Research as Story Building: The Case of the Active Environment

When dealing with issues of sustainability, architecture today has in its hands plenty of technical issues to tackle. Richard Stein's Architecture and Energy study from 1978, funded by the American Institute of Architects, demonstrated for the first time that the greatest energy extravagance of human activity resulted from the way buildings were produced. When considering the production and use of materials as "embodied energy", the construction industry accounted for more than ten percent of the total human energy consumption1. This viewing of the built environment as the result of a building process that includes the extraction of materials, the construction, the lifetime, and eventually the demolition of a building has forced architecture to tackle head-on a lot of numerical "facts". At the same time, it has provided a very "objective" manner through which to evaluate advancement in research and has reinserted rigor into the discipline architecture. However, when research in architecture occurs in the domain of numerical "facts", architects tend to expand their disciplinary boundaries and drift back and forth between architecture and collaborating disciplines. More often than not, it is the rigor of mechanical engineering, chemistry, computer science, and so on that permeates our discipline rather than the other way around.

But…

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For dealing with the same numerical "facts", research within the discipline of architecture has also developed some very familiar approaches. These different approaches I will here call *stories*. For example, the *techno-rationalist* is the story that considers buildings as hyper-efficient machines populated with "green" technology. This is a story of efficient building systems and components that promise to solve the problems that previous systems and components have caused. Extending the ethos of industrial production into a new "green" functionalism, the general mandate for energy efficiency has promoted - among other areas - investigation projects that range from the development of new materials for construction to better computational tools for the design of improved building envelopes or improved methods for heating and cooling.

Another story promotes the return to the *vernacular* in which architectural interventions are based on local needs, construction materials and reflecting local traditions. Sometimes viewed as resistance to the forces of globalization and other times as a critique to the contributions of the academic discipline of architecture, the *vernacularist* story embraces the capacity and wisdom of the people to manipulate their own built environment. Here too we can find research projects on new construction materials or on computational tools for the organization of building volumes and facades - like in the case of Christopher Alexander's *Pattern Language*[2]- or projects on alternative heating and cooling methods.

In yet another story, the *bio-organicist* one, buildings are discussed as evolving living organisms in an attempt to articulate an equilibrium between the built environment and nature. Researchers here turn to biology, biotechnology, and chemistry - among other fields - to draw "natural" analogues to their design methods or more candidly, they try to incorporate some of the material efficiencies that can be observed in nature into the artificially built environment. Needless to say that nature as a source of inspiration, has also provided numerous research projects on new synthetic materials, computational strategies for the design of building envelopes as well as alternatives to current heating and cooling systems.

At a first glance, when we attempt to approach the question of what is research in architecture today, *the systematic investigation into the study of materials, sources, etc, in order to establish facts and reach new conclusions* would seem to be a sufficient definition[3]. Especially if we were comfortable to adopt for sustainability the "scientification" model proposed by Buckminster Fuller, and the issues at hand were only technical issues, the rigor that the "neighboring" disciplines have already established could easily be adopted by architecture as well. However, precisely because architecture is also a cultural endeavor, along with the technical, we have to accept that in any research project in sustainability, the social, the aesthetic, or even the political are always latent. And this is where stories come in. All the afore-mentioned stories have one thing in common. At the same time as they provide avenues for investigation in the technical domain with very similar goals they also imply specific views of a future society. Stories like these are what re-orient research from the neighboring discipline to the discipline of architecture. If we are to find rigor in architectural research we ought to look for it in the consistency of the stories we tell. What I am proposing here is to consider research in sustainability as an investigation of the rigor with which the technical and the social, the efficient and the cultural, the aesthetic and the ethical, coexist. If we traditionally think of research as inhabiting the gap between the theoretical and the technical, forming vertical relationships from one to the other, in this case the story becomes a platform that those two are addressed simultaneously forming non-hierarchical, horizontal alliances. Matters of culture and technical matters become concurrent maters of concern. Stories like these are as much histories as they are projections of a possible future.

The research on the design of the *active environment* aspires to become a story like this.

THE ACTIVE ENVIRONMENT

This research project started by an observation on how the architectural community - theoreticians and practitioners alike - have recently put the notion of environment and its relation to architectural thought and practice under great scrutiny.

Just some numerous recent propositions are enough to map the conceptual territory of today's role of environment in ecological design. From a historical point of view, Lydia Kallipoliti[4] who looks at a large set of experimental, "opportunistic", ecological projects from the 60's and 70's suggests that they are not "performative agents of amelioration; rather they are, in themselves, their own ecologies, producing new worlds"[5]. In her work she discusses among other things the trend of experimental architects of the period to refocus the attention of the discipline from objects to isolated environments. According to Mark Jarzombek, at least when looking at the sustainability discourse from its technical or pragmatic perspective, "Sustainability emphasizes an environment that it defines as a world-of-chemicals-in-dynamic-interaction"[6]. Jeffrey Kipnis accurately describes ecology as a kind of topology, and offers insight on how architectural topology can exceed geometric topology if it is thought of as "intrinsic unities that unite vast numbers of conjugate variables enabling to mutate from one to another"[7]. In 2010, Sean Lally suggests that in architectural practice what seems to become the object of design is the "active context". He juxtaposes Greg Lynn's "active context" as an influence or a force that shapes a building's envelope to the "active context" as the design focus and medium itself[8].

It seems to me that the "ecological project" in architecture, coupled with the undeniable role of computation in design, has already - at least in theory - cast a new role in the notion of environment. Instead of being the passive, conceptualized or historicized context of an architectural object, the environment is quite literally becoming the object of design itself. We are moving away from the imposed-preconceived Cartesian object (pliable or not) that negotiates through its boundaries its presence within its immediate context9. Instead the discipline is already considering an architecture in which form is only an instance of the designed environment. Furthermore, beyond the technical pragmatics of clean, renewable, passive energy and all the performance anxieties10 they have induced, ecological design as a coherent cultural practice now entails the consideration of an artificial, composed, synthetic environment. An environment whose potentially designed properties (matter, energy, and information) locally participate in a perpetual exchange. In many respects, this new understanding of environment as the active environment aspires to be designed as a closed system of constant transformation, an autonomous milieu of exchange at all scales and all levels between substances, properties or qualities. Quite literally, could we be thinking of an exterior building envelope as an interior partition of an active environment?

My interest as a design researcher starts precisely here. How do newly forming propositions about the role of environment in the discipline become operational tactics in the design practice? In other words how can the active environment go beyond theory and become a **manipulable**[11] endeavor for the design practitioner.

BOUNDARIES AND PROPERTIES: PRECONDITIONS FOR THE DESIGN OF THE ACTIVE ENVIRONMENT

With this research project I have set as a goal to design and set the principles of a Computer Aided Design (CAD) software that would allow the practitioner to manipulate/design what I have called the *active environment*. The point of entry for addressing this research inquiry was a clear distinction that Reiner Banham has put forward. In *The Architecture of the Well-tempered Environment*, he asks us to consider a tribe's dilemma[12].

He argues that given a pile of wood, a tribe has one of two options : It can either build an enclosure to shield itself from the environment, or start a fire to tamper with the environment's meteorology. Although even for Banham this dilemma is rather unusual - after all why not just do both - it is being exploited here to make one distinction very clear.

When societies began forming, Banham argues, their spatial experience, their desire to make space - which of course included their need to survive as well as their need to form groups - could be expressed in one of two modes: Societies would either understand the articulation of space through the production and manipulation of enclosing envelopes or through the production and manipulation of energies. Those who use the former approach tend to "visualize space as they have lived it, that is bounded and contained, limited by walls, floors and ceilings"[13] while the ones who use the latter tend to "inhabit a space whose external boundaries are vague, adjustable according to functional need and rarely regular" [14].

This distinction, for this research project, boils down to the following statement: In Architectural discourse, space can be perceived as and operated upon either in terms of Architectural Envelopes - **Boundaries** - or in terms of Environmental Effects – **Properties**. This distinction served as the main precondition for the design of the *active environment*.

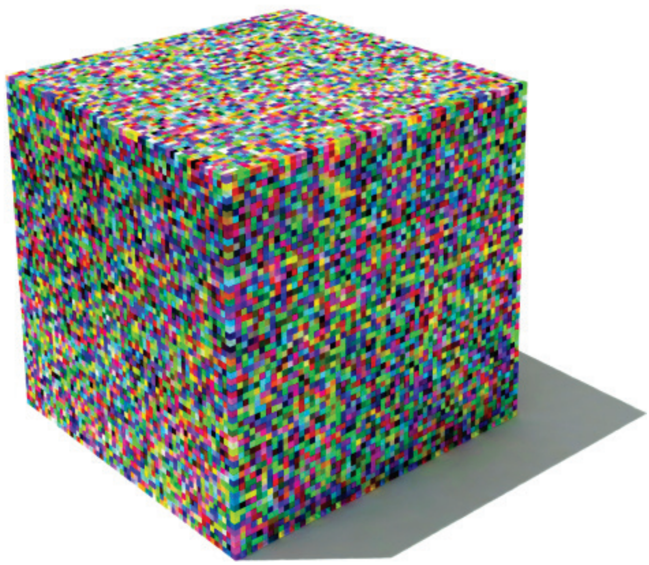
When considering the variety of CAD software that architects have at their disposal the distinction between boundaries and properties also exists. A Boundary representation (B-Rep) in CAD is a method of representation for shapes that uses limits as their defining element. Generally, In B-rep software, points are boundaries of curves, curves are boundaries of surfaces and surfaces are boundaries of solids.

Properties also exist in CAD software. In its most simple form, a color can be assigned to B-Reps. In the case of computer visualization (rendering), a material i.e. a texture, a level of transparency and so on can be assigned to B-Reps. In more sophisticated, solid modeling environments, solid B-Reps can have among other things, a material density or a structural stiffness. In advanced simulation software[15], properties and their resultant behaviors are assigned to B-Reps also. Properties, from the most basic modeling software to the most sophisticated simulation analysis tools, are NOT manipulable entities. They only come as attachments on Boundary Representations. Colors, qualities, materials, performance, optimizations etc do not actively participate in the design process. They are always afterthoughts. The reason is simple.

Properties are always assigned to boundaries. There is always a hierarchical relationship between the two. B_Reps always come first and properties are always assigned to them. Consequently, during the design process, properties in B-Rep software are not under negotiation. They are literally "dead entities". Unlike B-Reps that can be instantiated, transformed and combined to derive new B-Reps, properties can only be assigned and observed. They literally act as labels attached to B-Reps. They cannot be combined to derive new properties. Properties cannot become the object of design in CAD. They can only be evaluated. In the special case of properties as materials, the digital has rightfully so often been criticized as being devoid of physical materiality[16]. If we accept Antoine Picon's argument that such criticism is premature, and that the medium, instead, should be interrogated for its capacity to redefine materiality[17], I would agree. However, this will only hold true if in CAD we can make materiality a manipulable entity.

VSPACE : THE DESIGN OF THE ACTIVE ENVIRONMENT

VSpace[18] is a prototype computer application that demonstrates a reverse hierarchy between boundary and property. Unlike current design software that use boundary representations (vectors and their by-products) as the sole manipulable entities in a digital environment, VSpace treats boundary and property as concurrent- one influencing the other in equal terms. VSpace sets the foundations and establishes the principles for the development of a *Property Representation* (P-rep) design tool by examining its relationship to existing digital design tools. VSpace attempts to make properties manipulable entities during the design process.



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VSpace uses as precedent and expands the computation work of Lionel March from the 70's. "The boolean description of a class of build forms"[19] is re-interpreted as a viable computational model of reversing the relationship between boundaries and properties in design software. Influenced by the "compound" understanding of SHAPE in Shape Grammars[20] and starting with Alan Turing's original speculations on the mathematical laws of morphogenesis, the VSpace software uses Voxels as *property place holders*, Painting and Cellular Automata as two distinct design strategies for calculating with properties and the Marching Cubes Algorithm as a background engine that allows us to establish relationships between Properties and Boundaries. For the development of this study I have systematically studied all the basic elements/principles that B-Rep software are built on and have drawn parallels for VSpace. Because of the limited extent of this paper it would not be impossible to go through all the different aspects of this computational model. Here are a few fundamental ones:

1. VSpace : The voxel Constituent Space

Figure 1: A Voxel Constituent Space filled

For the development of any design software an initial consideration is the design space that exists prior to any design input. Unlike any B-Rep software that starts with the definition of a Cartesian coordinate system, VSpace starts with an empty Voxel Space - a 3 dimensional array of Voxels. A voxel is basically a space-filling polyhedron. In its most basic form it resembles a cube. Other polyhedra could be used to create a voxel space such as a combination of tetrahedra and octahedra[21], but for the purposes of this project I chose cubic Voxels. Voxels were borrowed from the discipline of medical imaging. For them, minimal spatial entities (Voxels) are used as registration devices of properties in order to recover a volumetric representation of the body. Underpinning this technique of visualization is the assessment that in numerous medical inquiries the *physiologic function* of the body is equally significant to comprehend at its entirety as is its *anatomy*[22]. In other words, in a specific branch of medicine they choose to see the human body as a collection of substances (properties) rather than a collection of organs (boundaries). This very crucial shift in reading of the body allowed me to borrow their technology and deploy it for VSpace.

In short, the characteristics of cubic Voxels in a Voxel Space are:

- Voxels V(i,j,k) have a position defined relative to all other Voxels. We will call this location in space.

- Voxels V(i,j,k) can store a number of Properties. We will call these Property A, B, C etc

- Properties have a value associated with them. This value infinitely ranges from zero to one and will be called Concentration (CN). CN indicates how much of property A, B, C etc is contained in a Voxel.

- In the case of 3 properties A, B and C, Voxels are visualized with colors in RGB space. This color visually indicates the concentrations CN of each property. (figure 1)

2. VSpace : Instantiation of distributed properties

Any B-Rep software allows you to begin by drawing (instantiating) points, lines and surfaces[23] (the geometry primitives) or even more composite primitives like cubes and spheres. In VSpace the equivalent to drawing with geometry primitives is drawing by **distributing properties**. For instantiating properties a few different methods have been developed.

- With **Distribution of Painted Properties** Voxels are instantiated locally through a gestural painting procedure.

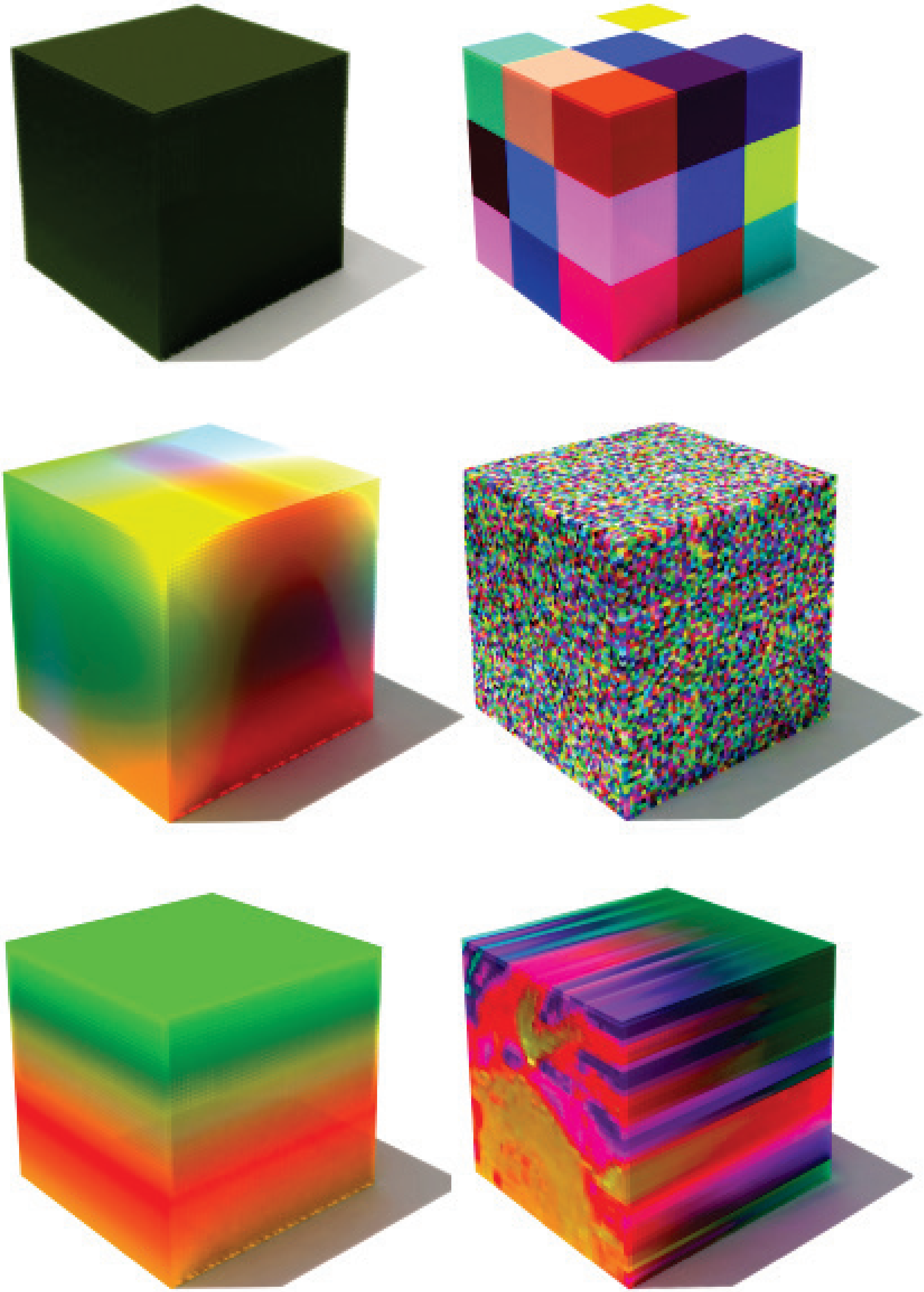
- With **Distribution of Pattern Primitives** any collection of Voxels is instantiated using a mathematical patterns that relate the location of each Voxel V(i,j,k) in space with a color. (figure 2)

- With **Distribution of Interpolated Properties** one or more regions/slices of Voxels are first instantiated either by painting or by importing "environmental" information and are then interpolated to create a 3dimensional distribution. (figure 2, bottom)

3. VSpace : Unary transformations of distributed properties

In B-Rep software, operations such as Translation, Rotation and Scaling are a few of the possible unary operations that transform a single boundary object from an original state to its new one. For VSpace the equivalent operations are:

Figure 2: Instantiation of distributed properties



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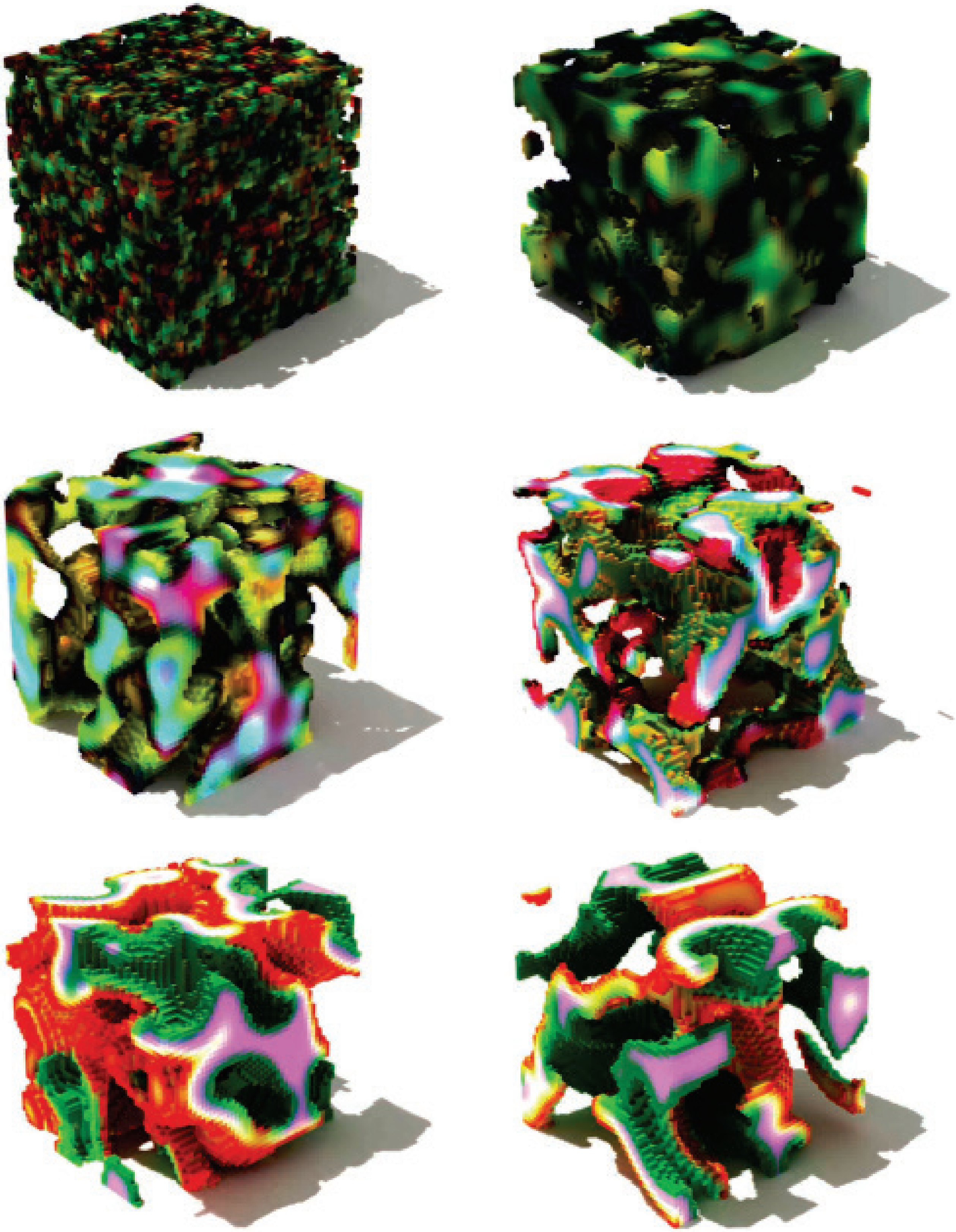

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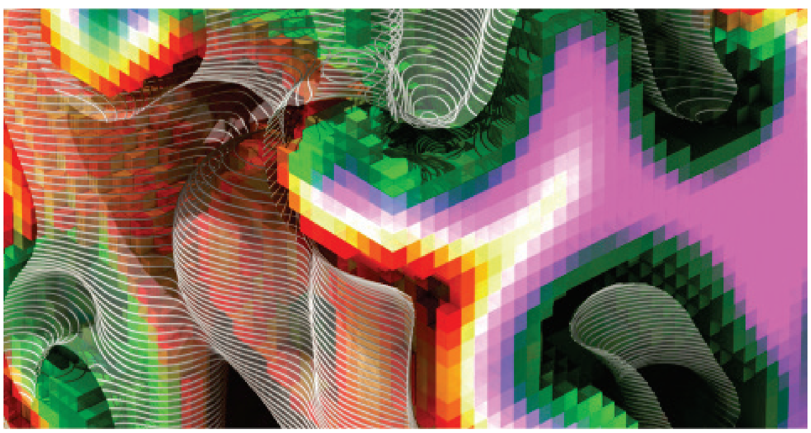
- **unary transformation - paint**. Painting with a brush cannot only be used to instantiate properties but also to transform them to new properties. Like in any bitmap editing software, by using a digital paint brush, the designer can access existing Voxel concentrations and paint new ones on top. As mentioned before the brush can have a color selected from a color palette, a size, affecting one or more Voxels at a time and an opacity that can add or subtract concentration values.

- **unary transformation - automata**. The 3 dimensional - ordered array - data structure of the Voxel Constituent Space allows designers to not only transform Concentration values directly on a Voxel but also gain computational access to concentrations of all of its neighboring Voxels. Therefore, in VSpace, in a Voxel space that is already propagated with Concentrations, the designer can describe rules of interaction between Voxels in a neighborhood in order to transform them to new ones. The discrete dynamical model that describes computations between cells and their neighbors generally falls under the umbrella of Cellular Automata. One of their principal characteristics is that they can reproduce the behavior of a complex system using simple basic interaction rules. Another characteristic is with automata precision is *statistical* rather than Cartesian. While for some designers it could prove useful to be able to employ interaction formulas to calculate or simulate anything from heat dissipation to urban sprawl, the significance for VSpace, from a design standpoint, is that in dynamic systems like these an emergent distribution of properties becomes visual material, which is then examined for its characteristics. (figure 3)



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4. VSpace : Boundaries from Properties

In VSpace, boundaries are defined as limits of property distributions (figure 4). They are visualized by employing what is known as the Marching Cube algorithm. It was first published in the 1987 SIGGRAPH proceedings by William E. Lorensen and Harvey E. Cline[24] and was initially targeted to the medical imaging industry for the visualization of data taken from CT and MRI scans. It was basically developed in order to reconstruct 3dimensional surfaces out of Voxel data set and is used today extensively among other fields in the medical imaging and 3d graphics industries. Simply put, in VSpace the application of the Marching Cube algorithm answers with a boundary to the following question: **Where in space does property A, B or C** (or any combination) **have Concentration CN = X?** (lower limit < X < upper limit). From a design perspective this question is quite fundamental as it allows us to derive **a boundary object from a property distribution**. If in B-Rep software the intuitive action is to first define a boundary object and then

ENDNOTES

1. Richard Ingersoll, The Ecology Question and Architecture in C. Greig Crysler, Stephen Cairns, Hilde Heynen, The SAGE Handbook of Architectural Theory, Sage Publications, New York, 2012, pp. 571-578
2. Christopher Alexander, Sarah Ishikawa, Murray Silverstein, Max Jacobson, Ingrid Fiksdahl-King, Shlomo Angel. A Pattern Language: Towns, Buildings, Construction. Oxford University Press (1977)
3. Definition from the Oxford Concise Dictionary
4. Lydia Kallipoliti's Ecoredux archive of ecological experiments in architecture has effectively shown how today's ideas and attitudes towards ecological design stem from the junction of information theory and ecology as separate disciplines in the 60ies and seventies. www.ecoredux.com
5. Lydia Kallipoliti, "EcoRedux: Environmental Architectures from Object to System to Cloud" in Praxis: Journal of Writing and Building, No.13 (Eco-Logics), 2012
6. Jarzombek, Mark. Molecules, Money, and Design in Thresholds 18. Design and Money, editors : Andrew Miller, Garyfallia Katsavounidou, James P O'Brien. MIT Journal, Fall 1999 p.32
7. Jeffrey Kipnis, A family Afair, in Mark Rappolt(ed), Greg Lynn Form, op cit, p.201.
8. Sean Lally, Eat Me Drink Me in Architectural Design (AD) : Territory. Architecture Beyond Environment. editor David Gissen, John wiley and Sons May/June 2010. pp.16-19
9. Tsamis Alexandros : Go Brown. Inner-disciplinary conjectures in Architectural Design (AD) : Ecoredux. design remedies for an ailing planet. (Ed) Kallipoliti Lydia. John Wiley and Sons June 2010. p. 80
10. Term borrowed from Kipnis Jeffrey, 'Performance anxiety?' in 2G no.16 (4) 2000. p.4-9
11. With the term manipulable I mean the way with which the practitioner can put her hands on and literally design an environment instead of an object. This is very similar to how issues of plasticity as they were theoretically developed in the 90ies became manipulable through the use of geometric topology as it was embedded in animation and later associative geometry (parametric) software.
12. *Reyner Banham, The Architecture of the Well-tempered Environment, The University of Chicago Press, Chicago,(1969), p.19*
13. Ibid pp. 19-20
14. Ibid p.20

Figure 3: (opposite) A Voxel Constituent Space filled

Figure 4: Single boundary from property distribution

attach properties to it[25], in VSpace we instantiate or transform properties first and then derive boundaries from them. The examples in figure 5 show different instances of boundary derivations from property distributions. Since boundaries can always be dynamically drawn as limits of property distributions, any operation that would transform a property concentration or a property limit would directly transform Boundaries as well. Here too methods of instantiation unary and binary transformation have been computationally articulated with respect to the properties that derive them. The technical specification goes on and on, but somewhere here we have to stop[26].

VSpace is CAD saturated with thermodynamics. It allows us to imagine space literally derived through the manipulation of distributed properties; it serves as a mode of work that shifts our attention from objects to the articulation of an environment of “qualities”, from edges to gradients, from boundaries to properties. A re-articulation of the notion of environment as a topology of exchange between properties – a milieu of perpetual transformation – would yield a for example shift in discourse of the part-to-whole relationship and inevitably offer a novel understanding of tectonics-The kind that expresses the *active environment.* VSpace although rigorous in its technical articulation was not developed in order to solve any problem. It was more thought of as an essential “stitch” of the building of a larger story. The story of the *active environment*. Its value lies, more than anything else, in its ability to propose a possible future for sustainable design. And by the way, here too research can be done for new composite materials, computational strategies for the design of building envelopes as well as alternatives to current heating and cooling systems.

15. See Autodesk’s Ecotect Analysis Software
16. See Kenneth Frampton, Studies in Tectonic Culture: The poetics of Construction in Nineteenth and Twentieth Century Architecture, MIT press, reprint (2001)
17. See Antoine Picon, “Architecture and the Virtual: Towards a New Materiality,” Praxis: Journal of Writing and Building, issue 6: New Technologies, New Architectures. p.114-121
18. VSpace started as a design project in collaboration with Kaustuv DeBiswas in 2008. It was first published in the Ecoredux exhibition in Columbia University, Avery Hall (October- December 2009). More recently it acquired the name VSpace and was developed as a mockup software package as part of a research project at Adolfo Ibanez University, Chile.
19. March, Lionel, The Architecture of Form, Cambridge University Press, (1976), p. 41
20. George Stiny, Shape. Talking About Seeing and Doing, The MIT Press (2006), pp. 215-216
21. For a thorough account of space-filling solids please see Wolfram : http://mathworld.wolfram.com/Space-FillingPolyhedron.html
22. Habib Zaidi, “Medical Imaging: Current Status and Future Perspectives”, Division of Nuclear Medicine, Geneva University Hospital, CH-1211 Geneva. Switzerland. In http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.15.5208&rep=rep1&type=pdf
23. For a thorough account of digital design primitives see: William J Mitchell, The Logic of Architecture.MIT press. 1990. pp. 37-57
24. William E. Lorensen, Harvey E. Cline: Marching Cubes: A high resolution 3D surface construction algorithm. In: Computer Graphics, Vol. 21, Nr. 4, July 1987
25. Consider applying a color to an object or a material for rendering or even more accurate physical characteristics like density or transparency
26. For a full account of technical specifications and theoretical considerations of the VSpace software and its extensions to physical space please see : Alexandros Tsamis, Software Tectonics, PhD dissertation MIT, 2012.

Figure 5: Instances of boundary derivations from property distributions

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ON THE USE AND DISUSE OF HISTORY FOR ARCHITECTURE