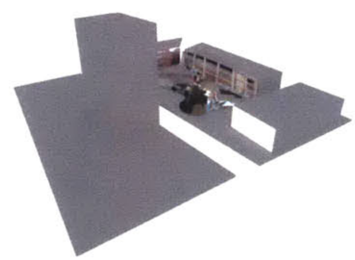
mapping of environment

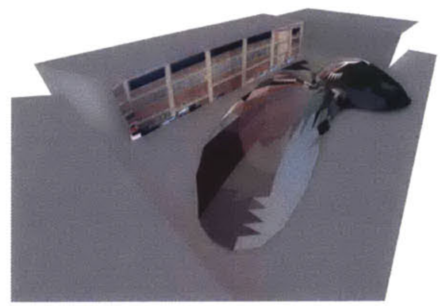
divide the object into small triangles. For each triangle in the object find its closest point in space and assign its material.

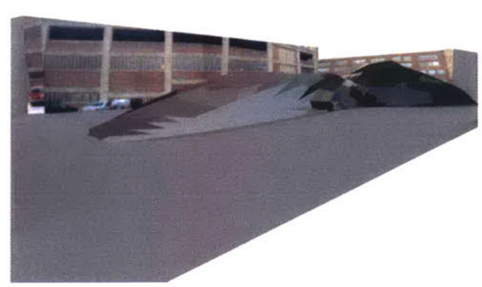


generation of voxel space

For this object, materiality is already defined. The closer the 'germinal object' reaches the edges of the site, the more it blends with it. The closer to the core, the more it distinguishes itself from it. The occurring object under transformation would yield areas that potentially assimilate to the environment and other areas do not; it is a matter of choice. In other words, material is an a priori condition for this project, while geometry is yet to be defined. This simple fact constitutes an inversion of the traditional mode of thinking, in which geometry is defined first and a material is chosen for it accordingly.







definition of material according to proximity

At this point, it would only be fair to criticize that the material is not articulated here in its entirety, as a range of properties. Rather, its color becomes its representation. An immersion into material properties (which requires a broad understanding of material science) would have to be combined with an advanced knowledge of computation, in order for materiality to escape its mere representation within a digital environment. A sophisticated mechanism, like the one employed by Devebec to extract light information, would potentially yield a deeper understanding of the phenomenon. For now, this project settles with its representation. It is present here more as a demonstration of a process and less as a final product.

## Substance experiment 03: Seed
## (import environment >> export geometry)

My final experiment is geared towards the expansion of the notion of voxel space as an attempt to exploit its generative potential within architecture. This time a more generic concept is deployed.
In the chameleon project, information was extracted from bitmap images that were directly used to generate a field of material properties. If we were to use Devebec's example, we would need to be focusing on something more specific in order to use this information constructively in a given condition. For instance, an accurate measurement of a site's temperature through countless thermometers dispersed within its volume would provide as with a field of locally varying heat values. An equivalent result, would be obtained if we were to use thermal images of its surrounding environment (figure 43). Thermal images could also be considered carriers of 'raw' information from a given context. Only this time, information is filtered through a device that records thermal radiance. In other, words it records heat's intensity and locale.

For the particular experiment, thermal images were used as platforms for the generation of a voxel space.

Physical form is conceived in the form of a seed that is implanted in the voxel space. The seed is considered as a parasite that intrudes the

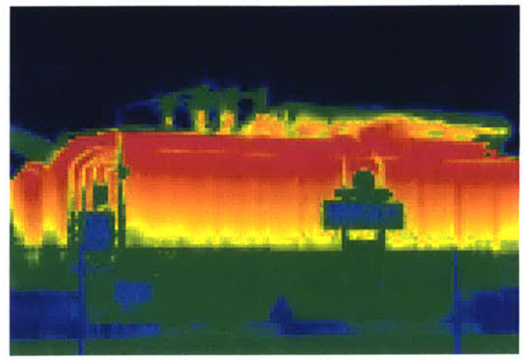
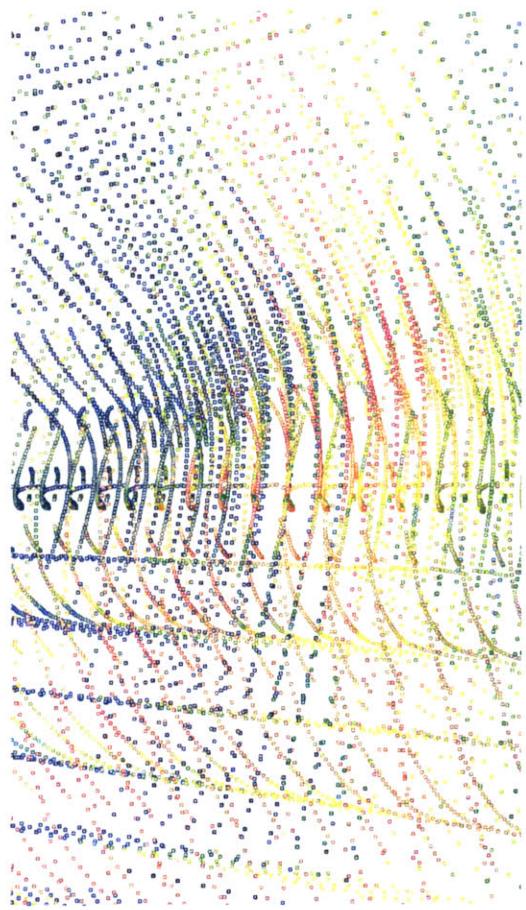
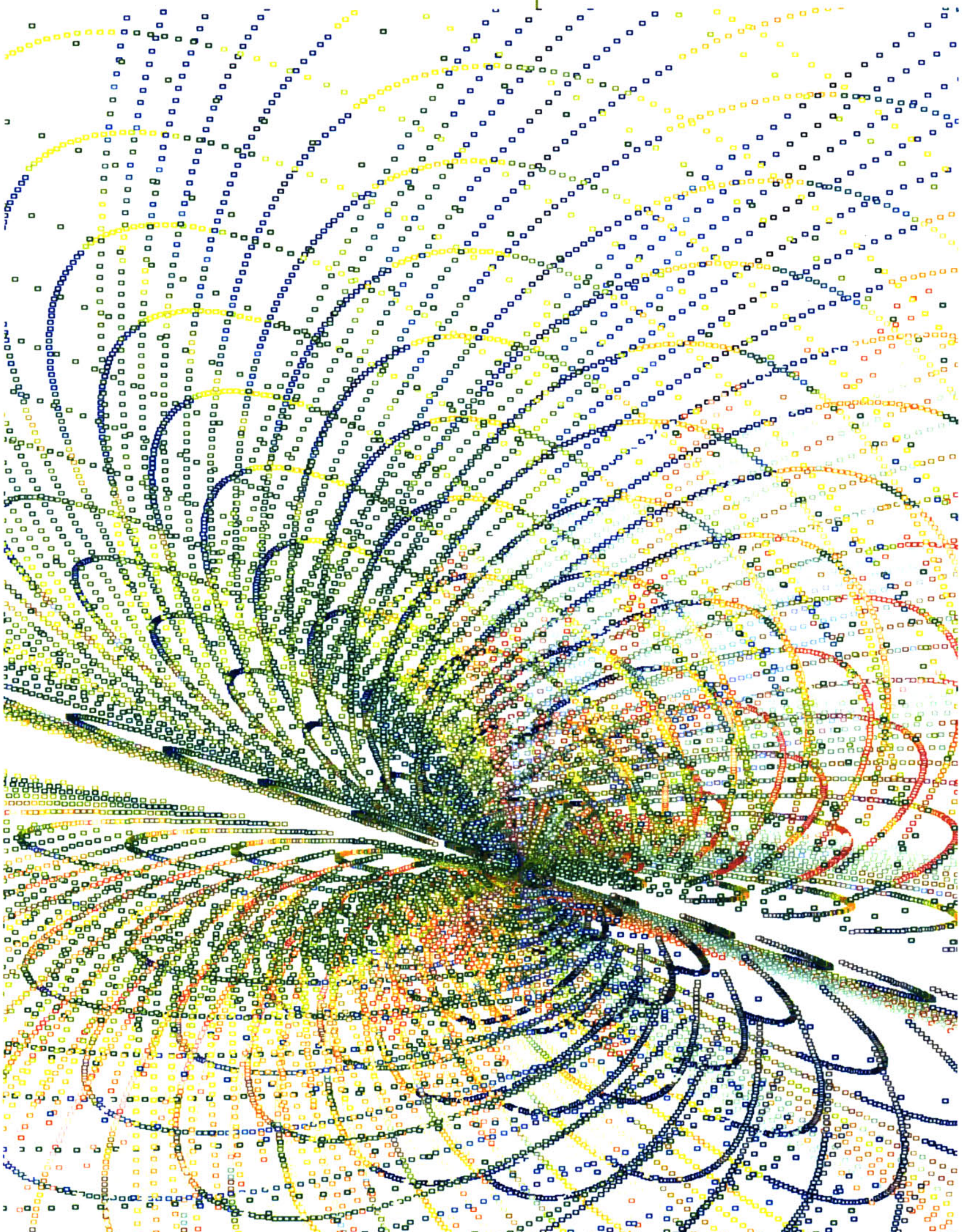


figure 43 >> generic thermal image



production of voxel space

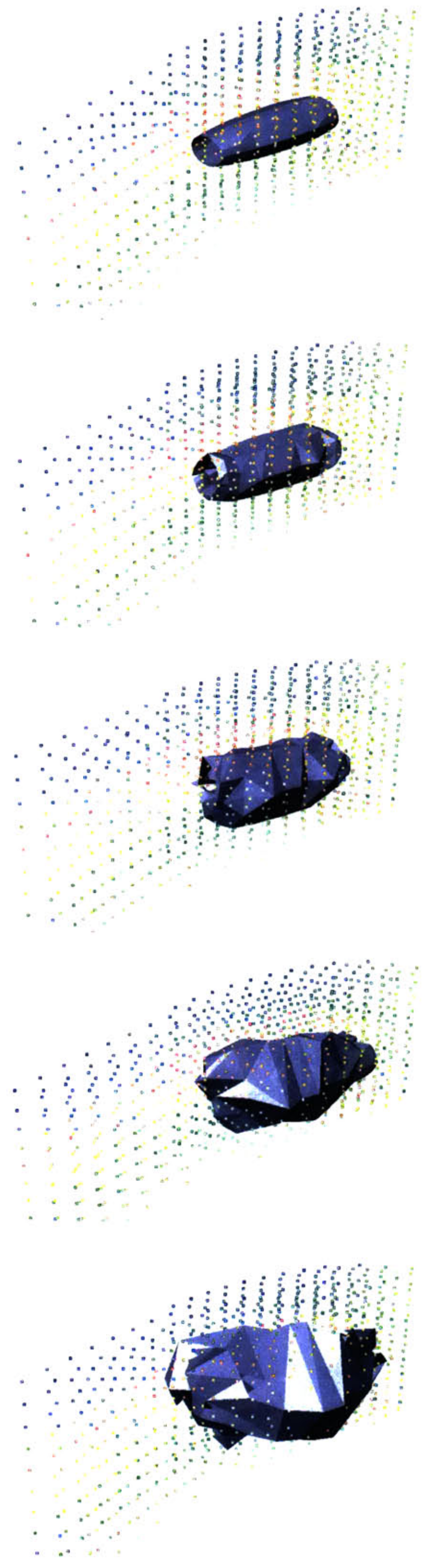


information field of the voxel based space in order to absorb heat. Geometry is a result of the parasite's thermophilic behavior.

More specifically, the process has the following steps.

Manually : definition of maximum area of voxel space
Scripting : production of voxel space through thermal images that are extracted from the site.
Manually : insertion of seed
Scripting : for each face of the inserted geometry find the closest point of the voxel space. If the point's red value is high move towards that point by a factor determined by the same value. If the point's red value is low move away from it.

The more red a point is the more heat energy it contains the more it attracts geometry.
The more blue it is the more geometry avoids it.
In this case geometry is manipulated by a raw information deployed in space. Through a more generic description, Space can be thought of as a scaffold of distributed properties and behaviors. Objects temporarily crystallize around information. For instance, material properties, conditions of light, functional aspects and form are treated simultaneously through principles of proximity/coincidence/relevance. Design, becomes a procedural expression of mediated perception and injection of desire.



# chapter 05: conclusion

Bernard Cache, with his objectile (figure 44), suggests that the introduction of digital technologies within the field of architecture has ramifications, not only in the design process, but also in the fabrication process. He consequently proposes an alternative mode of production that refutes established mass produced parts and introduces singular, unique objects that are constructed in toto and yield the imagination towards a novel line of fabrication concept, the non-assembly. Cache in this way, targets an infinite mass production of customized objects, by directly linking a digital model to a 3d milling machine. Although his theoretical approach seems to be applied mainly in the scale of furniture, it is in this project that he approximates a production of non-assembly and infinite variability.

At the same time, a robot ('contour crafter') for "printing" houses is already an extant reality in the construction industry. This robot is controllable through a digital file and is intended to build by pouring successive layers of semi-cured concrete; essentially the robot borrows the readily available 3d printing technology, currently used for building physical prototypes in a smaller scale. The principles behind the technology that Bernard Cache employs to fabricate his 'objectile' wood panels, is not all that different. Engineer Behrokh Khoshnevis, at the University of Southern California, who has been perfecting his 'contour crafter' (figure 45) for more

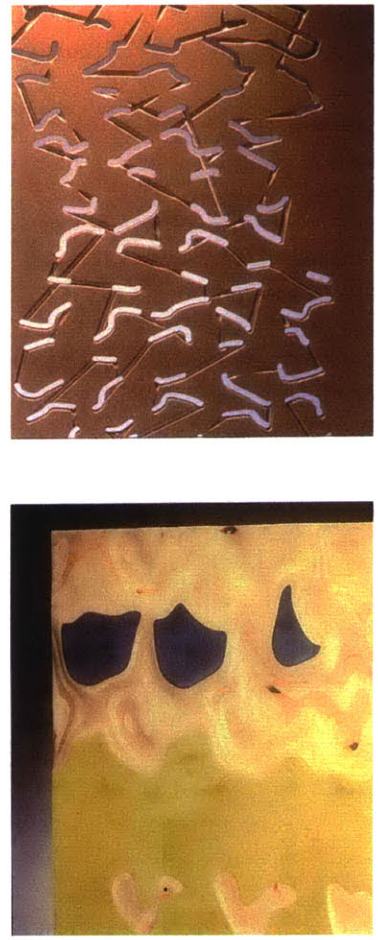


figure 44 >> Bernard Cashe, wood panels

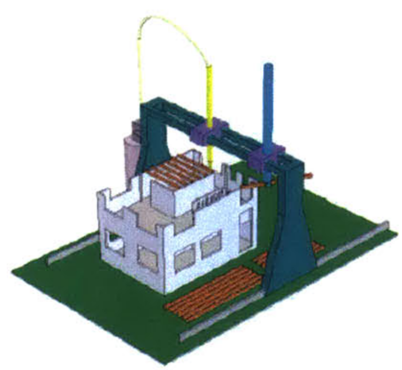


figure 45 >> Dr. Behrokh Khoshnevis , Contour Crafting than a year suggests that "within 2005 his robot will be able to completely construct a one-story, 2000-square foot home on site, in one day and without using human hands"[64].

At a time where the current rapid prototyping technology leaps into the domain of the construction industry, new experiments have started at the smaller scale. With the Local Composition Control (LCC), MIT's 3d printing laboratory has initiated a research for creating parts that have composition variation within them.[65] According to the research group, "material composition can be tailored within a component to achieve local control of properties (e.g., index of refraction, electrical conductivity, formability, magnetic properties, corrosion resistance, hardness vs. toughness, etc.)."[66] Such a technology would impact irreversibly our understanding of production. Objects would no longer be assembled out of disparate parts; on the contrary they would be produced as singular entities with variable material attributes in their monolithic bodies.(figure 46) For the case of the production of circuit boards for instance, microchips will no longer be soldered on a plate. Instead, printed layers of conductive and semi-conductive polymers would produce the part as a whole.[67] This fabrication process would take place on a layer-by-layer basis along two parallel parts: "(1) the accurate definition of the objects geometry (Geometry slice); and (2) rendering the composition of the body (Material slice). The boundary and composition information would be recombined to produce the drop-by-drop instructions loaded onto the 3D printing machine."[68]

64. Behrokh Khoshnevis in: http://www.newscientist.com/news/news.jsp?id=ns99994764

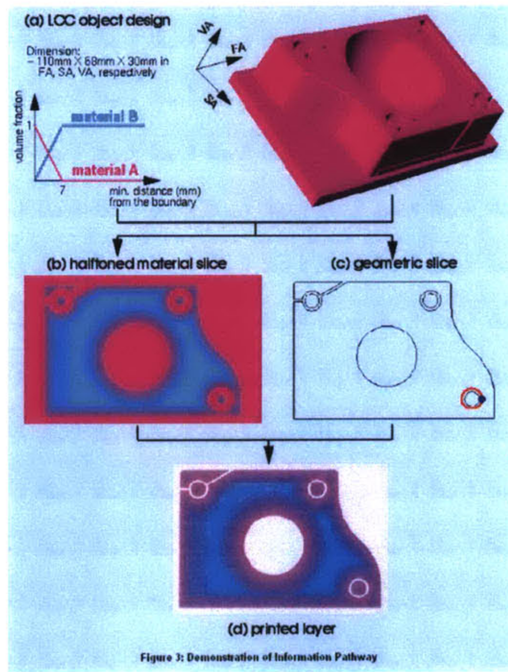



figure 46 >> Local Composition Control diagram. mit 3d printing lab

65. 3d Printing Laboratory group, MIT in http://www.mit.edu/~tdp/composite.html

66. ibid

67. research conducted at the University of California Berkeley, presented at a workshop on robotic algorithms in Nice. 2004. information found in http://www.newscientist.com/news/news.jsp?id=ns99993238&lpos=related_article3

68. 3dPrinting Laboratory group, MIT http://www.mit.edu/~tdp/composite.html

If a profound impact of the introduction of digital tools in the fabrication process absolves the architect from a consciously calculated development of geometry, how would a Local Composition Control technology inform the design process? In a mode of speculation, I would suggest that it would free the architect of the direct "calculation" of material. Materials would be no longer chosen from a catalogue. Rather, they would be custom tailored for the needs of specific projects in the form of non-homogenous entities. On the basis of current developments, the surmise is that a fabrication technique of non-assembly would emerge and material deployment in space would develop into an underlying principle of spatial production.

The modernist and post modernist heritage of fascination with geometry as the sole aspect under manipulation for the production of architecture would give way to a material archipelagos, exceeding the limitations of intricate plastic wraps and prodding into a reality where distribution of material in space becomes part of the digital equation.

Although the digital and the primitive have been considered as either unrelated or opposed realms of operation, I regard my experiments and investigations to encompass the domain of the latter. Refuting any 'expertise' in the use of digital methodologies, my intention was to merely open questions and set in motion a number of straightforward processes with the use of prime elements inherent within the digital tools such as U-V curves; the mesh components; the pixels. The relentless seek of the digital medium, which does not prioritize operations according to values and beliefs, but simply executes rules perpetually and in loops has yielded results that in some manner exceed texturally and contextually the crude successive steps from which they are directly derivative. If the occurrence of bizarre textures and emerging 'lapsus' can be fed back into materiality via the material distribution of novel fabrication techniques, then one can envisage the inception of a new discourse that entangles the development of a non-homogenous materiality

# B I B L I O G R A P H Y

S. Allen, "Contextual Tactics & Field Conditions", Points+Lines. Diagrams and Projects for the City.

Christopher Alexander, Architectural Forum, Vol. 122 No 1, April 1965

Battle & McCarthy, "Multi-Source Synthesis. Atomic Architecture", Architectural Design (AD), Vol.65, No.1/2, (London: Academy Group Ltd, 1995)

Johan Bettum, "Skin Deep. Polymer Composite Materials in Architecture", Architectural Design, Vol.72 No.1, Ali Rahim (Ed.), (London: Willey Academy, London, 2002)

Adriaan Beukers & Ed Van Hinte, "Lightweight Structures", in Architectural Design (AD), Vol.72 No.1, (London: Willey Academy, London, 2002)

Emmanuelle Bourlier, Christian B Mitman, and Andreas Froech "Material Effect" in Architectural Design (AD) Vol. 75 No. 5. (London International House, Ealing Broadway Centre).

Adriaan Beukers & Ed van Hinte, Lightness (Rotterdam: 010 Publishers, 2001)

Mark Burry, "Beyond Animation", Architectural Design (AD), Vol. 71, No.2, (London: John Wiley & Sons Limited, April 2001)

Bernard Cache, Earth moves: Furnishing of Territories (Cambridge MA: MIT Press, 1998)

Roger Caillois, "Mimicry and Legendary Psychasthenia", October: The first decade. 1976-1986, Cambridge, MA, 1987, p.58

Giuseppa Di Christina, "The Topological Tendency in Architecture" in Guiseppa Di Christina (Ed) Architectural Design: Architecture and Science (Great Britain: Willey Academy, 2001)

Deleuze & Guattari refer to Hjelmslev's net for the notions of matter, content expression, form and substance. In Gilles Deleuze & Felix Guattari, A Thousand Plateaus. Capitalism & Schizophrenia (Minneapolis: University of Minnesota Press, 1996).

Paul E. Debevec and Jitendra Malik. "Recovering high dynamic range radiance maps from photographs". In SIGGRAPH 97, August 1997. p. 369-378,

Anna Dyson, "Recombinant Assemblies" in Architectural Design .AD, Vol.72 No.5, (London: Willey Academy, 2002), p.62.
George Dyson, Baidarka. The Kayak, (Alaska Northwest Books, 1986)

Dwayne A. Day, "Composites and Advanced Materials" in http://www.centennialofflight.gov/essay/Evolution_of_Technology/composites/Tech40.htm

John Holland, Emergence: From Chaos to Order, (Cambridge, MA: Perseus Books, 1998)

Losee Jason, Prof. Graig Weeks, "The Composite Recurve Bow" in : http://www.engr.iupui.edu/me/courses/recurvebowfinalpres.ppt. Fall 2000

Behrokh Khoshnevis in: http://www.newscientist.com/news/news.jsp?id=ns99994764

Robert Kronenburg, Houses in Motion. The Genesis, History and Development of the Portable Building (Great Britain: Wiley- Academy, 1995)

Stanford Kwinter, Architectures of Time, Towards a Theory of the Event in Modernist Culture (Cambridge MA: MIT Press, 2002)

Monica Ponce de Leon and Nader Tehrani, " Versioning: Connubial Reciprocities of Surface and Space " in Architectural Design (AD) , Vol. 72, No 5 September / October 2002, p. 28.

Greg Lynn, Folds, Bodies and Blobs (La Lettre Volee, 1998),

Greg Lynn, "Architectural Curvilinearity. The Folded, the Pliant and the Supple"

Marla Mallett "A Baluch Bag" in http://www.marlamallett.com/up-three.htm

Martina Margetts editor. "Basket and Wood" in International crafts (Thames and Hudson Ltd, London 1991 ).

Kas Osterhuis & Ilona Lenard, "Variomatic SM" in Marie-Ange Brayer & Beatrice Simonot (Eds), ArchiLab's Future House: Radical Experiments in Living Space (New York: Thames & Hudson, 2002), p.182.

A. Picon, A. Ponte (Ed.), Architecture and the Sciences. Exchanging Metaphors, Princeton Architectural Press, New York, 2003, p.235.

Paul Rabinow, "Artificiality and Enlightnment: From Sociobiology to Biosociality" in Jonathan Crary & Sanford Kwinter (Eds), Incorporations. Zone (Series);6 (New York, NY: Zone, MIT Press, 1992), p. 249.

Jessie Scanlon " seamless " in Wireless Break the Rules. April 2004, p.167

Benjamin Tang, "Fiber Reinforced Polymer Composites. Applications in the United States" in www.fhwa.dot.gov/bridge/frp/frp197.htm.
Nader Tehrani, Kristen Giannattasio, Heather Walss, John May, Richard Lee, "edge" in Immaterial / Ultramaterial , architecture design and materials, (New York, George Brazillier Inc. 2002)

Anthony Vidler in "Homes for Cyborgs" refers to Tristan Tzara, "D'un Certain Automatism du Gout", Minotaure, 3-4, December 1933

Anthony Vidler, "Homes for Cyborgs" in Otagonno; Prosthesis, No.96, 1990.

Michael Weinstock. "Morphogenesis and the mathematics of emergence" in Architectural Design (AD) Vol 74 No 3 (London, International House Ealing Broadway Centre, May/June 2004 )

Ron Witte with Billie Faircloth, Judith Hodge, Suzanne Kim, and Clover Lee, "substance" in Immaterial / Ultramaterial , architecture design and materials, (New York, George Brazillier Inc. 2002)

## WEBSITES

www.fhwa.dot.gov/bridge/frp/frp197.htm.

www.rit.edu/~africa/somali/somaliAqalPg1.shtml

http://www.flipcode.com/tutorials/tut_rad.shtml

http://www.mit.edu/~tdp/composite.html

http://www.newscientist.com/news/news.jsp?id=ns99993238&lpos=related_article3

http://en.wikipedia.org/wiki/Main_Page

# APENDIX

Figure 1 >> Frederik kiesler : Frederik Kiesler with model of endless house, New York, 1959. Photgraph by Irving Penn. Taken from: Lisa Dennison & Craig Houser (Eds), Rachel Whiteread: Transient Spaces (New York: The Solomon R. Guggenheim, 2001).

Figure 2 >> Ionel schein : Projet pour une bibliothèque mobile, 1957, in: http://perso.club-internet.fr/azzi/HTMLFRANCAIS/PROJECTS/DIPLOME/MEMOIRE/GIAP/IONELSHEIN/ionelschein.html

Figure 3 >> Ionel schein : La Cabine hôtelière, 1956 in: http://perso.club-internet.fr/azzi/HTMLFRANCAIS/PROJECTS/DIPLOME/MEMOIRE/GIAP/IONELSHEIN/ionelschein.html

Figure 4 >> Greg Lynn. Ark of the world in : http://www.glform.com/

Figure 5 >> A view of the general layout of 'Our World' showing the original Phileban forms and one three-dimensional trajectory of change _ In Mark Burry, "Beyond Animation", Architectural Design (AD), Vol. 71, No.2, (London: John Wiley & Sons Limited, April 2001), p 8).

Figure 6 >> Cube to Sphere & Cube to Cylinder Surface Definition diagrams _ In Mark Burry, "Beyond Animation", Architectural Design (AD), Vol. 71, No.2, (London: John Wiley & Sons Limited, April 2001), p 8)

Figure 7 >> - Variomatic Housing _ In Kas Osterhuis & Ilona Lenard, "Variomatic SM" in Marie-Ange Brayer & Beatrice Simonot (Eds), ArchiLab's Future House: Radical Experiments in Living Space (New York: Thames & Hudson, 2002), p.183)

Figure 8 >> kolatan / Mcdonald studio. Reibould house in: Cyberspace. The world of Digital Architecture. Australia, the images Publishing Group. 2001

Figure 9 >> kolatan / Mcdonald studio. Reibould house in: Cyberspace. The world of Digital Architecture. Australia, the images Publishing Group. 2001

Figure 10 >> Carbon cycle in http://europa.eu.int/comm/enterprise/forest_based/images

Figure 11 >> free crystal growth_ In Stanford Kwinter, Architectures of Time, Towards a Theory of the Event in Modernist Culture (Cambridge MA: MIT Press, 2002), p.27))

Figure 12 >> free crystal growth : http://lachlan.bluehaze.com.au/chalk_river/2003/december2003/02dec2003/dscf0031.jpg

Figure 13 >> matrix and reinforcement of a polymer composite in http://web.media.mit.edu/~saul/grifboard/literature%20review.pdf

Figure 14 >>the black hat. In Adrian Beuker & Ed Van Hinte, "Lightweight Structures", in Architectural Design (AD), Vol.72 No.1, (London: Willey Academy, London, 2002) p.102. )

Figure 15 >> The X-29 Airplane. in Adriaan Beukers & Ed van Hinte, Lightness (Rotterdam: 010 Publishers, 2001), p.60.)

Figure 16 >> Evolution of materials. In Adriaan Beukers & Ed van Hinte, Lightness (Rotterdam: 010 Publishers, 2001), p.14-15

Figure 17 >> Luciano Fabro. "speculum Italiae" (The mirror of Italy) 1971 in : Zero to Infinity: Arte Povera 1962-1972 p.224

Figure 18 >> Luciano Fabro. "De Italia" (About Italy) 1971 in :Zero to Infinity: Arte Povera 1962-1972 p. 225

Figure 19 >> the Baidarka kayak. In Anna Dyson, " Recombinant Assemblies" in Architectural Design (AD) ,Vol. 72, No 5 September / October 2002, p.60.

Figure 20 >> the Turkish bow. In . Adriaan Beukers, Ed van Hinte , Light-ness, (Rotterdam, 010 publishers, 2001), p.86

Figure 21 >> sections of the Turkish bow. In . Adriaan Beukers, Ed van Hinte , Light-ness, (Rotterdam, 010 publishers, 2001), p.86

Figure 22 >> the Somali tent. In www.rit.edu/~africa/somali/somaliAqalPg1.shtml

Figure 23 >> Agal frame. In: www.rit.edu/~africa/somali/somaliAqalPg1.shtml

Figure 24 >> Agal plan. In: www.rit.edu/~africa/somali/somaliAqalPg1.shtml