This publication bears a title with an intentional strike through, which, first, should signify the act of design over computation for all designers. Second, it should remind us of our responsibility to continuously make inquiries into computation and its relation to design to advance our understandings of the subject area. The advancements in computer applications are certainly important, yet without a critical look, self-awareness and proper knowledge, both tools and experiments become destined to perish.

4

I'd like to save the term "computing" for the actual use of computers, which is different than the kinds of questions I usually try to ask and answer. As far as I am concerned, the relationship between design and calculating is equality. I say that for two reasons: one, I think when you design, you are actually calculating in a visual sort of way, whether you know or not, and the real central issue, at least for most of my work, is to try to figure out how calculating includes design. I think the formula runs amuck when people make design look like calculating in the usual sense. When you do that, it diminishes design, and as a result, calculating, too.

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Simplistically, research and design occurs in two distinct speeds: a high speed of frantic search for new ideas and potential applications and a slower rate that targets the consolidation and democratization of knowledge raising the level of discourse across the field. A great example can be found in the development of early design-computation and the exploration of digital media for design. On the R&D domain there has been an explosive amount of experimentation: concepts explored and applications developed.

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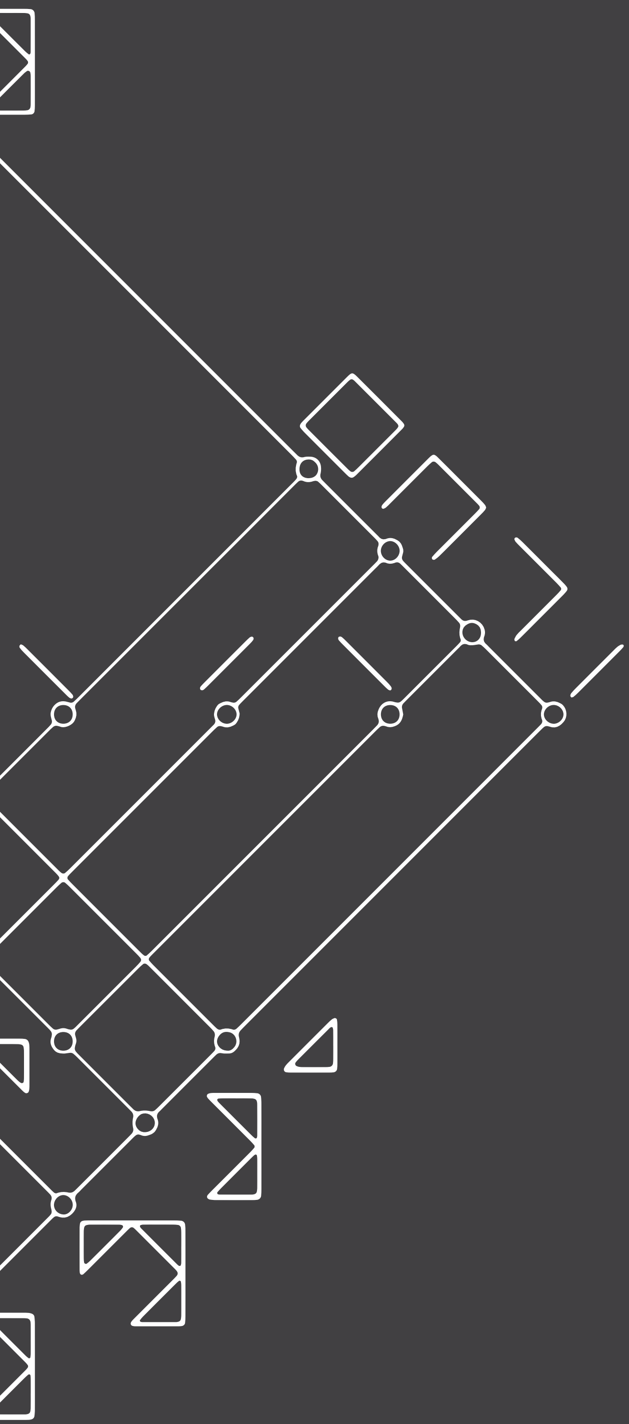
NOVEMBER 2012

~~computational~~ design



NEXT PAGE

THEORISTS OF DESIGN AND COMPUTATION

Editor: Onur Yüce Gün, PhD Candidate in Design and Computation,
Massachusetts Institute of Technology (MIT)

The role of digital computers in the design process for designers has remained an open question for over fifty years. The combinatorial nature of computers and the necessity of fluency in (any low-level or high-level) machine language have been creating the ambivalance that designers feel towards computers and computation.

The combinatorial nature of the computer derives from its capacity to operate strictly via discritized entities. A bit, the smallest unit that a computer operates with can bear only one of the two values: zero or one. Any negotiation with the computer must be excecuted in terms of these very bits' combinations[1]. For this very reason, the fluid continuity of design thinking requires discretization and codification for its operation on the machine.

Such technical and philosophical issues give rise to the research area of *design and computation*. This field investigates the reason for the words *design and computation* to co-exist and whether a meaningful synergy is possible.

Massachusetts Institute of Technology (MIT) boasts historical milestones in advancing the epistemology of *design and computation*. Although the initial studies in implementation of computer applications in architecture dates back to the early 1960's at MIT[2], initiation of the Design and Computation Group at the Department of Architecture in the mid-1990's engendered an academic group which would influence architectural education and institutes worldwide. William J. Mitchell's visionary motivation during the initiation of the group brought renowned academicians of *design and computation* together. As the program director of the Design and Computation Group at MIT and the founder of the Shape Grammars Theory, George Stiny has emphasized theory of calculation and computing as opposed to concentrating on computer applications.

A similar motivation to privilege theory determines this publication's intent to embody a critical outlook on the epistemology of *design and computation*. As opposed to arriving at immediate design theories via speculative[3] experimental[4] design projects, the contributors look into the history of computers and computing in design disciplines. Authors concentrate on the epistemology of *design and computation* looking

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Editor in Chief and Owner on behalf of
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Ankara Branch
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Issue Editor
Onur Yüce Gün

Coordinator of Dosya
Berin F. Gür

Translation
İlknur Urkun

Editor
Pelin Özgümüş

Cover Design and Design Application
Ömer Burak Polat

Konur Sokak No:4/3 Kızılay Ankara-TURKEY
Phone: +90 312 417 86 65 Fax: +90 312 417 18 04
e-mail: info@mimarlarodasiankara.org
http://www.mimarlarodasiankara.org

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beyond whatever mere technical computer skills can achieve. With their detailed analysis and openness about the limitations of computers in design[5], these eleven authors transpose the role of computation in design beyond mere applications of digital form crafting, simulating, manufacturing and assembly.

Although overlaps render difficult any strict classification of the articles' content, it may help to discuss the contributions under four sections.

> The *Understandings* section includes the transcriptions from the conversations with George Stiny and Humberto Maturana along with Şebnem Yalınay's etymological investigation.

In our conversation with George Stiny, he elaborates on what he values most in design: *seeing*. The ability to *talk* about what we see is indispensable to design. However, *talking*, for Stiny, is not a straightforward process; it incorporates interpretation, manipulation, and even omission of the things we see. The binary nature of computing and its symbolic structure proves inadequate[6] to handle Stiny's shapes, and thus he prefers talking about calculating as opposed to computing. The discussion covers a lot of ground, yielding well-structured insights about the roles of calculating, computing, and computers in design. However, the conversation also turns to talk about Leonardo's sponges, Duchamp's Fountain, and the renowned MIT Design and Computation Group.

Şebnem Yalınay examines the etymological roots of the word *computation*. She makes insightful connections between several potential meanings the word computation bears, and acts of design. Yalınay's article explores not only *the prospective meaning of design and computation*, but also its translation into Turkish, which sheds tremendous light on an area of long speculation. Yalınay's investigation inquiries into the role of *information* and *information processing* in design processes, and how these roles could be re-thought in (architectural) design education.

The first question Daniel Rosenberg forwards to Humberto Maturana triggers a human-centric conversation, situating the human within the ever-continuing presence of *the world* and *things*: humans *bring things forth* at the very moment they experience them. The world becomes present as a configuration of human perception and cognition, not as *a construction* of human sensory systems. Such understanding reveals insights into design and novelty: the source of newness, according to Maturana, is again the human experience itself. Towards the end of the conversation, Rosenberg brings the computers into the discussion to elicit Maturana's sincere feelings about where computers can be situated in humans' living: eventually the computer appears as an *organization* with *whole structural dynamics inside it* and *it does whatever it does according to those structural dynamics*.

> The *Historical reflections* section utilizes historical investigations to raise valuable contemporary discussions.

Theodora Vardouli introduces the roles attributed to computers in their early *apparition* in design processes in the mid-1960's. For Vardouli the early *anthropomorphizations* of a computer as a "clerk," "partner," "wizard," or "accountant" served two purposes: to situate the role of computers in design processes and to depict then-emerging abstract relationships between the designer and the computer. With her detailed historical investigation, Vardouli reflects on the contemporary term computational design to argue about the role of computers in current design practices.

Aslı Arpak investigates the emergence of the Design Methods Movement and the efforts of the group in *rationalizing design* following computer's reception as *a metaphor for the brain*, and *a tool to test the mental procedures*. Arpak's article informs us that the motivations behind the movement's foundation in the early 1960's also became the fundamental reason for departures from the group after a decade. Arpak claims that the approach of *behaviorists, representing a mechanized, quantified view* of design proved unsatisfactory for *existentialists* and *phenomenologists*. Emerging positivist, behaviorist, cognitivist, and *phenomenological approaches* thereafter influenced design education via their respective characterizations of computing in design.

The *Limitations and opportunities* section examines current approaches in using computation in design and proposes alternative understandings of the subject area for advancing design thinking.

Stylianos Dritsas talks about one of this publication's core subjects: knowledge, its embodiment and its effects following its becoming widespread. He traces the emergence and impacts of computation: once utilized to execute *mundane tasks of mathematical calculations*, computation relocates the use of human intellect to worthier fields. For Dritsas, such shift transposes the former concentration of architectural practices on the *design product* to the *inception and production* of design. As a result designers praise parametric design, building information modeling, and digital fabrication. However, for Dritsas, mere computational applications and tools cannot improve the unintelligent bulkiness of a composite wall when compared to a state-of-the-art *automobile of the same weight*. The real challenge according to Dritsas becomes *contextualizing current intellectual and technical capability towards inventing new modes of thinking and practicing*.

Axel Kilian highlights the challenge in incorporating alternative approaches[7] into the *early design exploration* processes, since already-established conventional tools grant designers a habitual comfort zone. For Kilian, redefinition of computational design applications requires awareness of the limitations engendered by the use of computers in design processes. According to Kilian, *design should not solely be about the execution of established processes but also about querying the understanding of the factors involved*, and computation should be understood as a *systemic sense* beyond the *lifecycles of artifacts* and *established scales* for discovery of novel approaches in design and computation.

The *Propositions* section includes articles which take on the challenge of defining novel computational frameworks following their respective theoretical investigations.

Alexandros Tsamis revisits his long-term research, contrasting "boundaries" versus "properties," this time looking outside *Barbarella's* window. For Tsamis, *the collection of bubbles floating in a translucent viscous liquid* we see outside the spaceship in Robert Vadim's 1968 movie perfectly renders the early idea that *space can be perceived, and operated upon, as an environment of pure property*. Tsamis highlights the paradox of working with strict boundary representations (B-Reps) on computers while dealing with designs of *gradients of spaces and materials*. His computational tool, V*Space*, generates representations of spatial constructions via *blending properties*, as opposed to discretizing them through a combinatorial logic.

Emre Erkal introduces his concept of *thereminspace*. Organized under the influence of *force fields*, spatial nodes of *thereminspace* become distributed over a *heterogeneous and nonlinear landscape* (in contrast to regularized grids of Cartesian space). According to Erkal, problematized as a design tool, *thereminspace* would enable the designer (as a performer) to work within the space of jagged *mountains* and *relaxed valleys*. He explains that the touch-free control of the pitch and volume of the theremin might inspire computational tools and spaces which can be designed and operated via (Thrift's) *qualculation* (quantification, calculation of qualities). Erkal's proposition also reveals the false feeling of seamlessness and continuity advertised by touchscreen devices of our day.

Carl Lostritto discusses re-evaluation and definition of *drawing* in the ubiquity of computers and digital applications. His vintage pen plotter, driven via Python programming language produces *drawings of computation*, which he classifies as *distinct from the image-heavy culture of digital design media*. For Lostritto, drawing belongs to and is a product of the action of computing. Lostritto claims that the drawings he produces *heighten the architectural potential of the line by defining it in terms of a physical presence on the paper*.

Finally, Kaustuv De Biswas introduces an inspiring initiative, *Sunglass*: a networked platform for design collaboration. Sunglass counters the object-centric nature of CAD and shifts the discussion to a more conversational framework for design, proposing *a difference engine driving parallel and synchronous conversations among designers, materials and languages*.

PURPOSE

This publication bears a title with an intentional strike through, which, first, should signify the act of design over computation for all designers. Second, it should remind us of our responsibility to continuously make inquiries into computation and its relation to design to advance our understandings of the subject area. The advancements in computer applications are certainly important, yet without a critical look, self-awareness and proper knowledge, both tools and experiments become destined to perish. Finally, this publication should help Turkish-language readers discuss how accurate the translation[8] of *design and computation* (or should I say *computational-calculative design*? –as a backward-translation from Turkish) was once done.

ACKNOWLEDGMENTS

This publication brought me the opportunity to contribute to the ongoing discussion in the field of *design and computation* via encouraging inquiry, criticality, and knowledge. A precious group of contributors, renowned in their respective research and practice areas, generously volunteered to join me in this quest, following private invitations. Their specific kinds of expertise develop the desired theoretical and critical spirit this publication aims to reflect.

This publication is the product of its contributors' invaluable and selfless efforts.

I would like to express my thanks to George Stiny not only for sparing time for the great open conversation published here, but also for his encouragement during the preparation of this publication. He is a tireless educator and theorist, and his insight has influences on many of the ideas present along this publication.

I am deeply grateful to my colleagues Daniel Rosenberg, Aslı Arpak and Alexandros Tsamis. Aslı and Daniel, beyond their direct contribution, supported me during development of intellectual framework of this publication. Alexandros' logistical support in the early stages of preparation was vital.

Pelin Özgümüş, Ömer Burak Polat and İlknur Urkun worked tirelessly for weeks to finalize translations, formatting and overall design of the publication. I admire their efforts and patience.

Last but not least; my sincere thanks go to Berin Gür and Chamber of Architects of Turkey, Ankara Branch for inviting me to prepare a special issue on Design and Computation. This project would never be possible without their invaluable recognition and invitation.

ENDNOTES

[1] For more elaborations on how processes are reduced to patterns for their execution on computers, see: K. Terzidis, Algorithmic Architecture, Burlington: Architectural Press, 2006, pp. 37-65.

[2] Woodbury points to SKETCHPAD, a system introduced by Ivan Sutherland in his 1963 PhD thesis. See: R. Woodbury, Elements of Parametric Design, New York: Routledge, 2010, pp. 7-12, 33-42.

[3] N. Andrews, “Climate of Oppression,” Log, pp. 137-151, Spring-Summer 2010.

[4] Picon makes distinctions between the terms computer aided design, digital architecture and experimental explorations. A. Picon, Digital Culture in Architecture, Basel: Birkhauser, 2010, pp. 60-72.

[5] Bazjanak describes how he became a convinced non-believer after investing quality time on several design problems using computers in mid-1960. See: V. Bazjanak, “The Promises and the Disappoinments of Computer Aided Design,” in Relections on Computer Aids to Design and Architecture, N. Negroponte, Ed., New York, Petrocelli/Charter, 1975, pp. 17-26.

[6] G. Stiny, Shape: Talking about Seeing and Doing, Cambridge: MIT Press, 2006, pp. 20,275.

[7] According to Mitchell, availability brings use. Furthermore sets of convenient and efficient tools privilege the shapes and constructions they readily generate while marginalizing the shapes and constructions they don’t. See: W. J. Mitchell, “Thinking in BIM,” A + U, vol. August, no. Architectural Transformations via BIM: Special Issue, pp. 10-13, 2009.

[8] Akcan problematizes translation with historic reflections under the section titled ‘Appropriating and Foreignizing Translations’. See: E. Akcan, Architecture in Translation: Germany, Turkey, and the Modern House, Durham & London: Duke University Press, 2012, pp. 15-17.

AN OPEN CONVERSATION WITH GEORGE STINY ABOUT CALCULATING AND DESIGN

George Stiny, Professor Of Design and Computation., *Massachusetts Institute of Technology*
Onur Yüce Gün, PhD. Candidate In Design And Computation, *Massachusetts Institute of Technology*

George Stiny is Professor of Design and Computation at the Massachusetts Institute of Technology in Cambridge, Massachusetts. He joined the Department of Architecture in 1996 after sixteen years on the faculty of the University of California, Los Angeles, and currently heads the PhD program in Design and Computation at MIT. Educated at MIT and at UCLA, where he received a PhD in Engineering, Stiny has also taught at the University of Sydney, the Royal College of Art (London), and the Open University. His work on shape and shape grammars is widely known for both its theoretical insights linking seeing and calculating, and its striking applications in design practice, education, and scholarship. Stiny has recently completed a book on design and calculating – Shape: Talking about Seeing and Doing (The MIT Press, 2006; and at www.stinyshape.org) and is the author of Pictorial and Formal Aspects of Shape and Shape Grammars (Birkhäuser, 1975), and (with James Gips) of Algorithmic Aesthetics: Computer Models for Criticism and Design in the Arts (University of California Press, 1978; and at www.algorithmicaesthetics.org).

In this conversation, George Stiny elaborates on what he values most in design: seeing. The ability to talk about what we see is indispensable to design. However talking, for Stiny is not a straightforward process; it incorporates interpretation, manipulation, and even omission of the things we see. The binary nature of computing and its symbolic structure proves inadequate to deal with Stiny's shapes, thus he prefers talking about calculating as opposed to computing. The discussion covers broad ground, aiming to develop well-structured insights about the role of calculating, computing, and computers in design. However, the conversation also turns to talk about Leonardo's sponges, Duchamp's Fountain, and the renowned MIT Design and Computation Group. The conversation took place on May 21st, 2012, at Massachusetts Institute of Technology, Department of Architecture, Cambridge, MA.

Onur Yüce Gün: What is/what should be the relationship between design and computing?

George Stiny: I like to think about the relationship between *design* and *calculating*, as opposed to computing. The reason I like "*calculating*" is because it is much more down to earth. It sounds very ordinary, so it's probably a surprise that it's capable of doing anything that has to do with art and design.

Onur: How is computing different than calculating then, especially in its relation to design?

George: I'd like to save the term "*computing*" for the actual use of computers, which is different than the kinds of questions I usually try to ask and answer. As far as I am concerned, the relationship between design and calculating is equality. I say that for two reasons: one, I think when you design, you are actually calculating in a visual sort of way, whether you know or not, and the real central issue, at least for most of my work, is to try to figure out how calculating includes design. I think the formula runs amuck when people make design look like calculating in the usual sense. When you do that, it diminishes design, and as a result, calculating, too.

Onur: So calculating is not something that is *auxiliary* to design, as opposed to common belief...

George: If in fact calculating can be extended to include design, and I think it can, then that runs the formula

design = calculating

in the other direction. Then the question becomes: "What do you learn about design by calculating?" You can pick particular kinds of styles or designs; you can investigate how rules change. You can come back later and apply different rules to change designs. It becomes very dynamic, a very open-ended kind of process. But this all depends on making calculating generous enough to include art and design. That really can't be emphasized enough, because it's not making design conform to calculating; it's quite the opposite: as a result, calculating becomes more than it usually is.

Onur: So, as I understand, you are expanding the meaning and potential of calculating when you use the formula "*design = calculating*." We see this equality quite often in your book "*Shape*" (www.stinyshape.org)– and you have a chapter entitled "*What Makes It Visual?*" (Stiny, 61) Could you elaborate on this question?

George: First of all, the title of the chapter "*What Makes It (Calculating) Visual?*" speaks to the central issue of the whole enterprise. If you show that design can be carried out in visual sort of way, you answer the question that I just posed about the relationship between design and calculating. In order to see that there is a difference between visual calculating and ordinary calculating, you have to first look at ordinary calculating. The classic model there is the Turing machine, or maybe grammar or syntax in linguistics. And really what this has to do with is symbol manipulation. Symbols behave like little stones or discrete components; you can shuffle them around, put colors on them, and so on. However when they

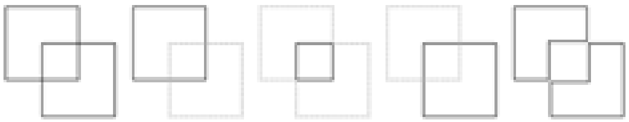

Figure-1

combine, they keep their original identity, so in combination they're independent. A symbol is a symbol is a symbol – always!

It's seems to me that Turing machines are really just one model for what calculating is all about. Since they came out of logic, they deal with a system of rules with true and false, or zeros and ones –discrete kinds of entities. It wouldn't surprise me if Turing were to welcome an alternative kind of calculating that comes out of the visual, artistic enterprise, that requires something quite different than zeros and ones – the discrete mathematics that he used for his calculating machine.

This is just a generalization. It's a very natural generalization, and it's one that opens up calculating to include art and design – ambiguity, things changing, no vocabulary or symbols to begin with. Calculating in the visual sense doesn't depend on vocabulary. It doesn't have primitives, atoms, symbols, or units. These evolve during the course of calculating; they aren't there at the start. By calculating visually, you allow anything you see to enter the process of calculating, and that's quite different from what happens in a discrete process, such as a Turing machine.

Onur: Then, is design an entirely visual act?

George: When we do things visually, what we do now may not be what we see next. Here I might add a little figure: if I take two squares and add them together, I might get three squares or two L's **(Figure 1)**, or I might get four triangles or a bunch of pentagons, and big K's and little k's (**Figure 2**). I might get any number of different kinds of things that don't preserve the atomic, unitary, symbolic properties the squares. Now if I represent this

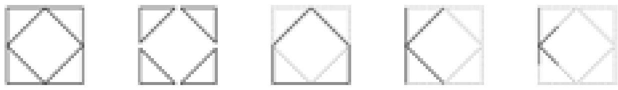

Figure-2

in rules that say square-one goes to square-one plus square-two, I can't see that these squares go together to do something quite different from squares. That's what I think is required to make calculating visual, and that requires generalizing the idea of identity that preserves symbols, and extending it to something I call *embedding*. And the interesting thing is that identity is a special case of embedding, so by doing visual calculating you automatically get symbolic calculating for free.

Now having said that, there is the deeper question: "Is design – is art – entirely a visual act?" Well, certainly design and art have a lot to do with making, and if you look at school curricula or schoolteachers talking about art and design, they almost never mention seeing, but always mention making. There's a lot of enthusiasm for making in art and architecture. People talk about making all the time. At MIT the model is "Minds and Hands" ("*Mens et manus*"), which is thinking and making. But without seeing, it's hard to understand how there can be any art at all. There are many cases in art and design that have nothing to do with making – that are described in terms of seeing. Duchamp's *Fountain* is a nice example. He didn't make anything, and it's one of the most famous works of art in the twentieth century! Certainly you can show that making requires seeing. But just looking makes new art, too – it becomes observational.

Onur: So, there are minds, hands – and then eyes, maybe?

George: You can't really avoid seeing. By focusing on seeing you include everything that happens in art; but if you focus only on making, you end up excluding many things. What happens to the object after it's made? Artists may look at their artwork and change their minds about what they see. And this may change what they've done. So from my point of view, the observational component is the key, with everything else following along. Without seeing, art and design "disappears."

So making calculating visual is the first thing to do – the visual aspect of calculating is at the very heart of art and design.

Onur: Then, how do all these ideas affect the ubiquity of computers and computing? How do we move from calculating with shapes and rules in your visual sense to computers and computing? What should the role of the computer be in a designer's life, and is this the case for the actual use of computers in contemporary design practice?

George: When I started doing this stuff many years ago, designers didn't want to have anything to do with computers. So there's been a major change in the way designers think about computation, as opposed to calculating, and how they approach computers. Certainly today, it's hard to imagine a serious, large-scale design practice that hasn't invested heavily in using computers. However, I think this investment is mostly used for representation in computer aided design. I think it's more of an archival kind of enterprise in which you are really trying to provide representations to evaluate designs and to track them throughout their lifetimes.

Practices utilize computers in ways they find useful to further practice. Does that mean they are doing calculating in the sense that I describe? The answer is 'no'. I think what happens when people are designing and calculating visually is that there is a kind of free flow of ideas – use of rules or schemas. It's a very dynamic, interactive process between the designer, the artist, and their work. One becomes engaged with whatever he or she is doing: an architectural drawing, a painting, a sculpture. And the action is calculating – *seeing and doing*.

Making calculating something that a computer can use today requires a certain kind of translation. And that translation is really a description of the object that someone is reacting to. That description can (and will) change when you look at the object again and again, trying to correct it all the time. So I think the computer doesn't really have much to do with design in the sense that I am talking about. The real fear is that people will give up on design in this robust, general, visual, artistic sense. The kinds of things you can do on a computer make life easier and straightforward and I think that could be a serious loss for architectural design.

So my conclusion would be this: people should use computers in practice whenever way they want to. But don't forget that there's something else involved that has to do with how you see and talk about designs. Calculating is much more generous and flexible than the kinds of things you can do using computers today.

Onur: I am not quite sure if that flexibility is always acknowledged by designers. Computing or calculating in design is immediately associated with algorithms, and their complex geometric outputs in contemporary architectural practice and education. Maybe that is why computing and computers are embraced for their potential to help harness variety in design. However, simulations and performance analyses fall short in determining the proper designs from amongst a virtually unlimited number of possibilities. Is there a way to benchmark countless versions of a design to pick the delightful few?

George: There are number of aspects to your question. In the three categories of the Vitruvian canon – firmness, commodity, and delight – certainly delight is at the center of architecture and art. It's the one thing architects or artists provide that's independent of any other discipline or profession. The issue of variety is another thing; the question is how many things you produce might be delightful? I think probably there are fewer things than most people would realize.

So my sense is this – in the first place you have to get delight right. Evaluating things in terms of performance is somehow troublesome. Think of silly buildings designed with computers that simulate how heat moves around spaces – and yet in the final picture, you see somebody in a room with a little space heater trying to keep warm.

That kind of performance evaluation and simulation in which physics is involved is really hard. It's just that the mathematics for it is not fully implemented. It's not up to the task yet, but it might become so one day. Will that conclude the design problem? Well, probably not, because there's still delight, and that's something constantly evolving, not just in respect to the designer but also in respect to the people who look at designs and use them, interact with them. Because they're all seeing, they're all in this important dynamic process. There's no end in architecture, there's no end in design, there's no end to looking. That's what's exciting.

Onur: This reminds me the debate about the huge market formulated around building energy analysis and simulation tools. Their accuracy is still at stake, as you highlighted. How valuable are these tools or their byproducts?

George: Well, there's something valuable in physical and performance analysis; certainly, it's very important. In the past, we had vernacular designs and their physical and environmental properties were improved over time. They converged to a certain kind of design and certain things were kept or changed after this benchmarking process happened over time. I think design still works in that way to some extent. How accurate and complete are simulation results for a huge building? I don't know. Nonetheless, what we do now is perfectly fine. The tools are definitely better than nothing.

But analysis is really a research issue. Building technology is a very serious kind of enterprise, and I think it goes hand in hand with ideas of calculating and delight. I've been outlining this approach in different ways; the physics I use is negligible. So there are options in which category of the Vitruvian cannon you're trying to apply.

Onur: What about parametric design tools? They generally tend to hide computational complexity, yet they still enable users to generate geometric as well as visual complexity. Are we really able to see what we are dealing with, when we are working with such tools?

George: I am not a big fan of parametric design, mainly because I think it simply scratches the surface of what happens in design. The trouble with parametric design is that it forces you to divide something into components and treat them as symbolic objects. Then you vary those components to produce something people might like. It may produce something, but you may not like it because of the components that are involved, or because you see it in a different way that's independent from what you've produced. And that makes parametric design, very much like Leonardo's sponge filled with colors, that he throws against a wall. There's a splash – then the designer comes in and looks at the splash. This design part needn't count in throwing the sponge. And that's the aspect of parametric design that's missing. I think people often times miss that, in a way this is just sponge throwing! You still need the designer to see what's there, and this may not match what's been combined and varied.

Onur: Then the designers are not necessarily able to see what they produce with parametric software, is that so?

George: Right, parametric design is a symbolic enterprise, and the visual kick we get out of it has very little to do with the things buried inside the machine. In that sense, the machine is hiding what it is you're excited about when you look at a design. It's the sponge!

Another problem with parametric designs is that they mostly look the same. You get to the point where you don't want to look anymore: variations are the ones you expect, colors are the ones you expect, layouts are the ones you expect. So there's no kind of creative spark to them, and yet for a designer who re-engages the material visually, I can see how that becomes a kick, because they're getting results they don't ordinarily get. It's simple, easy – press a couple of buttons or write some code, and you can get this wonderful array of things. The problem is that they look the same. And they look the same because they're combinatorial; they're putting components together without seeing how components interact. Change what's there. That's what's visual. That's where the kick is. That's what's missing.

I can show you a lot of calculating that demonstrates the poverty of parametric variation. For example, if you rotate the three triangles in this figure, you end up with two triangles **(Figure 3)**. There's a huge discontinuity that parametric design doesn't pick up, and that discontinuity has a lot to do with what visual calculating is all about. Three isn't two!

Onur: Although the tools are ubiquitous both in practice and academia it is hard to argue that the underlying logic (of parametric systems) is studied enough for their proper utilization. Inexperienced designers may either get stuck with whatever form the parametric program produces or suppress their own design intentions dealing with the mechanics of a system they don't fully comprehend. How could they find their way out?

George: If you want to know how these systems work, they're certainly worth exploring. But you have to realize that once you find out how they work, things might not be as interesting as you thought. I think the scary part of this is that people use these things and never bother to find out how they work. As a result they get stuck, as you point out, with the kinds of designs that are merely "available". Their own visual intuitions are no longer important.

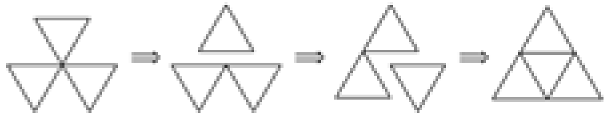

Figure-3

The other problem is this: suppose that you have a parametric model of something and you vary things, and the boss comes in and says "*Hey look at this cool thing up here, why don't we change that!*" But that's not a part of the parametric model, so in order to incorporate the change, you have to go back to the beginning, over and over again, which can take a lot of time and cost a lot of money, and you tell your boss that. Your boss either fires you for not doing the model in the right way – which is his loss – or he says "*I guess you better not change it because it costs too much money*", in which case it's the design's – and again his – loss. The tool, the parametric system takes over design. The loss of design activity, the loss of visual interaction, is the real thing to fear.

Onur: You have been one of the key individuals in the establishment of the renowned Design and Computation Group at MIT. This group has influenced many programs worldwide. Could you briefly talk about the spirit of the program, and compare and contrast it to others?

George: When I started the computation program in architecture at MIT about 15 or 16 years ago, the one thing I wanted to do was to make sure that calculating, as opposed to computation, was the way to investigate design, not simply an application of computer tools in design. I think the main thing that has kept the program fresh and viable, and active and exciting – that has provided a way for people to learn about design – is to actually view calculating as a good way of talking about design in the way we're used to. In fact from what I've said, design is calculating. The real emphasis is on design, not computer tools.

I think many programs elsewhere in the world emphasize the computer application aspect of design, and as a result, at least from my point of view, these programs don't have the exciting viability of the program we have at MIT. If there were no computers whatsoever, if we didn't have even one, no one ever invented one, but we did have my notion of visual calculating, we would still have the computation group at MIT. If there were no computers, and computer software and programs, many other schools wouldn't have a calculating component as a part of their architecture or design programs.

Onur: This might be the clearest way to explain it!

George: The key thing that makes the program work at MIT, and distinguishes it from many other programs is that it looks at calculating as a serious intellectual, academic issue that has to do with design, independent of existing software, computer programs, or anything you can buy off the shelf. Somewhere else, you would need to get that computer program, and then need to learn to use it to design. That's not the emphasis in the program at MIT; that's not what we're trying to do. Calculating as a serious, intellectual enterprise that's independent of the latest computer software, latest gadgets, 3D printing machines, etc. The subjects we teach have to do with thinking about architecture and design, and if there's a computer tool involved for a supporting role, that's good. We do run the whole spectrum from the theoretical kind of enterprise – which is the one that I'm most interested in – to practical concerns that have to do with visualization, parametric design, rapid prototyping, all of the rest, and fill in everything in between these two end points of the spectrum.

So I guess the short answer to your question is that the program thinks of architectural design as architectural design, and doesn't worry about the computation part, other than thinking about architecture and design as a kind of calculating – which is different than computer tools.

Onur: This should give a lot of clues about the program to curious candidates who are considering applying.

George, thank you very much for sparing time for this inspiring conversation. Do you have any final remarks for our readers?

George: I think I would like to return to what I said initially. One thing that I really like to emphasize is the formula "*design=calculating*", and to emphasize that thinking about design in terms of calculating really enriches calculating by expanding it – so that calculating does things that aren't found in any of the computer tools that I know of today. We think about things with our eyes. And it's that central role of seeing in design that I find most fascinating. If you ask me to think about anything that has to do what makes us creative and what makes us human, it's design and calculating. And I think that this is the most important aspect in the whole enterprise.

There are all of these problems about what it is that you're doing when you create and design things, when you engage your eyes. I think all of these could be thought about in terms of calculating. And how you do that is what really interests me.

COMPUTATION | UNEASY TO TRANSLATE AND UNDERSTAND-LANGUAGE, THOUGHT AND ARCHITECTURE

Şebnem Yalınay Çinici, Assoc. Prof., *İstanbul Bilgi University, Department of Architecture*

Words carry the layers of knowledge accumulated in time within their body. When we trace the words to their etymological origins we usually discover that they carry meanings beyond our knowledge. We even witness very familiar words becoming very unfamiliar to us. This is a kind of being-condition among language and thinking that bring each other into presence and allowing us to reveal knowledge there-in. In my opinion, the word *computation*, which we try to translate into Turkish as *hesaplama* (calculation) or *bilgi-işlem* (information processing) –whereas both translations don't exactly correspond to the word- in the domain of architecture, also carries this condition. In other words, when we take a closer look at this word that we use so frequently and think we know very well, we find it not that familiar after all. The fact that the meaning of the word cannot be verbalized very fast is a kind of indication that various layers of meaning are being carried within. The issue becomes even more complicated when we consider this word in terms of its relationship with design because the word, and the act of design is also inherently difficult to define. It is usually not possible to define and describe the word with exact descriptions because design always exists in a relationship with the uncertain. Therefore, when the words *computation* and design start to come together, the endeavor to understand what these two words mean together constitutes both the unavoidable and the exciting part of the task that is open to discovery. In other words, the fact that the word is not easily understandable is almost the source of the continuing thoughtful and productive energy channeled to this issue.

When we trace back to the etymological root of the word *computation* in order to understand how it evolved in time, we see that it originates from the Latin word *computare*.[1] '*Com*' means together or with while '*putare*' means to clear up, to settle or to reckon; so computare means to clear up, settle, reckon things together.[2] *Computation* was first used as a word in the 15th century, before the time of computers.[3] Therefore it is not a new word introduced by the development of computer technologies. It both carries the ancient Roman practices of arithmetic counting and calculation; and the non-numerical reckoning and clearing up simultaneously. However, due to the mental habits we inhabited through understanding the world by the methods of modern science and technology, we tend to think in categories; and inclined to understand the word *computation* through its numerical and mathematical connotations.[4] What does mathematics exactly mean then? When we trace the etymological origin of the word mathematics, once again we come across an unfamiliar meaning. Mathematics comes from ancient Greek word ta *mathemata*.[5] It means what is teachable and learnable at the same time.[6] *Manthanein* means learning while mathesis means teaching; in other words the original meaning of the word is the state of learning and teaching at the same time.[7] So the original meaning of the word mathematics does not lay in the relationships it has with numbers and operations, which our habitual way of thinking rapidly brings to our mind. The word, while containing what is learnable and teachable as its basic meaning, points at a different dimension of understanding and learning. However, what is considered learnable and teachable here is a way of knowing such as knowing the plantness of a plant or treeness of a tree. Thus, the word indicates a state of remembering what is thought to in fact already exist in the person as knowledge, where learning involves teaching. In other words, it describes the realization of what is in a way inherent rather than what is related to it. Since the word mathematics when translated into Turkish is *matematik*, which is almost the same to the original word. Thus, we can consider this information to be valid in our language as well. Unfortunately, *computation* cannot be translated into Turkish that easily. In my opinion this is in part due to the word itself, and in part because of the responsibility of translation to transfer meaning as well.

LANGUAGE AND TRANSLATION[8]

I may explain what I mean by referring to a point in Hasan Ünal Nalbantoğlu's essay *Ceviri/Yorum, Ihanet, Dostluk* (Translation/ Interpretation, Betrayal, Friendship): the affinity and 'friendship' that translation is bound to have with thinking.[9] In case of the lack of this affinity, the ideas and texts that we want to transmit via translation can lead to unintended misunderstandings and ideas. According to Nalbantoğlu if it happens, translation 'betrays' the thought that it means to transmit. I think understanding Nalbantoğlu's point will be illuminating for us, when we consider the difficulties we have in translating the word *computation*. Translating texts that are written in a non-native language is a serious responsibility. Since, this is not only the responsibility of translating the language, but also transmitting the thought, in Nalbantoğlu's words, 'intertwined (*hemhal*)' with the language. In his article, translation is rendered as an 'interpretation' and as an 'encounter'. Translation is an interpretation because the task is much more than mere technical word to word translation. Nalbantoğlu explains this with a quote from David Farell Krell: "the first step of translating a text should be translating one's self to the meaning, to the thoughts conveyed by that text.[10] Nalbantoğlu explains that "the person who attempts to make a translation has to first carry her/himself to the shores of other unknown geography, and should learn to think in that foreign land before returning to her/his own homeland (perhaps as a foreign afterwards)."[11] "Translation is more like an awakening, clearly seeing and the flowering up of the possibilities in one's own language with the help of the other foreign language...Translation is encountering another language in order to grasp one's own."[12] However, "what is essential in learning these is to see the 'uncannyness' of our native language that we are alienated from through an 'other', a 'different' language."[13] Thus the difficulty in translating the word *computation* can be considered as an advantage since it leads us to think what it can be in our own language. Every time we try to translate we start to be in some way alienated from our native language that we think we know so well and we see so familiar. At this point it is useful to remember that language is interconnected with thought and every verbalization is bringing forth an idea. Very briefly, in the chapter "Logos" in his book *Early Greek Thinking*, Heidegger explains the meaning of legein in terms of its relationship with word (söz) and presence, through Heraclitus's B 50 fragment.[14] His starting point is the relationship between *logos* and *legein*. The ancient Greek word *logos*, is widely known as 'mind' and 'comprehension with the mind'.15 However, its original meaning is 'word (söz)' and it is derived from legein meaning 'to say something important'.[16] Thus, our relationship with language is beyond being just instrumental, it involves both thinking and bringing something forth for the first time; even bringing it into presence. Thus it wouldn't be inappropriate to think that, the difficulty in translating computation into Turkish does not lie merely in language but also in our relationship between language and thinking.

COMPUTATION, ARCHITECTURE AND DESIGN

Basing on above mentioned essay by Nalbantoğlu, it can be argued that through our thinking habits generated in our own geography, it is difficult to find an exact translation for the word computation especially when its relation with architecture and design is concerned. Although I believe that the completion of Burcu Beşlioğlu's PhD. Thesis titled "*Türkiye'de Hesaplamalı Tasarım Kültürü*" (The Culture of Computational Design in Turkey) will have significant contribution to this issue, scientific resources on architecture, design, technology and computation studies in our country are just not known-enough yet. Yet, especially the recent endeavours in the domain of education offer important examples. Moreover, the potential translation of the word *computation* in architecture -beyond the ones that we have been inclined to until now, in relation with thinking and mathematics- and considering the meaning of clearing up together in its origins, can be opened to discussion via these examples.

Before discussing the situation in Turkey, a quick review on development of the relationship between computation and architecture in its British avant-garde origin may help; where a further understanding on a different concern on life, art and knowledge, rather than the expected technical and numerical one arises. Altino Joao Magalhaes Rocha in his PhD. Thesis titled *Architecture Theory 1960-1980: Emergence of a Computational Perspective* (2004) mentions that the origin of the computational design approach in architecture is based on the relationship between architecture and technology which emerged at the beginning of 20th century on the axis of architecture and 'knowledge for life'. The knowledge that is generated by means of science and art was criticized at the time for being closed and somewhat detached from life. During that period many intellectual movements were motivated by the idea that allowing access to knowledge for the crowds who need it, i.e., for the public, would significantly improve our relationship with life. At this point Rocha emphasized the concept of "third culture" in order to differentiate the emerging intellectual millieu. '*Third culture*' emerges as a term that helps us to understand the intellectual atmosphere that appears in England during the 1930's, as an expression of the desire to create a new world beyond familiar approaches. The concept of 'third culture' derived from the definition of intellectuals by the society, was kindled by C.P. Snow's book *Two Cultures* in 1959. *Third Culture* comes up as the title of John Brockmans's book, which is sort of a response to Snow's first book. It suggests that instead of people who work only on literature, scientists should also be considered 'intellectuals'. Brockman talks about the need for dialogue between artists and scientists, as well as for the dissemination of the knowledge that is created by this dialogue. And he explains this condition as third culture. He emphasizes that artists and scientists who produce knowledge in autonomous domains that are detached from life do not fit in the definition of the intellectual. He advocates that even knowledge that is considered to be at the highest level should be shared in an understandable manner. In order to illustrate this he compiles interviews with 23 scientists in his book *Third Culture*. The major contribution of the book has been the idea that bringing layman together with scientific thought and knowledge can generate a new understanding of culture that results from people's closer proximity to that knowledge.

According to Rocha this approach has been an important basis for the development of computational technologies in the domain of architecture. Third culture can be considered as a worldview that is at the basis of the convergence of people and groups that bring architecture with knowledge-generation and scientific research. Therefore it had impact on the constitution of intellectual environments that bring people from different disciplines with shared objectives together. To summarize, the common objective of Virginia Woolf (writer), Barbara Hepworth and Ben Nicholson (sculptor) and Berthold Lubetkin, Sergei Chermayeff, Walter Gropius, Leslie Martin and others, who came together around Desmond Bernal (physicist), the founder of the avantgarde movement in the 1930's in England, was the idea that life in relation to/supported by knowledge will be better. The movement started in England and spread to America, when first Gropius and later Chermayeff went there. The point I would like to emphasize here is the fact that these developments found ground mainly in the domain of education. The foundation of the LUBFS (Land Use Built Form Studies) by Leslie Martin in Cambridge University, Chermayeff's transfer to Harvard and him becoming Christopher Alexander's Ph.D. advisor are important turning points in the development of architecture and computation.

ARCHITECTURE, DESIGN AND INFORMATION

Here I would like to point out another knowledge relationship that is embedded into the word computation and that is again difficult to define: the relationship between architecture and design education and knowledge. As mentioned in Onur Yuncu's Ph.D. thesis titled *Research by Design in Architectural Design Education* (2008), the first discussions on how design is generates knowledge was started in the 1980's by Donald Schön's article *The Reflective Practitioner: How Professionals Think in Action* (1983). *Design Studies* and *Design Issues* journals started to be published during those years and they started to attract attention by a series of publications. Consecutive publications by Nigel Cross, Bruce Archer and Gerald Nadler on the subject were based on, perhaps as an interesting coincidence, the idea of "third way" in design education. This idea of the third way was suggesting that the methods and ways of knowledge generation of the positive and the social sciences were not sufficient for the field of design; and that design has a third way of generating knowledge that goes beyond these two approaches. In connection with this, the concept of 'research by design (tasarım yoluyla araştırma)' emerged in 1993 with Christopher Frayling's article titled *Research in Art and Design*, and according to Yuncu, it discussed design as a research approach rather than a research topic:

> The primary epistemological question transforms from knowing what design is and knowing how to design to knowing what through the act of design. The integration of the act of design in research transforms the status of design in design research from being an object of inquiry to being a research approach. (Yuncu, 2008, iv).

This is actually resulting from a difficulty embedded in architectural design education. This difficulty lies in the difficulty of architectural design in relating to its material from a distance. The structure that is being designed is thought to exist in a future reality while it is also the material that makes up the design itself. The gap created by this distance in the practice of architectural design has been the knowledge generation area of design. The representational domain where design takes place is transformed into potential research areas where 'research by design' takes place and architectural knowledge is generated (Yuncu, 2008). This is why the practice of knowledge generation in design is significantly different from positive and social sciences. The emergence of knowledge can only be defined beyond existing definitions as a "third way" because it is related to the way design processes define a problem and its singularity. Research by design in architecture education drags us back to the discussions of *ta mathemata* and the third culture, with is privileged characteristic displayed also in the relation between learner/teacher and learned/taught, because in the process of design education information is a state of action that is learned while being taught, that emerges as the work is being done, both for the studio director and for the student. As it is in ta *mathemata*. Also in the relationship with third culture, research by design perhaps carries us one step further by being producible by everyone rather than merely being accessible to everyone.

COMPUTATION, DESIGN + PRODUCTION IN ARCHITECTURE EDUCATION AND THIRD CULTURE

This is exactly why the environments where architectural design education takes place are the platforms where design research can be considered and discussed most intensively. As mentioned above in the review of the historical evolution of the relationship between *computation* and architecture, research on design technologies and what happens to design in relation with these technologies initially found place to develop in educational environments. This is because educational environments offer not only environments for research and investigating and developing knowledge, but also they provide opportunities for every individual to contribute to the generation of knowledge within the simultaneous learning-teaching dynamic, especially in design education.

Although research by design provides an opportunity for architecture to generate authentic information, it was limited in 1:1 realization during the 80's when the discussion emerged. The point where discussions on 'research by design' in terms of architectural design came short was its relationship with production and this started to be an important research topic as *computational* technologies developed. The load-bearing capacities of materials and load-bearing systems also become research areas in their relationship with design. Prototyping stated to be part of architectural design in education. However, the important issue was that the process of architectural design education was starting to interlace with the areas of implementation and realization. In terms of building, architectural design and education

PREVIOUS PAGE

cover

NEXT PAGE

Figure-1

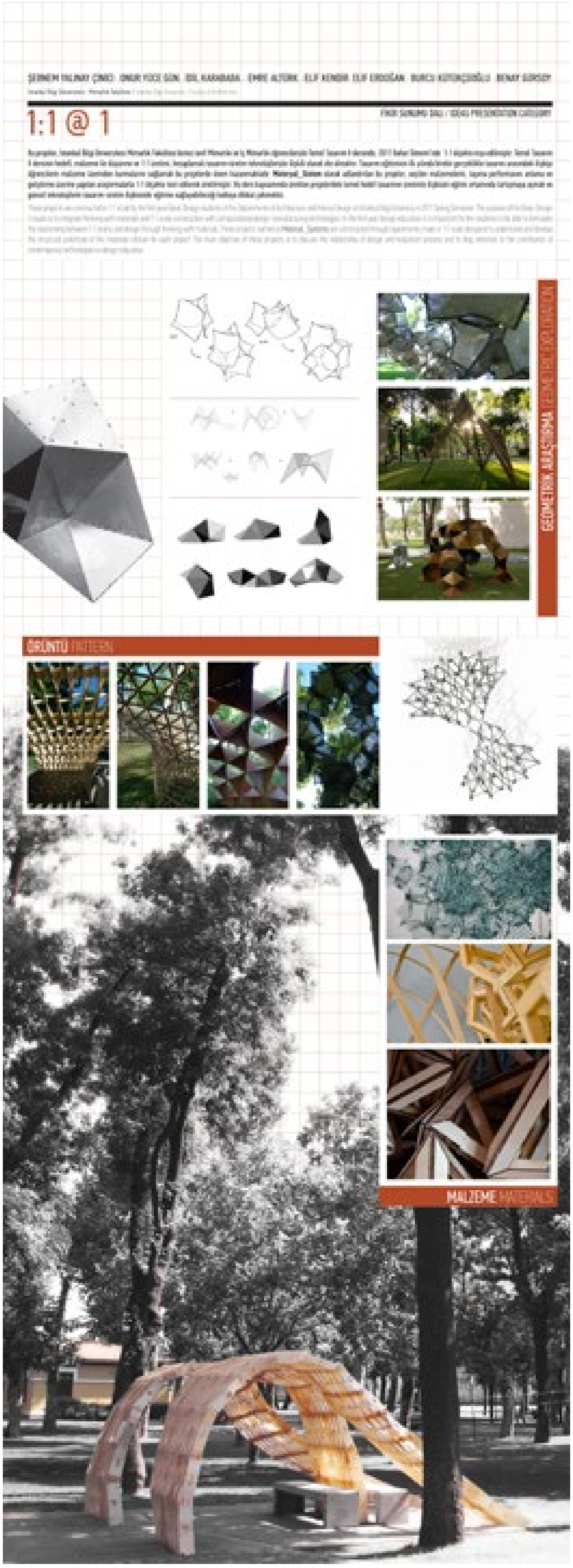

Figure-2

is getting closer to its materials via prototyping. Actually the relationship between architectural education and production was discussed for the first time with *Bauhaus* school in the 20th century. Its prevalence however could only start when computation based production technologies developed and became easily accessible.

Here I would like to point out how *computation* based design approaches, which we think to be more advanced and even mathematical and closer to calculation, are concerned about being part of life. These technologies are the founders of design environments and starting from the undergraduate level how they will be handled in education is becoming an important question in architectural design education. The fact that why this question is being asked, is an important indicator that computation and architectural design education is becoming, in Nalbantoglu's words, 'integrated'.

In this context I think that sharing two examples from the first year undergraduate studio in which I am also involved should be helpful. The first example is the Introduction to Architectural Design MTG (Mimari Tasarima Giris) course at YTU Department of Architecture in 2009-2011 and the second one is the student projects on how 1:1 production can be experienced in the first year studio in ARCH 112 (Computation Based Basic Design II) course at Istanbul Bilgi University Faculty of Architecture during the last two years. (**Figure-1 Figure-2**),

CONCLUSION

Perhaps we can conclude this discussion on the concept of computation by emphasizing a few points. First of all, when the concept is analyzed through its etymological origins, we can say that it is interlaced with a designerly way of thinking and knowing -as discussed in research by design part. Therefore we can say that design, advanced by developing design technologies, begins to involve production and fabrication as part of the design process. The fact of not being able to find an exact Turkish translation for the word perhaps should not be considered as a big problem, but instead an advantage; since we have the opportunity to go on understanding design as design with its extending meanings.

These technological advances and emergence of new possibilities in the design environment, while bringing the circles of education closer to 1:1 production and construction reality, offers possibilities to include any kind of site specific data, user demands, climatic conditions, tectonic preferences and any other variables, into design process –through a relational logic on a dynamic model. They provide capable tools to enhance our sensitivity and understanding when building something on earth and changing it into something else is concerned. Therefore, finally on the concept and the word computation it can be said that: with these advanced tools and equipments, design becomes a much more intellectual and philosophical challenge than ever before. Because while building on earth, how one can reveal the inherent potential and value of that very specific site by the knowledge gained from it -by an attitude of standing back and not dominating it with a will-to-power; I think, still is the most crucial and essential question of architecture.

ENDNOTES

1 http://www.cse.buffalo.edu/~rapaport/584/computetymology.html

2 http://www.cse.buffalo.edu/~rapaport/584/computetymology.html

3 http://www.etymonline.com/index.php?term=computation

4 http://www.thefreedictionary.com/compute

5 Martin Heidegger, "Modern Science, Metaphysics, and Mathematics"(1962), Basic Writings, David Farell Krell (ed.), San Francisco: HarperCollins, 1977, 247-282.

6 http://seansturm.wordpress.com/2010/07/12/ta-mathemata-we-can-only-learn-what-we-already-know/

7 Ibid.

8 Some pf the texts under this title are from the article I prepared as a 60th birthday present for Unal Nalbantoglu. See Sebnem Yalinay Cinici, "Ucuncu: hypokeimenon", Adile A. Avar ve Devrim Sezer (ed.) Hasan Unal Nalbantoglu'na Armagan-Symbolae in Honorem, 201-216, Iletisim Yayinlari, Istanbul, 2008.

9 Hasan Unal Nalbantoglu, "Ceviri/Yorum, Ihanet, Dostluk", Yan Yollar: Dusunce, Bilgi, Sanat, Iletisim Yayinlari, Istanbul, 2010.1

10 Ibid., 4.

11 Ibid., 4.

12 Ibid., 3. (Transl: Hasan Unal Nalbantoglu). Quote see Martin Heidegger, Holderlins Hymne »Der Ister«, [GA, Band 53] (Frankfurt am Main: Vittorio Klostermann, 1984), Wiederholung, 79. [Ing.: Holderlins Hymn »The Ister«, tr. By W. McNeill and Julia Davis (Bloomington and Indianapolis: Indiana University Press, 1996), Review, 65.]

13 Ibid., 3.

14 Martin Heidegger, Early Greek Thinking, 59-78.

15 http://www.thefreedictionary.com/logos16 Abdulbaki Guclu, Felsefe Sozlugu (Ankara: Bilim ve Sanat Yayinlari, 2003), 899.

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- http://seansturm.wordpress.com/2010/07/12/ta-mathemata-we-can-only-learn-what-we-already-know/

DESIGN AS DOING: A CONVERSATION WITH HUMBERTO MATURANA ABOUT WHAT DESIGNERS DO

Humberto Maturana, Biologist and Neuroscientist, *Co-Founder of Matriztica*
Daniel Rosenberg, PhD Candidate In Design And Computation, *Massachusetts Institute of Technology*

Humberto Maturana, a Chilean biologist and neuroscientist, has studied living systems and the phenomenon of knowing by shifting the traditional question of scientific and philosophical discourse from asking about *being* to asking about *doing*. For Maturana, *things* are not things unto themselves but rather they arise from our operations of distinction, in the realization of our living.

A living room or a workplace?
A table or a chair?
A tree or a ball?
A painting or a carpet?

If *things* are not there in themselves, what do designers *make* and how do they make *it*? In this conversation, Maturana explains how this epistemological shift affects our understanding of design. In a culture concerned so much with the nature of *things* and the production of *novelties*, Maturana's vision appears as an alternative perspective, which, based on biological-cultural foundations, shows us a more human-centered approach to design. Understanding design process and production as *doing* illuminates new pathways for design research, education and practice.

This interview was held at *Matriztica* in January 2011. I transcribed that conversation and edited this paper in August 2012 while I was a visiting researcher at the same institution, as part of an exchange program between *Matriztica* and MIT MISTI.

Daniel Rosenberg
Escuela Matriztica de Santiago 2012

Rosenberg: In the book *The Tree of Knowledge* you have said, "every act of knowing brings forth a world: all doing is knowing, and all knowing is doing" (Maturana and Varela 1998, 26), what do you mean by *bringing forth*?

Maturana: The expression bringing forth means *bringing a presence*, bringing to the present something without any reference to a source. Whatever you do, I would say, configures a presence, configures a world, configures the world that you live. At the same time, bringing forth occurs in the realization of our *living*. For example, as we talk we bring forth the whole world in which this conversation makes sense, while we live it.

Rosenberg: What about the idea of *constructing* a world proposed by the constructivists? Is it the same?

Maturana: It is not the same! It is something entirely different. To *construct* means an intentional act of fabrication. But we do not construct the world, we bring forth a world in the coherences of our living! Bringing forth is not intentional because it arises spontaneously with what we do. It is our living that constitutes the sensorial-operational-relational matrix in which whatever we do occurs and has sense. We do not make a world, it is not there before, it will not be there afterwards... because we bring it forth with what we do in the present.

Rosenberg: I want to relate this notion of *making* to design now. Donald Schön, a design theorist, defines the design process as a kind of making where "designers put things together and bring new things into being" (Schön 1987, 41). I would like to know what you think about this idea in relation to *bringing forth* a world.

Maturana: What design evokes is *making* as an intentional act... and making means that you put certain things together so that they are *there*. Do bees design the beehive? Well, they do not design it. It is entirely different from what we human beings do. In the living of bees the beehive *appears*, it is not designed. They bring forth a world... but they do not know they are bringing forth a world, and therefore they are not designing anything. The beehives are part of the world that the bees bring forth in their living. As a designer, I am also bringing forth my world when I am designing. If I am making a design, I am bringing forth whatever I am putting there because it is part of the realization of my living. As an intentional act, however, design specifies certain conditions of operation which will be the grounding conditions for something to happen, if those initial conditions are satisfied.

Rosenberg: What about the idea of design as bringing *new* things into being? Do you think there could be something *truly new*?

Maturana: I think that *newness* is a commentary of an observer: "Oh, this is new! I did not see it before, I did not imagine it before, I did not expect it before." But everything that happens is new! it is occurring there and it was not there before. So the emphasis on newness has to do with the cultural domain from which you are doing something. For example, this conversation is new. Was not there before, it is occurring in the moment in which it is taking place. Anything that has been said was not there before. Even if I say, "This was said by somebody in such and such moment in history," I bring forth that history in what I am saying now. So in what sense do we say something is new? Either it is always new or is new when I am surprised.

Do you see? Understanding how *things* are brought forth from a social matrix of human coexistence is more important than whether they are considered new or not. The origin of *things* comes from the pleasure we human beings feel when we do something together. *Languaging* is a manner of living together... and the spontaneous drift that follows this coexistence is modulated by our inner feelings and emotions. All the things or objects are, in this sense, inter-objectivities. All the objects have social roots, even when one person is designing a *new thing* in solitude.

Rosenberg: But how can you describe the case of a particular *thing* or *object* or whatever is distinguished by an observer as something new?

Maturana: Well, this is a cultural phenomenon. I can go now to the board and make a drawing and tell you, "Look, this drawing is new, it was not there before," and you may say perhaps, "Well, it is more than just the fact that it was not there before, I have never imagined this! This is very new for me." Or you could say, "Ah, that drawing has nothing new... I have seen it before." And we can talk then about whether what I am drawing is new for me and for you. We have a problem with newness but it is cultural, because we want to live on novelties.

Rosenberg: So what do you think about our culture today talking so much about the importance of innovation?

Maturana: For some people, I think, innovation is an addiction ... an addiction to novelty. If you do not make something that somebody else is surprised by, you do not feel satisfied. You would think to yourself, "Oh my goodness, he didn't even notice how new this is!" and you may have symptoms of deprivation and get depressed. Do you see? It is like not taking a drug. I am not interested in innovation, I am interested in conservation: Conservation of honesty, conservation of seriousness in what we do, conservation of mutual respect...

Rosenberg: And what about creativity?

Maturana: The act of creation is there all the time. But creativity, like innovation, is a cultural question. Now, in what sense does creativity appear as a question of necessity? Creativity is a necessity only when somebody else wants from you something different. But whatever you are thinking, saying or drawing right now by yourself... is new for you! It is an act of creation, in the sense that it was not there until you created it. But you may think: "Ah... but what will the other person think, is he or she surprised?" If the other person is surprised he or she will tell you: "Well, you are very creative, I had never thought about that."

Rosenberg: I think so... but what about the *things* themselves? What are we designing when we design something?

Maturana: Let me give you an example. You are an architect and you designed a house. You want to show it to your client, and you tell her, "Well, this is the living room." And the woman that is going to buy the house replies, "Oh no, this will be my workplace." What did you design? A living room or a workplace? Well, it depends... for you it is a living room, and for the woman a workplace.

Rosenberg: Can we say that this situation has to do with the notion of interpretation in design?

Maturana: The woman is not *interpreting* your design. In an interpretation you must have something with respect to which you can speak as if it was *there* with independence of what you do. But things are not there in themselves because, as I told you before, we bring forth our world with what we do. You are just living and bringing forth your world with what you distinguish. You are just saying, "I am going to *live* this place as a living room," and she is saying, "No... I am going to *live* this place as a workplace."

Rosenberg: But as an architect, I could say that the lady is interpreting my design in a different way from what I was expecting.

Maturana: Perhaps, if you are the architect and you like very much what you have designed, then you would want to say that. But that is not what is going on. For you, what is occurring refers to an interpretation with respect to what you have put there as a reference... that you may have specified in some way or another: By writing *living room* on the drawings or specifications of the house, for example. But the whole problem with the interpretation of *Reality* is that you have no way to speak about a Reality that you are going to interpret. When a person says that there is an interpretation of Reality, this person is saying there is something *there* and that what you are saying does not fit that. But you cannot say what is there! The problem appears when talking about entities instead of talking about living. It is more interesting to see the invitation to coexist under that we call *interpretation*.

Rosenberg: Can we say then that the living room is the organization that I want to conserve as a designer, even though for the client the organization would be different?

Maturana: Yes, because it would depend on what you are specifying as a designer. If you specify: "This is a living room, and a living room is blah, blah, blah... and a living room is only a living room if blah, blah, blah is conserved." In that case, the woman is destroying your living room by living that place as a workplace. Whenever you distinguish a composite entity, you imply a particular organization. You specify a configuration or relation that cannot change, because if it changes you will use a different name or class.

Rosenberg: What happens when a designer is making something and he does not yet know the name or class of what he is creating? In that case there is not a class identity.

Maturana: But you have a word for that: He is designing a *thing*! I do not know what kind of *thing* is this *thing* I am designing here [pointing at a table]. You may tell me, "This is a table..." And I may tell you, "No... this is a chair." So we begin to talk about whether this thing has to go into the class *table* or class *chair*, but both belong to the class *thing* or even to the class *furniture*. But the distinction of a class identity is not fixed or unique.

Imagine I am little boy [sitting on the floor with his hand on top of a *chair*], and I sit here and say, "This will be my table, Father." Would you tell me, "Stupid boy, that is not a table, that is a chair?" Perhaps...I hope not. You move from a *chair* to a *table* with what you do, with the distinctions that you make... things are not there in themselves! You either bring forth a *table* [again, sitting on the floor with his hands on top of the *chair*] or you bring forth a *chair* [now, sitting on the *chair*]. When you make a design, however, you may specify whether this [pointing at the *chair*] is going to be a *chair* or a *table*. And then, if you want, you can make a catalogue and put on one page different kinds of *chairs*, and on the other different kinds of *tables*.

Rosenberg: This reminds me of a story... my little niece was scribbling one day, and said, "This is a tree." But after a couple of days she found the same drawing and I asked her what it was, and she said, "This is a ball."

Maturana: This is interesting ... you may have tried to show her that she was wrong: "No, this is not right! You saw a tree before and now you see the same thing as a ball?" To which she may have explained: "Yes, but now it looks round so it is a ball now... I did not show the trunk before, I just imagined it." Would you punish her or say "how interesting"?

Rosenberg: I would say "how interesting" and try to understand what is going on... can we look at the process and talk about what my niece is doing when she sees a tree or a ball?

Maturana: Yes of course. We can look at the process, and ask, talk and write about it. You can ask the child and take notes to explain the behavior of children and what is happening inside children. You may reflect about the imagination of children: "The child can see a tree in a ball when she imagines a little thing underneath, the trunk, which is not visible." You may have observed that two days after seeing a tree, the girl has seen her brother playing with a ball, and that now she imagines her drawing as something that can move and bounce. I mean ... yes, and then you could write a psychology paper titled *Children's Imagination*. I am not saying you should not reflect on this, I am only inviting you to see what you are reflecting about.

Rosenberg: Yes, but my niece is putting these lines together and she is seeing different things... the same with a painter making a painting. For example, what do you think Pollock is doing in this picture? (Fig. 1)

Maturana: If somebody comes here and see what Pollock is doing, he may not see he is painting a painting. He may say, "Wonderful! This is a beautiful carpet." What is it, a painting or a carpet? It is nothing in itself. It depends on what you do. But, if you really want to know what Pollock is making, you will have to ask Pollock. Everything depends on the person that is doing and the person that is observing. The person that is doing something is bringing forth with his or her doings a particular domain of operations... and Pollock may claim he is making a painting. So now look how he moves, where he steps, he is stepping on the painting, not on the lines but on the white space that he left

Figure-1: *Jackson Pollock painting in his studio*

accidentally or intentionally. We do not know. And his life is changing with the painting or whatever he is doing there. And how do you know he is changing with that? Because when he is doing it, he stops, looks, says and does something... and the painting is changing with him and he is changing with the painting... or with the carpet or whatever it is in his mind.

From an observer's perspective, we never know what is in the mind of other people if we believe that the mind is a real thing in the head... but if we understand that which we call the mind is an epiphenomenon that we can see like observers in the sensorial-operational-relational matrix of our existence, then we can see the *things* that we attribute to the mind. If we want to see the mind of Pollock while he is painting then we must co-live with him... in this way the things that he brings forth are the spontaneous and natural consequences of his and our living together.

Rosenberg: But I am not only talking about the painting as a class but about the process of creating something by putting those lines together on the canvas ...

Maturana: You will have to ask Pollock, and he may tell you, "Well it was appearing as I was painting" or maybe, "Well, I had a dream..." or, "I just imagined it. I wanted to have a tangle that was beautiful, so I am here making a tangle and modifying what I do as I see it, and when I feel satisfied with the configuration and found it beautiful, I could say I have finished." Better than asking Pollock, though, it is to co-live with him for some time, if you really want to understand what he does.

Rosenberg: What about using the computer for design? The computer uses predefined symbols which may become a limitation when we want to see things in different ways... for example, when we see a tree in a ball.

Maturana: Well, you can still do that with a machine. With the painting you do what you want by taking the brush, putting the ink or oil, and then sliding the brush on a surface. With the computer you do what you want by taking a program, putting certain parameters, and then getting a line on the screen or whatever. What is the difference?

Rosenberg: The difference is that somebody designed the program, the interface, and the symbols that you can use to make drawings in a computer.

Maturana: Well, somebody invented the brushes too, before you were born. If as a designer you do not like the computer or a particular program, then do not use the computer or the program! The machine is like a brush, it will do certain things because it has a structure—it has a whole structural dynamics inside it, and it does whatever it does according to that structural dynamics... within the coherences of the organization *computer*. But if the machine begins to do something you do not expect from the class computer, you will probably say, "This computer is broken, it is not a computer anymore, it has gone crazy."

Rosenberg: But in a way *things* afford certain doings and not others...

Maturana: Of course, things are structure determined entities, so the task is to understand what is the organization, what is the structure, and what is the domain of variability. And I am sure Pollock will tell you, "Well, I have been painting for twenty years now and I have found that you have these dimensions of variability with the brush...with a thick brush, with a thin brush... with a long-handled brush, with a short-handled brush." He will describe all the variations that he can do with something that seems to be so simple.

Rosenberg: Do you think he is creating his own set of symbols by working within this domain of variability?

Maturana: If you come to his studio and you see Pollock working with his student, you may then discover that indeed he has created his own set of symbols. How do you know that? You may see that Pollock is saying things or making gestures with the brush that the student understands and you do not. What does it mean that the student understands? It means that the student does something that Pollock accepts as valid. Again, a symbol does not exist in itself. Here you are reading the book From Being to Doing (Maturana and Poerksen 2004). What does it mean to change from being to doing? We cannot speak about the being we can only speak about what we do. So first you should attend to what the designer is doing and then you attend to the names. And the names will have a different evocation, and you will find out that this will be very valuable for you in design!

Rosenberg: I see... can you give us a final reflection to close this interesting conversation?

Maturana: Because you are an architect, I would like to add that the intentional act of design consists of manipulating the world that you live... something will happen—in the flow of the changing cosmos that you are bringing forth with your living—so that you will be able to make a particular desired distinction and say, "this is what I wanted to do".

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COMPUTER OF A THOUSAND FACES: ANTHROPOMORPHIZATIONS OF THE COMPUTER IN DESIGN (1965-1975)

Theodora Vardouli, PhD Candidate in Design and Computation, *Massachusetts Institute of Technology*

PROLOGUE

"Computational Design" is a term in wide currency. Followed by the hype often associated with digital technologies, the phrase is invoked to describe a vast spectrum of design practices which employ computational media as an integral part of their conception, representation or realization processes. The ubiquity of computational tools, the hastiness for the development of faster and more efficient computer applications, and the excitement associated with the label "computational," prime a pragmatic approach to the term "computational design," leaving little space for contemplation on its conceptual premises.

Within this context, the sparse efforts to define the term usually take the form of a comprehensive listing of the design and fabrication technologies at hand, as well as the methods through which these are utilized. However, this extensive definition, where "computational design" is equated to the sum of the available computer tools and use processes, fails to capture the term's essential meaning, implications and potentials. Does the adjective "computational" describe a special subsection in the well-defined disciplinary category of Design, or does the concatenation of "computational" and "design" engender a third entity, a new field of knowledge, with its proper inquests and ways of pursuing them?

Setting aside the controversial question of whether Design and Computation can in fact be considered a new discipline, it can be argued with certainty that the coupling of the terms "computational" and "design" carries crucial epistemological implications: it suggests the utilization of an informational machine, the computer, in the creative process of design, which still escapes definition besides the numerous attempts to formalize it. Besides its current naturalization/neutralization, the phrase "computational design" contains an irresolvable tension between the systematic, linguistic and combinatorial space of the machine and the fluid, perceptual, continuous space of the designer.

This negotiation between two different, and at times antithetical, worlds legitimates the existence of a field of knowledge which inquires into the conditions of their coexistence. Does "computational design" exist as a synthesis of oppositions, merging the world of design and the world of computation, or does one of the two fields impose its operational modes upon the other, making design more computational or computation more designerly? Untangling the difficult conceptual problem is essential in order to critically position ourselves as designers and researchers in the vast pluralism of practices which invoke the term "computational design" and to orient our creative efforts toward the inception of new computational agendas, conscious of their stakes and challenges.

Currently, the questions pertaining to the intensive relationship between the constituent parts of the phrase "computational design" tend to be obscured by its ubiquitous and opportunistic use. However, looking back to the first encounters of computers and design, one discovers a rich legacy of speculation on the implications of this merging. Inquiry into the early computational era (1965-1975) can therefore expose (part of) the cultural and historical origins of the popular but loosely defined term "computational design." Furthermore, an exploration of the computational transition in design can problematize the boundaries between the domain of computers and this of designers and bring forth ideas and questions which surpass the actualities of digital tools and methods.

The intense impulse to situate the new entity of the computer in the traditional, empirical processes of design lead to assignments of anthropomorphic roles to the machine, such as the"clerk," the "partner," the "accountant," and others. These different "occupations" were eloquent metaphors denoting different approaches to the ways that the innate characteristics of the computer could be reconciled with the elusive characteristics of design, as well as to the new relationship of the machine as a design actor with the designer-author. The main body of this paper places these metaphors in conversation, thus revealing different models of computation, as well as different processes of design. The purpose of this short survey is to bring forth computational "role models" which survive until today, assert them as historical and cultural artifacts, and present their conceptual counterpoints, re-opening them for discussion.

COMPUTER OF A THOUSAND FACES

The first Computer Aided Design (CAD) system, SKETCHPAD, made its appearance in 1963, as the result of Ivan Sutherland's PhD thesis in the Massachusetts Institute of Technology. The introduction of Sutherland's program in the design world initiated controversial debates on the role of computer aids to Design and Architecture. Sutherland's writings about SKETCHPAD explicitly reveal his approach computer graphics applications as something more than drafting aids. More than half a century before the popularization of Building Information Modeling (BIM), Sutherland was discussing the machine's ability to organize and process information. This, he argued, offered the prospect of structured representations containing explicitly stated topological information about a drawing and therefore enabling the designer to embed constraints, perform easy modifications and even compute difficult problems emerging during the design process. In the abstract of his doctoral thesis entitled *SKETCHPAD, A Man Machine Graphical Communication System*,[1] Sutherland wrote:

> It is easy to add entirely new types of conditions to Sketchpad's vocabulary. Since the conditions can involve anything computable, Sketchpad can be used for a very wide range of problems. For example, Sketchpad has been used to find the distribution of forces in the members of truss bridges drawn with it.

Figure-1: *Ivan Sutherland's SKETCHPAD. The user "sketches" on a 7 by 7 inch scope device with a 1024 by 1024 raster using a light pen and presses command buttons with the second hand*

Source: *"Vision and Reality of Hypertext and GUIs: 3.1.2. Sketchpad - mprove.de" Available at: http://www.mprove.de/diplom/text/3.1.2_sketchpad.html.*

THE CLERK

A widely shared rhetoric in the first years of CAD, was the claim that the computer would liberate the designers from the tedious, quantitative tasks involved in design, thus allowing them to channel their energy towards the truly creative parts of the design process. An indicative example of this approach was Walter Gropius' intervention in the 1964 conference *Architecture and the Computer*.[2] As denoted by its title, the conference sought to map the implications of this powerful new machinery in the discipline of Architectural Design. One year after SKETCHPAD, Gropius, founder of the Bauhaus school and of the renowned Cambridge-based architectural firm *The Architect's Collaborative* (TAC), would advocate for the imperative to make an intelligent use of computational tools "as means of superior mechanical control," offering "ever-greater freedom for the creative process of design."[3] The conceptual basis of this optimistic claim was a partitioning of the design process into a set of "objective," quantitative tasks on the one hand, and intuitive, qualitative creative processes on the other. In this fundamental divide, the computer would play the role of a sedulous slave in the service of the designer, performing measurements and calculations, faster and more efficiently than its human master.

As soon as the computer entered the ecosystem of the architectural firm, this division was transformed from a source of optimism to the cause for a widespread disillusionment, questioning the relevance of the machine to the important questions of the discipline. Before forming a boisterous critique, shared amongst designers, this concern had been prophetically framed by the American architect Christopher Alexander. In *Architecture and the Computer* Alexander had observed that in order for the computer to be truly useful for design, the important design problems should be formalized in a way that they could be input and processed by the machine. Until then, the "army of clerks,"[4] as Alexander characterized computer aids, would be of little assistance to designers.

The criticism that designers needed something more than unimaginative clerks, soon became widely shared amongst designers. One decade after the first encounters of architecture and the computer, there was already an atmosphere of a pre-mature end. The 1975 collection *Computer Aids to Design and Architecture*,[5] edited by Nicholas Negroponte, under the intention to serve as a reflective retrospective of the first decade of CAD, is infused with a climate of disillusionment, stemming both from the world of research and practice in the United States. Articles such as this of the UC Berkeley Professor Vladimir Bazjanac, with the

Figure-2: *The computer in the architectural office. The Applicon 800 System.*

Source: *Teague, Lavette. A Decade of Discovery and Development. in Reflections on Computer Aids to Design and Architecture. 1975. , ed. Nicholas Negroponte. Petrocelli/Charter.*

telling title *The promises and the disappointments of computer-aided design,*[6] narrate the transition from an enthusiastic belief to the revolutionary potentialities of the machine to the disappointment about its poor performance in the world's "messy realism." The early optimism about the wonders of CAD gave its place to skepticism and restraint about the imposition of the machine's operational modes to the designer. As is revealed by the discussions of Patrick Purcell, research fellow in the Department of Design Research at the Royal College of Art in London, or Murray Milne, at the time Associate Dean of the UCLA School of Architecture and Urban Planning, it soon became evident that in order to understand the role of computational systems in design, one should first better understand the design process itself.[7]

THE PARTNER

At the time that *Reflections on Computer Aids* were written, Nicholas Negroponte was already counting eight years of research in computer graphics in the renowned MIT Architecture Machine (ArcMac) Group, which was later transformed into the Media Lab. From its first years of operation ArcMac offered a strong counter-point to the figuration of the computer as a clerk and oriented its efforts to the development of a system that could "assist architects with those activities they call "design" (as against specification writing, preparation of working drawings, accounting, etc...)."[8]

The Architecture Machine Group's first major work under this agenda was *URBAN 5*, a research project for computer-aided architecture jointly funded by the IBM Cambridge Scientific Center and MIT, which started in 1966. Besides the intention to actively involve the computer in the decision making processes of the designer, *URBAN 5*[9] did not fully escape the predispositions of the time about the tasks that a computer could efficiently perform, namely the performance of hard calculations and the checking of violations in constraints that exceeded the designer's cognitive capacity. However, Negroponte soon became self-critical of the rigidity of this approach and envisioned a "system (that) could really change itself to reflect the design attitudes of a particular designer."[10] This realization reoriented the ArcMac's efforts to an area which would later become the epitome of the Group's work: *interaction*.

The computer vision experiments which were at the time being conducted in the Artificial Intelligence Department at MIT, opened new possibilities for Computer Aids, which were explored in the first book publication of the Architecture Machine Group entitled *The Architecture Machine: Toward a More Human Environment.*[11] *The Architecture Machine* presented the vision of interconnected personal, "domesticated" machines connected to a central host, which would surpass the role of the clerk (ie. a problem solving device) to rise to the level of a problem worrying partner. Through just-in-time interventions, responsive to the designer's idioms and idiosyncrasies, the machine would allow the architects to think simultaneously of the very big (global constraints) and the very small (local needs and desires), thus leading to what Negroponte characterized as a "humanism through intelligent machines,"[12] where the machine would "exhibit alternatives, suggestions, incompatibilities and oversee the urban rights of individuals."[13]

Influenced by the techno-humanistic cybernetic visions of a harmonious synergistic relationship between men and machines, which were floating in the MIT air in the 1960s and 1970s, Negroponte proposed a model which surpassed the rigid division of labor in the design process and called for a partnership between the computer and the designer. The idea of man-computer symbiosis, borrowed by JCR Licklider's highly influential

Figure-3: *URBAN 5's overlay and the IBM 2250 model 1 cathode ray-tube used for URBAN 5.*

Source: *Negroponte, Nicholas. 1970. The Architecture Machine: Toward A More Human Environment. Cambridge, Mass.: MIT Press.*

1960 text,[14] polemically asserted the computer not as a rigid, counterintuitive machinery, but as a tool for creative amplification: a design partner. In his 1970 article entitled *The Semantics of Architecture Machines,*[15] co-authored with Leon Groisser, Negroponte noted:

> A paradox exists in all man-machine interactions and is epitomized in the interactions between the architect and the computer. The paradox is as follows: Architects are concerned with issues generally considered to be unmanageable by computers. These issues draw upon human experiences, senses, attitudes, even idiosyncrasies, none of which are enjoyed by machines at this point in time. So the standard procedure is to partition the design task: the man is given what he is good at doing (which is usually what he enjoys), and the machine is given only those tasks it can handle efficiently.[16]

Negroponte and Groisser sought a way to render the innately syntactic informational machine sensitive to the semantics of Architecture, meaning, context and missing information, thus promoting the machine from an unimaginative slave, measuring "kips, feet, decibels, acres, coulombs," to a design partner understanding "calipers of participation, contentment, responsiveness, adaptability, diversity, resilience and so on."[17]

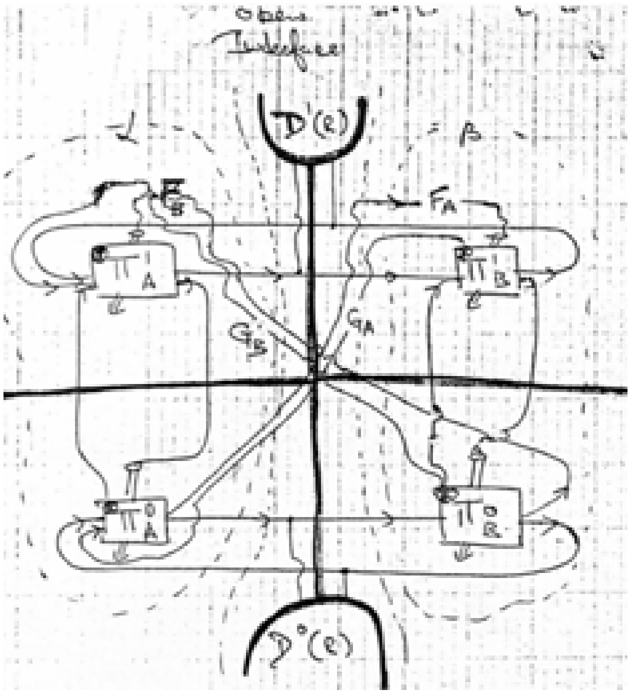

Figure-4: *Gordon Pask's sketch for Conversation Theory.*
Negroponte, Nicholas. 1975. Soft architecture machines. Cambridge, Mass.: MIT Press.

The interface became the key to surpassing the syntax-semantics dichotomy and to re-establish the lost unity of the design process. Through numerous research proposals, with the most robust being the 1976 Proposal to the National Science Foundation entitled *Graphical Conversation Theory*,[18] ArcMac outlined the maxims of a successful interaction between the designer and the computer and developed haptic and visual interfaces allowing the designer to interact as fluidly as possible with the machine, without being stifled by denatured formalizations.

> This disjunction is cumbersome but can be alleviated by the nature of the so called interface between the two protagonists. [...] They (researchers) are trying to make it approach the interface with which we are familiar in human discourse. Thus we work on interfaces, not only the interface between computer and architect, but also the interfaces between the machine and the nonprofessional.[19]

THE WIZARD

The shattering of the hierarchical, master-slave relationship between the designer and the computer, opened the door to speculation about a radical re-diagramming of the design process and the role of its actors. The abolition of the boundaries between the professional architect and the non-expert user dominated the work of the Architecture Machine Group in the first half of the 1970s. Apart from the operation of this rhetoric as a challenging motivation for taking the enterprise of creative amplification through computers to its conceptual and technical limits, this vision was heavily influenced by a zeitgeist which denounced architectural professionalism as morally suspect and envisioned the design of systems and platforms which would allow for personal liberty and creative individualism. Drawing references from sources as diverse as cybernetics, participatory design and advocacy planning, the counterculture movement in the United States and the radical megastructural fantasies in Europe and Asia, the Architecture Machine Group engaged with the agenda to empower people to shape their own environments through resilient computational infrastructures.[20]

Inspired by a rave optimism on the potential of Artificial Intelligence, ArcMac started with the ambitious vision of the Architecture Machine as a self-configuring, "intelligent" environment, able to sense and respond to the user's most intimate desires. This prospect was presented in the *Design Participation Conference*, organized in September 1971, by the Design Research Society in Manchester.[21] The Architecture Machine Group's paper entitled *Aspects of Living in the Architecture Machine* discussed the idea of a "responsive architecture" as a concept which "takes both movements (computation and participation) to their limiting cases; in some sense invalidating the corner stones of their existence."[22] The imminent, seamless spatialization of the user's design intentions, prior even to their verbalization, seemed like pure wizardry. A wizardry, however, which as Negroponte admitted in his 1975 book Soft Architecture Machines,[23] remained yet distant.

THE SURROGATE

Setting aside the vision of the "Wizard machine,"[24] Negroponte returned to the idea of a creative amplifier, this time partnering not with the professional designer, but with the non-professional user of architecture. The moral rhetoric accompanying the ArcMac's Group attack to the opportunistic interpretations and simplifications of the professional architect, imposed additional constraints to the conception of the "design amplifier." The role of the machine was to empower non-expert users, who knew very little about design but plenty about their living preferences, to spatialize their intentions and produce their own designs. The success of the entire enterprise was therefore contingent on the non-paternalistic partnership between the non-expert user and the machine. In *Soft Architecture Machines*, Negroponte assigned to the computer the role of simultaneously a "benevolent educator" and a "thirsting student,"[25] whose goal was to establish a mutual understanding with the user by interacting with him in a visual and verbal manner. By making inferences on the user's sketches and statements the computer would ideally be able to construct a model of the user and therefore operate as his surrogate, his expert alter ego, his own native architect.[26] In the *Soft Architecture Machines* model, a fleet of interconnected design amplifiers, controlled by Architecture Machines, forms an omnipresent cybernetic system of user surrogates negotiating the user individual desires and global criteria pertaining to the sustainability of the urban whole.

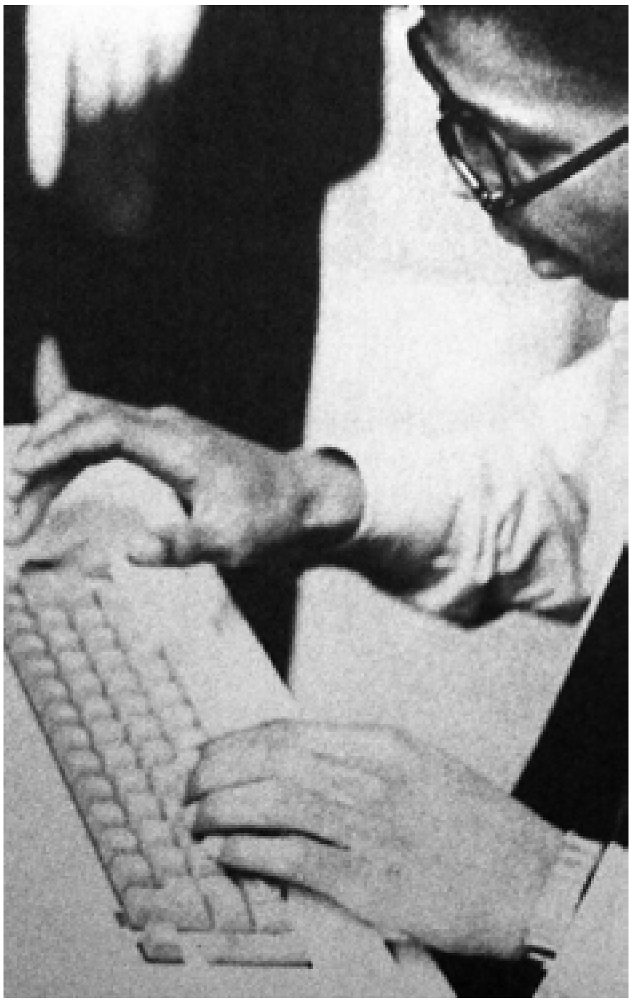

Figure-5: *Computer Aids to Participatory Architecture, by the MIT Architecture Machine Group.*

Source: *Negroponte, Nicholas and Leon Groisser. 1971. Computer Aids to Participatory Architecture. [Principal Investigators: Leon Groisser and Nicholas Negroponte]. Cambridge, Mass: Massachusetts Institute of Technology.*

THE ACCOUNTANT

Besides Negroponte's meticulous analyses in support of the non-paternalistic claims that he made for his system,[27] the dominating agency of the machine was inevitably a source of discomfort. After assassinating the professional architect, the computer came back as a bearer of good intentions, issuing promises of neutrality and objectivity. The Hungrarian-born architect Yona Friedman, one of Nicholas Negroponte's main influences in his shift toward design participation, offered a counterpoint in the figuration of the machine as a decision-making agent in design participation. In his chapter on Urban Mechanisms, in the book *Toward a Scientific Architecture*,[28] which formed the main conceptual diagram and technical basis for the "Design Amplifier prototype, Yona Friedman envisioned the machine as an "*accountant*" objectively recording personal and collective histories and feeding them back to users and communities without "agency" or "intelligence". Friedman's data-centric discourse on urban mechanisms ("accountant's point of view") which could be read as a prophetic precedent of the currently popular discussions of the "real time city." The constantly fluctuating map of the city updated in real time by the flows of the city's inhabitants on the existing physical networks and their constantly shifting preferences, could act as a "city barometer." This source of data would inform the urban inhabitants about the effect that their design decisions or even use of the fabric of the city can have to the system as a whole and allow them to trace recurring patterns and develop personal and collective anticipatory mechanisms. The accountant just kept the books; it was up to the inhabitants to own and manage the data in order to reflect on the implications of their past actions and plan their collective futures.

EPILOGUE

Almost forty years after the collection Reflections on Computer Aids to Design and Architecture was featuring the question: "A new concept of architecture or just a quicker working method?"[29] written in a speech bubble coming out of a dinosaur-shaped metallic skeleton, the analysis and critique of such early computational anthropomorphic

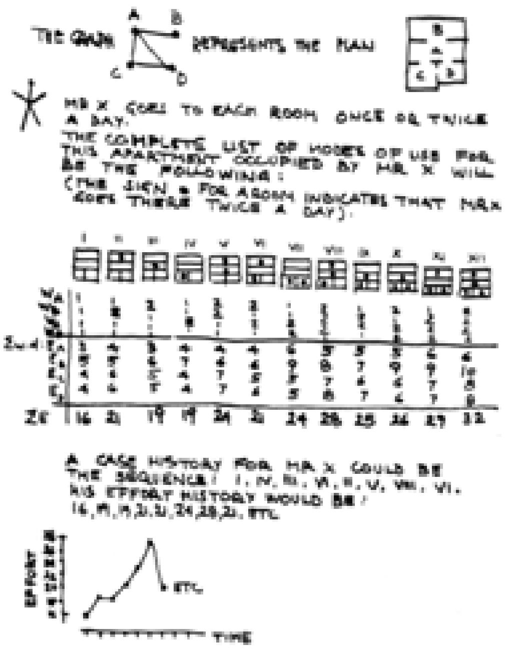

Figure 6: *Monitoring of user habits in Yona Friedman's FLATWRITER machine.*

Source: *Friedman, Yona. 1975. Toward a Scientific Architecture. Trans. Cynthia Lang. Cambridge, Mass.: MIT Press.*

metaphors can offer ways to problematize the brand "computational design" and to rethink the computer's role in the intricacies of design. The figurations of the "clerk," the "partner," the "wizard," the "surrogate" and the "accountant," engendered by the intensive encounter of the accustomed processes of design and the new entity of the machine, offer a repertoire of rich metaphors, which condense an amplitude of visions, questions and tensions worthwhile revisiting today. By looking at these proto-computational narratives one can expose the cultural and historical origins of current computational fantasies and compare them with their historical doppelgangers. The growing computational evangelisms of the potentialities of intelligent environments, smart cities, open data management, bottom up participation reflect echoes from the past, besides their appearance of unprecedented novelty, of an a-chronic here and now. At the same time, discourse around new types of computational tools, which seek to upgrade the computer from an electronic pencil to that of a design aid, offering structured, hierarchical representations, can perhaps benefit from the evolution of a history which departed from the same point more than half a century ago, to spiral back to where it started.

"Computational Design" is an intensive term, it contains an internal contradiction between two worlds -which at least in their current conceptual and practical definition- appear different in nature; one discrete, combinatorial and explicit and one continuous, fluid and unenunciated. Departing from the canonical and naturalized conceptions of the term it is time perhaps to engage in the difficult conceptual exercise of understanding this internal tension and develop platforms and ideas to negotiate it. In this quest, the thousand faces of the computer can serve as thought experiments allowing us to untangle this tension, by revisiting, recasting, reinventing them.

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1 Sutherland, Ivan. SKETCHPAD, A Man Machine Graphical Communication System. PhD Massachusetts Institute of Technology, 1963.

2 Gropius, Walter. 1964. Computers for Architectural Design. Paper presented at Architecture and the Computer, Boston, Massachusetts.

3 Ibid.

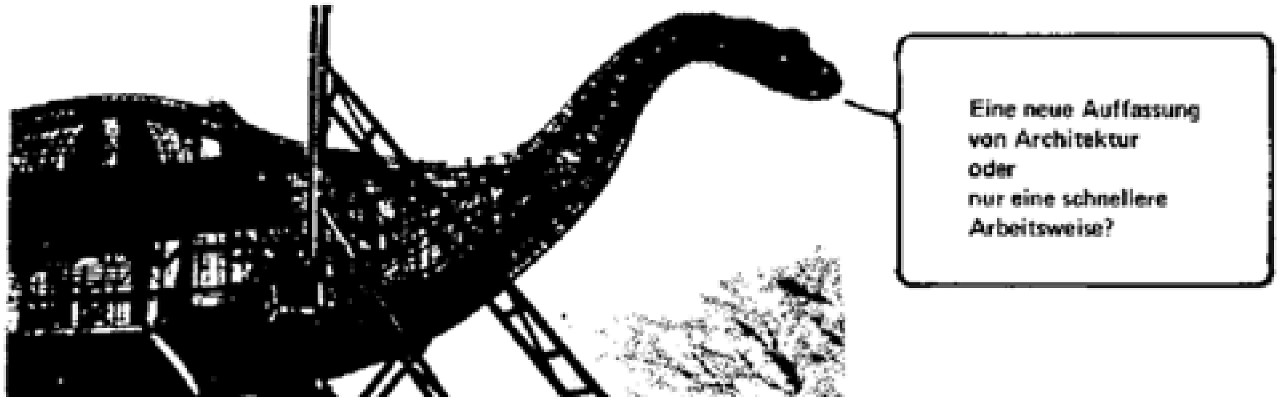

Figure 7: *"A new concept of architecture or just a quicker working method?"*

Source: *Weber, Jos. Denmark, Holland, Germany. in Reflections on Computer Aids to Design and Architecture. 1975. , ed. Nicholas Negroponte. Petrocelli/Charter.*

4 Alexander stated: "A digital computer is, essentially, the same as a huge army of clerks, equipped with rule books, pencil and paper, all stupid and entirely without initiative, but able to follow exactly millions of precisely defined operations. [...] In asking how the computer might be applied to architectural design, we must, therefore, ask ourselves what problems we know of in design that could be solved by such an army of clerks [...] At the moment there are very few such problems." Alexander, Christopher. 1964. A Much Asked Question About Computers and Design. Paper presented at Architecture and the Computer, Boston, Massachusetts.

5 Negroponte, Nicholas (ed.). 1975. Reflections on Computer Aids to Design and Architecture. Petrocelli/Charter.

6 Bazjanak, Vladimir, 1975. The promises and the disappointments of computer-aided design. Ibid., 17-267 Purcell, P., 1975. United Kingdom. Ibid., 207-233.

7 Milne, M., 1975. Whatever became of design methodology. Ibid., 30-36.

8 Negroponte, Nicholas and Leon Groisser. 1971. Computer Aids to Participatory Architecture. [Principal Investigators: Leon Groisser and Nicholas Negroponte]. Cambridge, Mass: Massachusetts Institute of Technology, 58.

9 Negroponte, Nicholas and Leon Groisser. 1970. URBAN 5: A Machine That Discusses Urban Design. In Emerging Methods In Environmental Design And Planning., ed. Gary T. Moore. Cambridge, MA: MIT Press.

10 Negroponte and Groisser, Computer Aids to Participatory Architecture, 59.

11 Negroponte, Nicholas. 1970. The Architecture Machine: Toward A More Human Environment. Cambridge, Mass.: MIT Press.

12 Ibid., 1.

13 Ibid., 7.

14 Licklider, J. C. R. 1960. Man-Computer Symbiosis. In IRE Transactions on Human Factors in Electronics HFE-1 4-11.

15 Nicholas Negroponte and Leon Groisser. 1970. Sector: The Semantics of Architecture Machines. Architectural Design, XL, 466-9.ü

16 Ibid.

17 Ibid.

18 Massachusetts Institute of Technology. Architecture Machine Group. 1976. Computer Mediated Inter- and Intra- personal Communication. Cambridge, Mass.: Massachusetts Institute of Technology, Dept. of Architecture, Architecture Machine Group.

19 Negroponte and Groisser, The Semantics of Architecture Machines.

20 Negroponte and Groisser, Computer Aids to Participatory Architecture.

21 The Conference was organized by Nigel Cross, in collaboration with Chris Jones and Reg Talbot. Cross, Nigel (ed.) 1972. Design Participation. Academy Editions.

22 Negroponte, Nicholas. 1972. Aspects of Living in an Architecture Machine. Ibid., 63-67.

23 ———. 1975. Soft architecture machines. Cambridge, Mass.: MIT Press.

24 Ibid., 108.

25 Ibid.

26 From 1973-1975 the Architecture Machine Group launched a computer aided participatory design research program entitled "Architecture by Yourself." The computer program that was being developed was named YONA, an acronym standing for "Your Own Native Architect" and of course referring to the intellectual father of the entire enterprise, the architect Yona Friedman, who also participated in the research program. See: Architecture Machine Group. 1978. Architecture Machinations: A Weekly Newsletter of the Architecture Machine Group. Cambridge, Mass.: MIT Department of Architecture.

27 An analysis of the discursive role of the "design amplifier's" computational structure in Nicholas Negroponte's non-paternalistic claim can be found in my thesis for the Master of Science in Architecture Studies, Design and Computation Area at the Massachusetts Institute of Technology, advised by Professor George Stiny. The thesis is cited as follows: Vardouli, Theodora. 2012. Design-for-Empowerment-for-Design: Computational Structures for Design Democratization. S.M., Massachusetts Institute of Technology, Dept. of Architecture.

28 Friedman, Yona. 1975. Toward a Scientific Architecture. Trans. Cynthia Lang. Cambridge, Mass.: MIT Press.

29 Weber, Jos. Denmark, Holland, Germany. In Negroponte (ed.), Reflections on Computer Aids, 257.

THE DESIGN METHODS MOVEMENT: THE RATIONALIZATION OF DESIGN IN THE 1960S THROUGH POSITIVIST AND PHENOMENOLOGICAL MODELS

Aslı Arpak, PhD Candidate In Design And Computation, *Massachusetts Institute of Technology*

INTRODUCTION

In the early 1960s, theorists, scientists, and engineers extensively studied the phenomenon of "design," and this research soon developed into the "science of design" as coined by Morris Asimov (1962). Although there was a logical-positivist approach to design methodologies in the beginning of the twentieth century with Modernism (Galison 1990, Cross 2000), the types of design research and design theory questions that we ask today took shape starting in the 1930s. Early theories of computing, the digital computer of the 1930s and 1940s, early cybernetics research, widespread industrialization, the World War II, and the early Cold War period dealt with exceedingly complex problems. Examples of these problems included large-scale organizational problems, such as war tactics, urban planning strategies, or management approaches; or organizational models of the mind, such as cognitive design processes, reasoning, or decision-making. These types of problems required complex problem-solving with larger cognitive capacities than individual entities possess. Consequently, rooted in military research, many new disciplines emerged in problem-solving, decision-making, and management science. Techniques such as operations research, statistical analysis and mathematical optimization were widely utilized in many areas of the industry as the war technologies were being applied to civil domains (Dantzig 1965, Dantzig and Veinott 1968, Hillier and Lieberman 2008). For instance, the field of ergonomics (or human factors) was formerly established centering on war equipment, measuring the physical and cognitive abilities of the situated users (Wickens et al. 1998, Meister 1999, Wickens and Hollands 2000, Salvendy 2012). Combined with industrialization, these principles propagated into the civil spheres both theoretically and practically.

In this context, designers had to resituate themselves to respond to these emerging technologies and sciences. Together with disciplines such as cybernetics, early modern cognitive science, and early AI, design activity was rethought and reshaped on the basis of behavior, perception, and cognition (Wiener 1948 Rpr.1961, Ruesch and Bateson 1951, Skinner 1953, Skinner 1957). The computer applications began to challenge the traditional understanding of design and creativity. The methods, introduced in practice and academia, were changing the ways designers approach design issues. The types of design discussions that we have in the scope of computation have a big tangent in the twentieth century history of science and history of computing in this way. Today, we recognize that incorporating computational ideas and principles in architectural design is not the sole utilization of computers or computational tools to aid formal decisions. We also emphasize that it is also not a direct translation of analogue processes into the digital, such as switching from drawing or physical modeling to drawing or modeling in computer-aided design (CAD) systems. Instead, computational methods have had deep implications on our understanding of the act of designing and the methods we employ throughout. Computing has posed design as a procedure, which is part of several other organizational procedures, and it has emphasized the cognitive and perceptual aspects of these procedures for the designer to explore. The early investigations in this topic were systematically carried out in the 1960s Design Methods Movement, engaging various disciplines and perspectives. In the articulation of potential design methods, several approaches emerged. While some researchers supported more analytic and mechanistic views, some researchers focused on experience and phenomenology. This paper studies how the positivist and phenomenological approaches formulate the phenomenon of design and how this formulation affects our understanding and communication of design practices.

ANALYTIC AND POSITIVIST MODELS OF COGNITION IN EARLY DESIGN METHODS

The rational and explicit handling of "design" started with a series of conferences and symposia in the UK during the 1960s and was developed further through subsequent publications worldwide. The event that can be acknowledged as the starting point of these studies is The Conference on Design Methods in September 1962 at the Imperial College London, organized by J. Christopher Jones and Denis G. Thornley (Jones 1963, Jones 2002). This conference was the first time that scientists and engineers began to study design from a specifically scientific viewpoint and to evaluate design methods. With the developments in cognitive science and early AI, design began to be handled in a cognitive and perceptual framework. The early digital computers, developed by Alan Turing and John von Neumann, laid the groundwork for further computing theories in which the computer was used both as a metaphor for the brain, and a tool to test the mental procedures. Coupled with the mathematical and organizational theories, which originated in the military, design began to be defined from various perspectives, such as design as problem-solving, design as decision-making, or design as information-processing. The cognitive and perceptual processes were rationalized, externalized, and tested for automation.

Mathematician Gordon Pask (1928-1996) participated in the Conference on Design Methods, and he was among the first scientists to emphasize the procedural aspects of design (Pask 1963). For Pask, design can be explained explicitly with algorithms and computable procedures. Thus, it can be defined and computed by humans or other mechanisms. The specific mechanisms that Pask refers to are the emerging computer technologies of the 1960s. In the context of the possible human-computer interactions at the time, Pask particularly interrogates the concepts and relations of design and visual perception. As Pask also mentioned in his conference talk, Marvin Minsky (1927-) and his lab team were pursuing research in the same field at the Massachusetts Institute of Technology (MIT) during this period (Pask 1963, Minsky 1974). Minsky and his team were studying "sketching" within the scope of human-computer interaction. In their projects, they were teaching a computer a set of design criteria that was defined by the user. Minsky predicted that the computer would aid the designer with its comparative calculations, and this was an ambition for collaborative design with the machines. Mathematician Christopher Alexander (1936-) was among the researchers to define design as a form of problem-solving (Alexander 1963). According to Alexander, design is shaped by our definition and therefore by the structure of the problem. As an extension of this idea, his investigation in the conference paper is highly focused on the components and substructures of physical structures. He further develops this theory in his thesis titled "Notes on the Synthesis of Form" (1963), which has become an important resource in design research, and introduces the "pattern theory" in his further studies (Alexander 1977).

In the early 1960s, design was discussed in scientific terms in relation to many fields including industry, engineering, and architecture. Many new technologies were being developed alongside emerging interdisciplinary studies. Early cybernetics and AI research had rigorous experimentation with digital computers and computer applications.

The use of symbolic languages and digital construction was a perfect complement to the positivist thought and had important consequences in the succeeding design and computing theories. When Ivan Sutherland designed the first graphical interface in the computer in 1963, he was explicit about the discrepancies between the computational structures and real structures –digitally represented objects and the real objects (Sutherland 1963). The abilities and limitations of computers and computational tools are deeply rooted in this phase (Upitis 2008). Being also a metaphor for the mind, the symbolic model was used to articulate cognitive and perceptual procedures. Once again, the symbolic structures suitably accompanied a mechanized view of the mind. Originating from this separation, there were symbolic and non-symbolic articulations, which became important distinctions for AI in the subsequent years.

These types of interdisciplinary research and problematics resulted in the creation of new scientific domains including information processing, decision-making, and complex systems. Considered one of the most influential scientists of the twentieth century, economist Herbert A. Simon (1916-2001) is the founder of these disciplines with his studies starting in the 1940s. In his book Administrative Behavior (1947, Rpr.1997), which was based on his doctoral thesis, he investigates the reasoning processes together with the behavioral and cognitive processes. Simon, along with Allen Newell (1927-1992) and John C. Shaw (1922-1991), focused on themes of both AI and human psychology and cognition in their research at the Carnegie Mellon University in the 1950s. Newell et al. (1958) sought to disprove the claim that the problem-solving processes were solely human activities. As a result, they succeeded in teaching a programmed computer how to problem solve. Thus, they were trying to make the problem-solving processes – like design– more understandable, and make the procedures explicit so that they could be automated. As Simon stressed, they separated the "information-gathering" stages and "design" stages, so that they focused on the reasoning and strategies independent of memory. This separation was an important distinction to make, which allowed Simon to focus on the sharing of knowledge and educational models in his theory. In the following years, Simon shared his further developed design theory when he was invited to MIT in March 1968 (MIT Compton Lectures, Lecture Archives 1968). Simon's design theory carries a pedagogical importance and his book Sciences of the Artificial (1968, Rpr.1997) has become one of the main resources in design research today.

EXPERIENTIAL AND PHENOMENOLOGICAL MODELS AND THE EDUCATIONAL CRITIQUE

Meanwhile in the 1960s and 1970s, the Design Methods Movement advanced with various events and meetings in both Europe and the US. Some of the highlighted events were the Design Participation Conference in Manchester (1971), the Design Activity International Conference in London (1973), the Portsmouth Changing Design Conference (1976), and the Design Methods in Action Conference in California-Berkeley (1977). Through such events, the design methods applications and principles were quickly making their way into design schools. For the most part, the positivist and mechanistic model was adopted following engineering design, to make design more efficient and optimized. For instance, mechanical engineer and industrial designer L. Bruce Archer (1922-2005) was teaching at the Ulm School of Design (Hochschule für Gestaltung, HfG Ulm) along with the mathematician Horst Rittel (1930-1990) and sociologist Hanno Kesting (1925-1975). Archer was a strong methodologist and published two important papers: "Systematic Method for Designers" (1963, Rpr.1964 and 1965) and "The Structure of the Design Process" (1968), which was based on his thesis. Their teaching agenda involved rigorous utilization of design analysis and design methodologies. In 1964, Archer became a professor at the Royal College of Art (RCA) in London and an important member of the Industrial Design [Engineering] Research Unit here. In 1967, he helped to found the UK-based Design Research Society (DRS), which has continued to organize various key events in design research today. The Design Methods Group (DMG) was co-founded at UC Berkeley by Gary Moore, Marvin Manheim and Martin Krampen with the help of Rittel, who began teaching there in 1963. The DMG Newsletter, founded also by Moore in 1968, served as an important source of information for design researchers worldwide and turned into the important journal Design Methods and Theories. In this manner, theorists were circulating design methods among design schools. The first resistance was received from the formalist design traditions at design schools and these confrontations were causing debates over the school curricula. Although the positivist approach has proven it use in other types of design problems like optimization, a strong critique of the positivist design methods approach developed in the subsequent years, especially in the issues regarding creative design processes and experiential parts of design.

In the 1970s, the divergences had become apparent among the theoreticians of the Design Methods Movement. Two of the early supporters, Alexander and Jones, announced their disassociations from the movement (Jones 1977). In 1966, Geoffrey Broadbent and Anthony Ward had organized the Design Methods in Architecture Symposium at the Portsmouth School of Architecture (Broadbent and Ward 1969). Broadbent (1981) reflects on the growing oppositions back in the day and explains that Ward had a particular agenda for the symposium: to provide "the confrontation between those whom he saw as behaviorists, representing a mechanized, quantified view of design and those (including himself) he saw as existentialist/ phenomenologist." Broadbent points at Ward's behaviorists Bruce Archer, Tom Markus, and Ray Struder, and explains their approach to design:

> Design was to be "scientific"–Struder was looking for a "unit of analyses in design measurable, in his words, against dimensions that are both relevant and empirically accessible." The designer has to start by analyzing human behavior, from which he could derive "quantities, qualities, and relationships." (Broadbent 1981)

The positivist, behaviorist, cognitivist, and phenomenological approaches soon had important influences in design education and teaching. Simon situated the "sciences of the artificial" as divergent to the "natural sciences," and keenly argued for the teaching of design science at institutes cultivated by disciplines such as architecture, law, medicine, or business, and not only by the disciplines of natural science and engineering. However, this tradition kept on evolving with great support to the positivist design approach, and promoted a direct application of the engineering techniques to design in order to increase efficiency. This approach thrived with the advanced computer applications and CAD systems in the schools of architecture. The main flaw of the positivist approach was to try to explain all scientific phenomena with "units" and "measurable dimensions" (Broadbent 1981). This approach has been highly critiqued by other theorists, primarily by those who argue for experiential and non-symbolic design methods. In his theory of Shape Grammars with Jim Gips, mathematician George Stiny keenly argued that these models can hardly serve as models of the mind or the models for creativity (Stiny and Gips 1972, Stiny and Gips 1974, Gips 1974, Stiny 1975). Shape grammar theory, along with other theories such as the space syntax theory (Hillier and Hanson 1984, Hillier 1996), emphasized the experiential aspects of design and focused on visual computation instead of the symbolic. Stiny placed very strong emphasis on this issue:

> Of course, the question of units is nothing new. It comes up over and over again without a solution. [...] There is a lot riding on whether or not it's practicable to calculate without units or symbols. The whole reach of calculating as a creative way of reasoning depends on the answer. (Stiny 2006)

This issue has indeed been critical for design practitioners and theorists. Starting in the 1970s, the limitations of symbolic systems have been evaluated and criticized in cybernetics and AI by scholars like Hubert Dreyfus (1972) as well as in design research. In design computing, Stiny has been strongly challenging the symbolic design methods and existing CAD systems (Stiny 2006). As Stiny emphasizes, the fully symbolic and fully mechanistic approaches in design methods, design tools, and cognitive models are not compatible with the creativity involved in the act of designing. Over the years, the symbolic and positivist methods have proved their validity in design processes that require statistics, optimization, and evaluation. By recognizing the relevancies of these methods together with their limitations, design methods can become much more inclusive and holistic. Incorporating different types of computing, such as visual computing or tactile computing, and joining the experiential and phenomenological aspects of design to design methods can increase designers' awareness, creativity, and flexibility. Stiny has succeeded in offering the shape grammar theory and its applications, allowing designers to engage in design via visual computing while offering a systematic approach by means of shape manipulation, rule application, and schemas. He emphasizes the importance of first-hand experience, engagement, non-symbolic manipulation and offers a new aesthetic paradigm. This position has been crucial in order to revisit and recognize the validities and restrictions of fully positivist and fully symbolic approaches, and it has been providing new grounds for design computing today. These types of holistic, experiential, and non-symbolic models have been evaluated and practiced by key design theorists and educators, such as

Donald Schön, William Porter, N. John Habraken, and Terry Knight at the School of Architecture and Planning at MIT among many other schools.

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DIGITAL &PHYSICAL SENSIBILITY

Stylianos Dritsas, Assistant Prof., *Singapore University of Technology and Design (SUTD)*

INTRODUCTION

It took several hundreds of years and the joint effort of the most brilliant minds of their time for the development of perhaps the first known algorithm to mankind: an apparatus for the multiplication of large numbers (Ball, 1912). In the short account of the history of mathematics, W. W. R. Ball presents a wide range of ingenious and sometimes clumsy set of contraptions, from as abstract as geometric diagrams and look up tables to as tangible as abaci and counting rods; all invented for the sole purpose of solving the mysterious problem of multiplication. However it was not until the development of the arithmetic/proto-algebraic method by the Arab mathematicians of the 8th century that the problem was once and for all solved [yet it took a few more hundred years until the methodology was adopted in Europe and beyond]. In its core lays a brilliant yet simultaneously mindless process of mechanically manipulating symbols [by transcription of digits on a piece of paper for instance] the validity of which is exclusively depended on the meticulous application of a few rewriting rules upon a limited set of numerical digits. This is quite a remarkable feat especially once reminded that today we learn how to perform the exact same process in our very early years of elementary school. For while knowledge creation requires substantial amount of time and effort and its early adoption finds steep barriers upon entry, once past a certain threshold of resistance it propagates at cataclysmic rates until it becomes a norm that nobody henceforth thinks of the world being without it [or the efforts that went into its development in the first place].

Computation is a concept which took off after the wide adoption information technology of the mid 70s but its roots span long before the commercialization of personal computers. The fields of mathematics, logic (Alan Turing, Alonzo Church) and engineering (Charles Babbage) are all key contributors and date well before the WWII (Castels, 1996). It is derived from the same concepts of algebraic calculation; the mechanical transformation of numerical quantities towards solving complex scientific problems; or at least as it was originally envisioned as few of the great-grandfathers of computation may have anticipated the social and cultural repercussions of information technology. The emerging pattern is perhaps that what initially appears as an innocuous technical innovation has far reaching effects by the mere introduction of new capability paving the grounds for human creativity to express itself upon. A key insight behind computation is in its removal the human factor from performing the mundane operation of shifting digits and letting a machine execute said operations at far more accurate and efficient rates. Why waste human capital in performing tasks machines can render better after all? A profoundly industrial concept seems thus to be the instigator of information technology and the shift of focus from physical to virtual due by an often forgotten factor: human presence was not eliminated altogether but merely displaced. It was exactly displaced into the realm of describing the sequences of "information events" required to take place for achieving a certain task. Colloquially we identify this process [computer] programming but if we remove its layers of technical specificity and look at its core principle we may notice that it is fundamentally a study of the concept of "the process": the analysis and design of functional constructs for manipulating resources, virtual or physical that is, via information.

ARCHITECTURE AND INFORMATION TECHNOLOGY

Professions and industries were created, adapted and perished in the light of this operational mode of thought and production [a calculator, once a job description of a human being, is now describing a mass produced object]. More than forty years later architecture and the building industry as a whole are at the cusp of fully aligning with this reality and pushing down knowledge gained into the elementary school grade. The concept of architectural computation is not new: Rocha (2004) offers an account of the early development of design theory starting with pioneering work already from the 60s. Yet, today we identify digital architecture by the realized products of the last and first decade of the millennium (Kolarevic, 2003; Kolarevic and Klinger 2008). There is an interesting philosophical debate of where we are situated at the moment and where we are heading towards. Which are the core principles that are being displaced by technology into the process domain, and where; and most importantly how can we successfully adapt, flourish and reinvent architectural education and practice?

The reasons for the slow rate of adoption of technology within the architectural domain is an interesting subject but nevertheless one of sociological study [was it out of rational necessity or self-inflicted bias] but it may suffice to observe that perhaps the special relationship between [virtual] information and [physical] matter at the very threshold of which architecture is situated may have contributed. Unlike other fields, for example the social sciences, we are quite literally grounded into physical reality. It is not thus coincidental that digital design methodology become accepted when the hiatus between creation in the virtual context and fabrication within physical material was reestablished by digital fabrication and manufacturing. Technologies which existed and employed in industrial design applications well in advance compared to architecture, but only recently become accessible and affordable for architectural production.

On the design thinking domain we can observe the definite shift of focus off the architectural end-product which is now placed upon the methods of its inception and production. Alexander's (1964) notions of the diagram [program] and the pattern [process] are early interpretations of this shift. In academia today we talk about "the design process" and its generative relationships as well as in practice we discuss about "the design protocols" and its performance specifications. What Rowe (1992) expresses as normative design thinking has moved away from classical prescriptive notions [ought to be] of typology and classification, apparent and underlying patterns of an architectural object to the realm of the descriptive [what is] analysis and design of the process itself. And exactly by this shift of focus [from objects to methods] we have witnessed a progressive virtualization by abstraction of architecture.

While technology has thus added one more degree of separation between architectural thinking and making and in doing so has perhaps altered the balance of existing tectonic sensibilities, on the other hand the exact same virtualization of the architectural language by use of information technology as means of design and production had some surprisingly positive side effects. For instance it is easier today to engage in every aspect of design from the extremely abstract conceptual to the very technical and scientific due to the mere existence of common substrate. The industrial specialization and separation of roles into finely grained isolated compartments of knowledge seem to have naturally fallen apart by the mere fact that design people, independent of background, can speak the same language: the language of design computation. Asymptotically thinking architecture appears to merge and converge into an instance of System's Design with the focus area of built space.

RESEARCH AND DESIGN

The transformation of architecture in the light of information technologies is speckled with creativity as well as controversy. The media wars of the end of 90s early 00s; the productive yet wasteful debate of whether computation is a legitimate medium for design, gave way to a phenomenal rate of production in the first decade of the millennium [but why not]. Critics argued whether the so called digital design regime exhibits the same level of architectural sophistication compared to its very immediate industrial design predecessors [perhaps not]. However it is also unreasonable to contrast between design languages evolved over decades of strive for innovation and new paradigms of thought and practice that has barely gone beyond scratching the surface.

An interesting and illuminating example may be found in the debate by which digital design is no more than a neo-formalist phenomenon. It is indeed easy to arrive to this conclusion by merely observing the most prominent examples of digital design [specific examples omitted for brevity]. However, form in itself and for the majority of the design of the past decade, has been a secondary consideration if at all any. It was the genuine fascination with potential for unconventional generation and the creative learning experience, as part of the adaptation to the notion of "the process", which was the true driving force; form was the delightful side-effect.

Arguably one of the most important lessons learned from this experimental phase, borrowed and adopted from science and technology is the concepts of "design by research": What kind of design may we arrive at, given a particular technology? A regime which signals we have more technology at our disposal than potential good causes and applications to employ it towards; a fundamentally different approach, perhaps the exact opposite, of the traditional direct/forward engineering mindset of finding technological solution to best fit particular problems at hand. As such design appears more open than what a psychologist would describe as a creative problem-solving phenomenon (Lawson, 1980).

This is not a new pattern but a recurring one. We may observe the same characteristics in the early stages of the industrial revolution at the time its fruits become available to the building industry. Affordable steel and efficient manufacture gave rise to a similar context of design euphoria. In other words, from a perspective of technological determinism, it appears that phases of disruptive technological innovation alternate with phases of stability and this directly [within a certain lag] reflects at the architectural domain. However research and design is continuously evolving at various speeds independent of circumstance but perhaps with variable magnitude.

Simplistically, research and design occurs in two distinct speeds: a high speed of frantic search for new ideas and potential applications and a slower rate that targets the consolidation and democratization of knowledge raising the level of discourse across the field. A great example can be found in the development of early design-computation and the exploration of digital media for design. On the R&D domain there has been an explosive amount of experimentation: concepts explored and applications developed. Some have been more successful than others while it is arguably very difficult to prune through the wilderness of esoteric products of imagination that only small expert communities may appreciate and even comprehend. But from exactly those nuggets on innovation as a whole the community resulted in the wider adoption of parametric design principle for the creative design and building information modeling for the delivery-oriented design masses. Both modes are important and interdependent on one another; for if no randomized evolution takes place the likelihood of stagnation increases, while without steady incremental adoption, blind exploration may yield wasted effort on potentially social and cultural irrelevant tangents.

INFORMATION MATTERS

Speaking of social and cultural mandates, it seem today [even though our inauspicious global economic predicament constituting creative thinking marginally more precarious] there are very clear directions to look towards for innovative research and design. For instance, despite the concentration of the architectural community's interest around the concept of sustainable design we are still away from a contemporary approach to green architecture. Current applications seem to struggle to move beyond adoption of green practices for commercial valuation purposes, techno-rational approaches of energy control resembling more of MEP rather than architectural design, or jealous conservationist views seeking to suppress any form of expression beyond narrow focus on functional austerity and morale. The stakes for an inspiring and exciting new version of architecture are high. This is not unlike the earlier challenge for the development of a digital design language and it is also not without precedence as the debate for sustainable development already begun in the 70s. What is perhaps the real challenge is to contextualize current intellectual and technical capability towards inventing new modes of thinking and practicing.

Let us think of a car for a moment; a design object of profound intelligence, conceptualized, analyzed and manufactured using advanced technology to achieve visual and functional perfection; utilizing electronic and mechanical systems that dynamically monitor and adjust the vehicle's performance in real-time. Now, a building on the other hand, and in particular a wall for instance, is drawn in two dimensions, analyzed statically and made out of extruded aluminum and planar glass; studs and chipboard; brick and mortar. Quite a detrimental description, one may argue, however it may also come as a surprise [at least to most people outside the building industry] to find out that building components, weight and cost about the same as small vehicles, even though pound for pound the performance hiatus is gapping. What is the reason then for this disparity of expectations? How would buildings look and work if they were designed similar to automotive, aerospace or even a certain consumer grade industrial products?

While this observation is disturbing, it is also revealing of a great opportunity for investigating new modes for thinking and producing architecture. Our expectations for buildings are perhaps low because we design using coarse abstractions in disjoint dimensions: towards aesthetic appeal and threshold compliance to building control regulations and financial return on investment. We thus may need to first shift our mental paradigm and look at buildings as complex and dynamic systems, investigate methodologies for integrating design with analysis, experiment with new materials and manufacturing processes for their construction and increase their design information density. Do we have the capacity of looking at architecture beyond lump sum generalizations and delve into the minute complex phenomena beyond narrative? We absolutely do. Computational design has established the platform on top of which we can analyze, simulate and design in a both creative but simultaneously thorough modes. It is exactly those digital design methodologies we developed over the past decade we may best employ in looking at current mandates from a fresh perspective.

The most prominent arenas for contemporary research as already hinted are design computation, building materials and digital fabrication. In particular, on the design computation domain there has been a long trail of thought on the performance analysis and design of built space: exploration of computation to assist us understanding the repercussion of design action in terms of aesthetic, functional, financial, human and environmental aspects in a unified and integrated manner. The result of this development gave rise to building information modeling. Today we build some highly elaborate relational models for the sole purpose of automating documentation and coordination [to eliminate the mundane]. However, as soon as we have these models available [and realize their potential] we may attach introspection and optimization mechanisms that seek to highlight and improve particular characteristics or sets thereof. This development will allow us to actually first understand the implication of design, discover unforeseen synergies and then seek for design expression and innovation moving away from coarse generic aphorisms. What stands beyond this is the development of true dynamic models which exist today but do to high computational time/cost are only limited to small niche domains. Once these obstacles are overcome we may see the emergence of design computing environments where one could design interactively within a running simulation enchasing intuition about building statics, human behavior, etc.

Material design is also a domain where we shall expect future research and design. This can be better seen parallel to the evolution of digital fabrication. As the cost of advanced numerical control manufacturing technology has rapidly decreased over the past decade (UNESCE, 2005) we have witnessed an accelerated adoption of CNC technologies within architecture. Digital fabrication presents an opportunity to reestablish links between physical and virtual weakened due to information technology and develop a digital tectonic sensibility by exploring form, material and the formation process in vastly new ways. For instance, the levels of accuracy and control of manufacture using said technologies are unprecedented in architecture. Within digital fabrication there two segments of interest: prototyping and manufacture. Prototyping discusses design development shifting away from visual representation of a design object [rendered images and maquettes] into the process of performance simulation [exploring material properties, architectural detailing, manufacture and assembly process]. In building construction we have the opportunity to rethink of the notion of prefabrication within the context of flexible manufacturing, more commonly known as mass-customization (Pine, 2001). This shift the balance away from the industrial concepts of standardization which prefabrication is inspired and come closer to the domain of bespoke design to production which has been traditionally architectures turf (). The capability prospect of achieving increased complexity at the same efficiency characteristics of traditional standard manufacture offers the possibility of repositioning digital design from currently the early-adopters/luxury products domain [in response to formal/cost complexity implication] into an offer of intrinsic design sophistication for everyone. Digital prototyping and manufacture research meet at the domain of material due to the following of realizations: digital design has exhausted formal exploration [everyone today is capable of producing it], current building material are problematic [within the environmental argument], experimentation with material is more accessible [due to prototyping and manufacture]. Thus an interpretation of these parameters may suggest that given our increased fabrication resolution capability we may either revisit traditional material [such as wood, concrete and steel] from a new digital perspective or we may drop down a level of detail into design composition of material properties from first principles within the realm of composites.

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COMPUTATIONAL DESIGN AS A PROCESS TO SUPPORT DESIGN EXPLORATION RATHER THAN DESIGN CONFIRMATION

Axel Kilian, Assistant Prof., *Princeton University*

Much has been achieved in translating analytical processes into computational models. Such analytical processes are essential for evaluation and simulation of design definitions and the progress in computer hardware and algorithms has allowed for increases in the size and complexity of such calculations that make many of today's designs possible that were unthinkable a few years ago. This progress is not limited to the realm of the tangible but also and more so to processes of feedback and control in physical artifacts. What largely remains untouched in computational terms is the early design definition and exploration.

Design has been predominantly represented through geometric modeling but the concepts behind the design are rarely included in the computational model beyond geometric representation. But it the fluid back and forth translation between design concepts and formal representations where much of design innovation takes place in th earl stages of the process. It is this fluid design state that is hardest to capture with current computational approaches. Current trends to incorporate performative metrics as a way to provide immediate feedback to generative design steps are promising but such feedback loops usually also have to be rebuilt if substantial conceptual shifts occur in the design.

Computational design is still used and viewed too much as a problem solving method that comes into play once the task has been clearly defined. Yet much of the potential of a design challenge lies in the variation of the challenge definition. Many good designers do challenge and redefine the design definition, but much could be gained from playing rapidly through a range of very different scenarios beyond the initially defined starting condition to gain insight into the dependencies of the given constraints. For instance if the design challenge is a high-rise building it would be very useful to understand what drives the decision for such a typology and how those drivers may be satisfied with a different architectural typology if other benefits can be gained. A similar question remains in the exchange between disciplines in a design project. True innovation often involves solutions that cross boundaries between disciplines and thereby render existing computational disciplinary models useless. Worse the investment into a computational process may stand in the way of a novel approach and maybe discarded out of fear of the loss of time in rebuilding. Therefore different exploration directions are no longer equal but those directions supported by existing metrics and computational metrics are favored over other unconventional directions that may hold more promise in the long run but would require upfront investment in remodeling the computational processes to test them. This effect reinforces the need to stay weary of established processes no matter how refined they are and encourage tool building on an individual basis in order to retain a certain fluency in building novel computational design models as needed. Design should not be solely about the execution of established processes but about querying the understanding of the factors involved. This is a much more complex task and it goes far beyond the traditional geometric and numerical representation of current computational practices but it happens in designers minds regardless of the involvement of computation. The question is whether by externalizing such processes more can be learned and explorations can be pushed further to improving the downstream design processes.

COMPUTATIONAL DESIGN VS DEPLOYED COMPUTATIONAL SYSTEMS

Computational design in architecture and engineering has largely been limited to the definition of form and performative evaluation such geometries. Interactive architecture has been developing to expand the use of computation into the occupational stage. As most other disciplines around product development are integrating the computational systems from the design stages into the deployed stage where they become an integral part of the operation of the object. The Smartphones are an obvious example for this development. The physical artifact has become relatively generic as a device with little changes occurring to the physical device – most changes happen on the functional inner architecture and most important on the computational architecture and interface and increasingly through its networked state connecting the device to much larger systems disembodied from the device(the cloud etc.) This trend offers new possibilities to the idea of design exploration where the design is never complete but in fact an evolving prototype in the real world that reconfigures itself through computational driven reconfigurations and new network connections that expand its capability and meaning as a device. A similar thing does already happen to the network enabled use of architecture in terms of navigation and transactions for instance in the hotel sector where transactions for choosing and booking a room are adhoc through a networked device that is location aware. The architecture itself may not change but the way it is viewed and accessed is and therefore also its potential users and perception. Much use of the term “Smart” has been used and of course there are also examples of “smart” architecture. It seems to have been used mostly for performative architecture and the integration of actuation and sensing for adaptive facades and the regulation of building systems. But it may go much further through a distributed sense of what a building or a collection of buildings can be and do and by linking them to users in novel ways affect programming, usage, and energy consumption as well as the flow of people in between buildings in the city.

COMPUTATION AS A HOLISTIC PROCESS

If computation is understood more as a systemic sense not limited to any particular stage of the life cycle of an artifact and also not limited to a particular scale one may arrive at different approaches in computational design as well. With the emphasis in this edition title being on “design” in “computational design” one may ask what the computational aspect adds to design. Computation is still an obstacle in many cases in translating design intent; it lacks the fluidity of human thoughts and the emergence of ideas so common in successful brainstorming sessions. But it does offer the juggling and processing of very large data and association sets at levels unthinkable for a human or at least with the same precision. But that precision maybe what is in the way of a more creative process as forgetting also requires reinventing or reassembling from what is still retrievable. Such that a human brain seems to constantly reconstruct its knowledge in filling the gaps and missing pieces and fluidly shifting from recalling things to creating new thoughts. This is bound to be a messy and unreliable process and most of the times will produce unusable results, errors, confusion. But in a design process focusing on searching a novel approach it can be very helpful to allow for such cognitive noise enriched by strong associations to the background knowledge and experience a person may have. But this will rely on a number of representations of the idea beyond geometry and form, or start out with a formal idea but be translated into a conceptual reading of it, or be interpreted functionally. These type of translations and reinventions of an idea in the concept stages is what is very hard to capture or implement in a computational way with the current emphasis on geometry and the underlying numerical representation. So the desire to celebrate the accomplishments of a geometry based computational design approach excelling at producing images and instructions for machining and fabrication is understandable but looking at the computational design challenge overall the gap in contributions to the conceptual realm is very large and rarely discussed. This critic of the dominant approach to computational design today is not meant as a glorification of human designers but more a reminder of the respective strengths and weaknesses of the different approaches and to see them not so much as competing process but as a potential collaboration between design in the mind and its externalized computational processes. One may also ask what constitutes the design construct in the end, does it include the process, the code the concept development or only the result that remains and survives the designer and processes that created it? As noted earlier this distinction maybe dissolving as more computation moves into the final product computational processes have a larger impact on the perception of a designed object even to the point where the physical construct becomes exchangeable as the computational infrastructure carries over. Architecture is different of course due to its scale and reliance on infrastructure. But if one gives up the expectation that reconfigurability of a large structure has to also mean large scale physical reconfigurability the question of the impact of systemic computation on architectural and urban scale becomes more interesting.

DESIGN IN A SEA OF DATA

Data visualization and queries done interactively using computation provide insights never possible through a static representational depiction. If such visualization becomes the basis of decision making and not just retrospective evaluation new possibilities open up. If the computational system developed for decision making during the design phase also transitions into the usage phase for decision making on the use of the design as well as an evaluation of the design intents some insights about the process may be gained. But data alone does not offer much especially a lot of it – and the algorithmic processing of the data needs to be geared towards certain points of interest during their design so again the evaluation will most likely prejudiced toward certain expected outcomes. But can this type of data in its unstructured redundancy potentially contain non numerical and non-geometric insights about spatial relations and architectural questions? Even simple things once embedded in the complexities of the world create enormous data trails when comprehensive monitored but what is it good for? It all sounds very much like brute force computation because it is possible not necessarily because it is necessary. In Ben Fry's piece "origin of Species" he processes the entire set of editions of Darwin's book and shows in one overview page dynamically how the editions expand and contract how new text blocks enter and disappear –a fascinating example of retracing a design development based on the traces left in the work. This is paper based book writing revisited through computational means but it provides immediate insights into an otherwise for the novice impenetrable history of the development of this seminal book. What insights could be gained by tomorrows historians from mining the practically infinite data set we accumulate around almost any everyday action in our lives, intricately traced down to the start and end time of music played, phone call made, door opened, subway ride taken. Does such minute tracing of an individual's action within a similarly traced society reveal patterns and insights that may allow for the retracing a person's design thoughts after the fact, the tracing of an idea from origin until fruition a few hours, days later? It certainly sounds like a much looser gaze than staring at the geometry files or the code logs of computational design development because it is much more likely to catch traces of adjacent and possibly relevant outside influences, conceptual leaps, meandering thought patterns or dead ends. Ultimately computation already acts as connective tissue between many disciplines through shared algorithms and common models of abstraction. Distinctions remain between disciplines but brute force computing in data processing already replaces more refined and differentiated approaches in cases like automated translation or simulation. So ironically the lowest common denominator may become the de facto unifying approach to different problems across disciplines not because it is the best fit but simply because it exists and is possible to apply given the computational infrastructure. Computational design in a conceptual sense has not benefited or suffered from this approach yet but it is probably only a question of time and the research left to be done to develop the appropriate models. Also the boundaries of what constitutes a computational process will change. Data is cheap but insights rule and will determine advantages between different players. Facebook is facing the dilemma that it has enormous amounts of such highly personalized data but is struggling to gain insights from it that help it to make money. But such efforts are driven by a business perspective and if no short term gains can be made from the enormous investments such efforts will not prevail on an interconnected large scale. But just as back dating of tree logs is possibly by an almost uninterrupted chain of growth ring patterns for many world regions tomorrows computational processes will likely not have a problem with synchronizing and cross linking fragmented data islands across domains.

Therefore computational design is really becoming the design of the world through the traces we leave and the decisions we make based on looking back on these traces and it will be less and less an isolated geometric or numeric, performative or optimization driven computational island but more one aspect in a sea of factors that correlated by time, location, person or else and relied on for many parallel aspects in decision making in design as well as in operating the designs once they are made.

HAVE YOU SEEN OUTSIDE BARBARELLA'S WINDOW?: A SOFTWARE APPROACH TO CAD

Alexandros Tsamis, Associate Prof., *Universidad Adolfo Ibañez (UAI)*

In his 1968 article entitled "The Triumph of Software" , Reyner Banham proposes a distinction. By comparing two films, Stanley Kubrick's *2001: A Space Odyssey (1968)* and Robert Vadim's *Barbarella* (1968), Banham recasts the terms "Hardware" and "Software" to characterize their respective architectural settings. He writes of Barbarella's "ambience of curved, pliable, continuous, breathing, adaptable surfaces" and juxtaposes it with "all that grey plastic and crackle-finish metal, and knobs and switches, all that ... yeah ... hardware!' in 2001*: A Space Odyssey*.

In 1968, the word hardware was commonly understood as equipment- things that could be touched by hand, machine parts, knobs, switches, etc.

On the other hand, the term software was just beginning to emerge in the fields of information theory and computer science. It was still up for grabs. For Banham, *Barbarella's* "software" environment is a responsive environment. "Responsive environment in the sense of not being rigid and unyielding; articulated only by hinges between disparate rigid parts".

However, as Sylvia Lavin rightfully points out in her 2002 essay "Plasticity at Work", Banham's distinction between "Hardware" and "Software" merely brings to the surface the softer side of "hardware". In other words, "Software", for Lavin, is relating to another kind of Hardware, albeit a different kind of formal expression that is plastic, pliable, and continuous.

Nevertheless, there is another kind of "Software" in Barbarella; even softer that the "curved, pliable, continuous, breathing, adaptable surfaces" with which Banham very much obsesses. Although Jane Fonda makes it hard for most of us to focus anywhere else, all we have to do to find it, is look outside the window of her spaceship. When Vadim is called to "render" the outside he doesn't build a set. For him, the spaceship's environment can effectively be portrayed as a collection of bubbles floating in a translucent viscous liquid; as a colorful lit mixture of water and oil; as the igniting of hand-held fireworks (the kind that you probably get as an ornament on your fancy summer cocktail) or like milk, as it drops on a well oiled up glass surface. He relies on effects of fleeting physical phenomena; the kind of environmental effects that **Boundaries** cannot capture, regardless of how pliable they are. Quite literally, Vadim films environments of evolving chemical phenomena, juxtaposes them against the space ship window and allows them to assume the role of the outside.

Here, the architectural setting of outside is understood and visualized as pure **Property.**

In this paper, a "Software" understanding of space implies precisely this: Space can be perceived as, and operated upon, as an environment of pure Property.

In "*The Architecture of the Well-tempered Environment*" Banham pushes for the "abandonment of the ethics of the structural solution in favor of the performative space of fire", he claims that architecture as we know it (the history, perception and production of enclosing envelopes) is only a special case of what he called the production of "fit environments". Today, in an age of great ecological concern, the architectural community - theoreticians and practitioners alike - have 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. 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". Most speculatively, Sanford Kwinter who has been arguing for some time now that "Matter is the new Space" recently proposed that "Morphogenesis (in architecture) is dead!" and also that "Space is the result of matter energy and information coming together". 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". 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.

It seems to me (and all this is pure conjecture or bias on my part) 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, environment is quite literally becoming the object of design itself. We are moving away from the imposed-preconceived Cartesian object (pliable or not) which negotiates through its boundaries its presence within its immediate context.

Instead the discipline is already considering an architecture in which the "hardware" of form is only an instance of the "software" of environment.

Furthermore, beyond the technical pragmatics of clean, renewable, passive energy and all the performance anxieties 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 aspires to be actively 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, **Environment has become architecture's new interior**.

My interest as a designer starts precisely here. How do newly forming propositions about the role of environment in the discipline become operational tactics in the design practice? The object of investigation here is how the tendency to prioritize **property** over **boundary** in the perception of space can constitute for a practitioner a **MANIPULABE** endeavor**.** At this point calculation/computation enters the discussion.

THE CURIOUS CASE OF REPRESENTATION

A mode of representation, it can be argued, preconditions our perception, in that the way in which we represent "things" leaves out those aspects of perception that are left unrepresented. And yet, paradoxically, precisely those boundaries of our representations allow us to perceive and therefore manipulate new things.

Coming from music, Jeanne Bamberger makes a distinction between "units of perception" and "units of description," in which she writes:

Individuals in particular disciplines tend to take the objects and relations named by descriptive, symbolic conventions associated with the discipline as just those that exist in the particular domain. Through practice, symbol-based entities become the objects, features, and relations that tacitly shape the theory and structure of the domain- how users think, what they know, teach to others, and thus what they take to be knowledge. As a result, units of description may come perilously close to (pretending to be) units of perception – we hear and see (only) what we can say.

For example, Descartes' method of coordinates, which was conceived as a generalization of the proportional diagrams of the artist and architect, translated the form of a curve and the position of a point into numbers. Moreover, it was D'Arcy Thompson who employed Descartes' method in order to translate for example the form of a fish into a precise mathematical entity. By inscribing it onto a grid of rectangular coordinates, the fish (now its outline) can be reconstructed. These coordinates could then be altered- mathematically deformed- to obtain new, transformed figures from an original set of coordinates. His attempt to mathematically describe the difference between species, gave him the tool to manipulate "imprecise" geometrical objects through a comparison of their related forms.

Thompson's "theory of transformation" makes precise mathematical definitions of forms that were previously only described verbally or studied in isolation. He suggested a precise method in which forms are studied relative to one another. In *Growth and Form* he makes an observation about the modes of operation within the scientific world.

The study of form may be descriptive merely, or it may become analytical. We begin by describing the shape of an object in the simple words of common speech; we end by defining it in the precise language of mathematics; and the one method tends to follow the other in strict scientific order and historical continuity. Thus for instance the form of the earth or of the raindrop or the rainbow or the hanging chain or the path of the stone thrown up into the air, may all be described, however inadequately, in common words; but we have learned to comprehend and to define the sphere, the catenary, or the parabola we have made a wonderful and perhaps a manifold advance.

For Thomson, an approximate description, which is closer to perception, precedes (scientific) representation. But is this truly the case? Is it not also the case that the mathematically defined object, the represented object, is also there to be perceived? - i.e. isn't the "thing" in front of you?

As we can deduce from Thompson's observations on form, "things" can be mathematically defined: the earth is now the sphere, the raindrop is the catenary, and the hanging chain the parabola. Kepler's famous "ubi material, ibi geometria" reflects this same frame of mind. The scientist, now having a choice, works with representations of "things" instead of the "things" themselves. But as George Stiny would say, for a designer this is not a problem. In design, unlike in science, representations of "things" are only temporary and when they exist they become "things" themselves, autonomous "things". Literally, representations are the "material" of design.

Thompson's theory of transformation, more generally known as the mathematics of topology, caught the attention of the 90's architectural discourse, lending it as a conceptual and at the same time an operational tool with which to handle approximation. In other words topology, as it was embedded in animation and later associative geometry (parametric) software, it allowed designers to put their hands on issues of plasticity as they were described earlier in this chapter. Topology is already embedded in the architect's CAD software. A NURBS surface- within 3D modeling software- is by default topologically defined; a possible relocation of any control point throughout the surface affects the position of its neighboring points, which are redefined respectively. It is a surface defined by equations and relationships, rather than a singular form projected on the screen. The designer was able, through transformational geometry, to visualize and manipulate formal approximations, which do not belong to the realm of the square and the compass.

Nevertheless, if we apply our distinction between boundary and property we will see that all operations of geometric topological transformations are associated with boundaries; "soft" and pliable boundaries. I couldn't agree more with Michael Meredith who advocates the transition from "control to design". Control (manipulability) is not the end of the game. It doesn't mean much by itself. It doesn't give value to any project. Nevertheless, it serves as a pre-condition for the act of design.

Especially when we are dealing with digital computers and their strict mathematical (parametric or algorithmic) definitions.

VSPACE: THE ENVIRONMENT OF REACTION DIFFUSION.

What I am advocating for here is to examine our current CAD Design tools as they certainly impose through their structure an ideology to the design domain. They are not "generic" or "universal" design platforms. The reason is quite simple. Any structured form of representation is accompanied by choices. If we just consider the term B-Rep (Boundary Representation) we will see that in CAD today the world of design is the world of boundaries; a world that is a relic of Decartes and his scientific method. In B-Rep software all design activity happens at the level of boundaries. B-Rep software are advocates of what Banham terms "the structural solution"

In VSpace on the other hand, the manipulable entities are properties. It is also not a "universal" design machine. It comes with its own structure, its own preconditions. Ultimately it seeks a mode of expression that addresses the recently forming understanding of environment and its role in the contemporary discourse.

A continuously evolving environment of exchange between substances – products and byproducts – was theoretically described in a lecture given to Manchester University in 1952 by Alan Turing, who speculated upon the 'chemical basis of morphogenesis'. Turing suggested that: 'A system of chemical substances, called morphogens, reacting together and diffusing through a tissue, is adequate to account for the main phenomena of morphogenesis.' In short, his hypothesis was that 'form' or 'formation' could be explained as the result of chemical interactions between substances.

The Belousov-Zhabotinsky (BZ) type reaction, introduced by Boris Pavlovich Belousov in the early 1950s and further investigated by Anatol Zhabotinsky in 1964, proved Turing's speculations to be true. Wave-like patterns emerged from the catalytic oxidation of malonic acid by potassium bromate. Narrow, uniform regions, sections of clear spot exhibiting hexagonal arrangements, striped areas, and areas of intricate mixtures of stripes and spots, all coexisted in one sample, depending on the variation in the concentration of substances. By changing the properties of the environment through exposure to different lighting conditions, or by changing the concentration of either substance in the mixture, the system appeared to produce steady states.

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", although still within the "structural solution" logic, is re-interpreted as a viable computer model of reversing the relationship between boundaries and properties in design computer applications. Influenced by the "compound" understanding of SHAPE in Shape Grammars 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. The design world in VSpace is a world of interaction of properties.

Revisiting the BZ reaction digitally, three 'substances' A, B and C, whose concentrations can infinitely vary from zero to one, can be distributed as mixtures in a voxel space. As substances interact with each other, gradient fields start to form and eventually three-dimensional figurations emerge. In this computed environment, nothing gets lost; product and byproduct are of equal importance, all are present within the same system, and all are equally responsible for the emergence of pattern.

Although at a nascent stage in regards to its efficacy in architectural design, the reaction-diffusion model of thought 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 parts to properties. A re-articulation of the notion of environment as a topology of exchange between product and byproduct – a milieu of perpetual transformation – would yield a shift in discourse of the part-to-whole relationship and inevitably offer a novel understanding of not only the way we design but also in the way we build. Here is where computation finds its most significant role. In a constant feedback loop between design as a cultural endeavor and practice with its pragmatic requirements, computation acts as a negotiator.

oh... here goes Jane Fonda again.

ENDNOTES

1 Banham, Reyner, 'The Triumph of Software', New Society, Harrison Raison, London (October 31, Volume 12, No. 318, 1968), pp 629-630.

2 Lavin, Sylvia, 'Plasticity at Work', Mood River, Ohio: Wexner Centre for the Arts, (2002), pp.74-81.

3 Boundaries describe where one thing stops and another begins. They refer to perceptible edges and in mathematics they are usually described with descriptive geometry. From a common sense point of view, boundaries describe the shape of things. On the other hand, properties refer to qualities. Color, temperature, transparency, density and so on. Properties are also perceptible things and in mathematics are usually described with numerical values. Although one could go on and on about trying to accurately define the terms Boundary and Property, they are used here with common sense.

4 Hight, Cristopher, 'Putting out the Fire with Gasoline: Parables of Entropy and Homeostasis from the Second Machnine Age to the Information Age', in Softspace, From a Representation of Form to a Simulation of Space (ed.) Sean Lally & Jessica Young, Routledge, London (2007) pp.18-19.

5 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.

6 Quoted in Jason Payne, 'Heather Roberge, Matter and Sense' in Softspace, From a Representation of Form to a Simulation of Space, editors Sean Lally & Jessica Young, Routelage, London (2007), p.127.

7 With the statement "Morphogenesis is dead" I assume Kwinter means that form can no longer be the sole object of inquiry in design.

8 Kwinter's last two statements come directly from my notes of his lecture at the NEAR Conference: At the Intersection of Architecture, Nature, Technology held at Pratt University on March 24-25,2011.

9 Kipnis, Jeffrey, A Family Affair, in Mark Rappolt (ed) Greg Lynn Form, Rizzoli, New York (2008), p.201.

10 Lally, Sean, 'Eat Me Drink Me, in Architectural Design (AD): Territory Architecture Beyond Environment, (ed.) David Gissen, John Wiley & Sons Limited, London (May/June 2010) pp.16-19.

11 The 'ecological project' refers to the architecture community's recent attempt to define a sustainable aesthetic. It seems that we are oscillating between three categories of sustainable approaches: first, the 'techno-rationalist', who understand buildings as hyper-efficient machines populated with solar panels and live greenery in the hope that more optimized components and systems will solve the problems that previous components and systems have caused; second, the 'bio-organicist', who design buildings as if they are exotic plants in the hope that they will live harmoniously with the rest of the plants on the planet; and third, the 'neo-vernacularist', who promote going back to living in the mountains in the hope of growing their own tomatoes and living happily ever after.

12 Tsamis, Alexandros, 'Go Brown. Innerdisciplinary Conjectures' in Architectural Design (AD) : Ecoredux. Design Remedies for an Ailing Planet, (Ed) Kallipoliti Lydia, John Wiley and Sons, London (June 2010), p. 80.

13 Term borrowed from Kipnis, Jeffrey, 'Performance anxiety?' in 2G no.16 (4) 2000, p.4-9.

14 Bamberger, Jeanne & Dissea, Andrea 'Music as Embodied Mathematics: A Study of a Mutually Informing Affinity', International Journal of Computers for Mathematical Learning 8, Kluwer Academic Publishers, Netherlands (2003), p.132.

15 Thompson, D'Arcy, 'On Growth and Form', Cambridge University Press, Cambridge (1992), p.271

16 Ibid. 271-2

17 Ibid. 17

18 Where there is material, there is geometry.

19 George Stiny, 'Shape. Talking About Seeing and Doing', MIT Press, Cambridge Mass (2006)

20 Meredith, Michael (Author, Editor), Aranda-Lasch (Editor), Mutsuro Sasaki (Editor), 'From

Control to Design: Parametric/Algorithmic Architecture', Actar (2008).

21 Either as independent packages or as platforms for custom software, scripts and so on.

22 For a thorough account on VSpace please see, Tsamis, Alexandros, "Software Tectonics", PhD Thesis. MIT, 2012.

23 Alan Turing, 'The Chemical Basis of Morphogenesis', Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences, Vol 237, No 641, 14 August 1952, p 37.

24 Ibid

25 For a detailed account of the reaction-diffusion morphogenetic phenomena see Brian C Goodwin, 'Structuralist Research Program in Developmental Biology', in Mark Rappolt (ed), Greg Lynn Form, Rizzoli (New York), 2008, p 177.

26 March, Lionel, 'The Architecture of Form', Cambridge University Press, (1976), p. 41.

27 This project was initially developed in collaboration with Kaustuv DeBiswas, a PhD candidate in Design and Computation (Department of Architecture, MIT) whose contribution was key to the development of the algorithms.

28 A voxel is a three-dimensional unit (similar to a pixel in two dimensions) that for the purposes of this project acts as a placeholder or tissue for the reaction-diffusion process to take place. It allows for the definition of a six-manifold topology, as it is defined by location in Euclidian space with X, Y, Z coordinates and a color, which is calculated as a combination of R, G, B values.

THEREMINSPACE: THE NEXT CHALLENGE FOR DIGITAL DESIGN TOOLS?

Emre Erkal, Dr. Architect, *Erkal Architecture*

Design tools and the environment produced with them have a cyclical relationship. What is designed and built gets to shape the current frameworks of spatial understanding and therefore, what is expected in the future. In turn, they are produced by design tools which are limited in their own ways with the same frameworks that the society finds relevant for solving spatial problems.

The design tools of the modernist period in architecture – which attained its full potency in the 19th century and is still active even though its heydays are over – have been the part and parcel of architectural education as well as practice. These tools are mainly mechanical in nature, and learning to use them involves sensorimotor training as well as conceptual education.

The spatial logic of modernist architectural production has been characterized by a series of buildings: Walter Gropius' Bauhaus, Le Corbusier's Villa Savoy, Frank Lloyd Wright's Falling Water, Mies van der Rohe's Barcelona Pavilion and the Seagram Building, Phillip Johnson's Glass House and similar projects. In effect, Mieasian perspectival paradigm of the empty void, Le Corbusier's notion of the open plan was instrumental in conceiving of the modernist

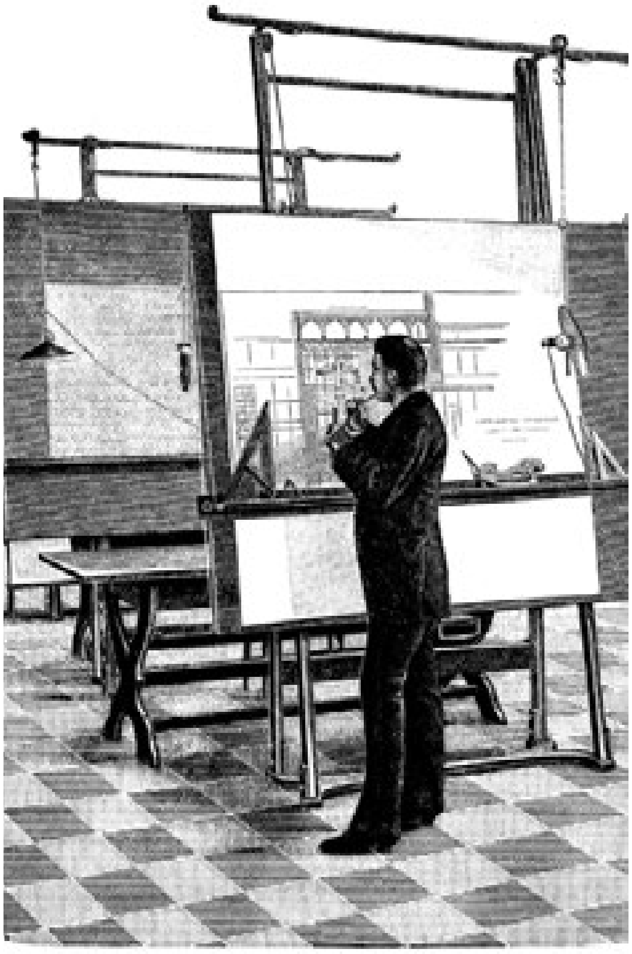

Figure-1:. *Design tools of a 19th century modern architect*

Figure-2: *Mies van der Rohe: Perspective collage for a museum*

Figure-3: *Mies van der Rohe: Neue Nationalgalerie in Berlin*

spatial logic (Giedion, 1941). The idea of space as a Euclidean void constructed in three dimensional Cartesian coordinate systems is the prevalent notion in modernism.

It is reported that by the virtue of technological proliferation and the rise of networks, a new kind of society and a new kind of urban space is emerging today with flow being its primary figure (Castells, 2004). Therefore there is a further challenge for today's designers. In addition to their expected responsibilities in producing the environment, they have to develop the pertinent design tools for utilizing this emerging spatial logic. Just as the drafting table and orthogonal projections of plan and section were the tools of the mechanical modernist architect, the contemporary architect has to develop a responsive sensorimotor relationship with the design tools and its product in the process of design.

In order to find clues to this problem, it is arguably illuminating to study the evolution of interfaces developed for musical production. Musical interfaces are relevant to the spatial logic of contemporary society in that they are devised to modulate a continuous flow. They are also temporal by nature and they need to couple the performer with with physical world, establishing a sensorimotor relationship. One such interesting device is Theremin from 1919. Theremin could shed light on avoiding the pitfalls of digital abstraction for setting the agenda for new design tools.

QUALCULATION AND THE NEW URBAN LANDSCAPE

Many thinkers have recently identified the omnipresent nature of computational abundance in the urban environment as a defining factor of the emerging notion of space.[1] With the recent advances in computation, the current environment is infused with computational devices working at various scales. Furthermore, some characterizations argue that agglomeration of devices and interfaces yield to a seamless and almost haptic experiencing of space and time even though the basis of this thick computational background is inherently an enormous quantification of discrete intensities. Thrift draws attention to the changing nature of computational calculation in our urban habitat allowing the "construction of new generative microworlds which allow many millions of calculations continually to be made in the background of any encounter" and calls this new calculative sense, qualculation (Thrift 2004, p. 584). Qualculation follows a qualitative change in the cultural environment especially in urban settings as quantitative calculations becomes proliferated, pervasive and ever-present.

The term qualculation was initially proposed by Cochoy to clarify the qualitative aspect of decision-making within calculative frameworks, such as consumers' selection of products in a marketplace. Cochoy develops the argument in further studies, taking the shopping cart in a supermarket as a space of calculation for the wandering urbanite (2008). Other theoreticians have expanded this term in certain directions: Callon and Law insisted on the technological and spatio-temporal nature of market-shaping (Callon and Law, 2005).

Thrift's use of the term is part of a critique of the recently emerging urban environment dominated by the 'security-entertainment complex', quoting Bruce Sterling (Thrift, 2004 and 2011).

Thus for Thrift, qualculation could be argued to be a new calculative sense with several properties: speed and intanstaneity, faith in numbers, some degree of memory, the environment complementing the body as a cognitive prosthesis (p. 592). Echoing what all the senses did when they emerged, qualculation is now triggering a cultural change.[2] Thrift lists the identifying properties of this change: the existence of prostheses that provide automatic aid in some cognitive tasks such as navigation, spatial coordination based on continuous tracking, continual access to information enabled by connectivity, and a more flexible sense of metric. These lead to a diminished sense of place that surrounded institutions and domestic houses, as it was established over centuries and culminated with the rise of modernism.

A quick survey of the literature on the field of ubiquitous computing would explicate the extents of this shift in technical terms. Computation can be relegated to any point on the landscape, going beyond the notion of computation being limited to a computational device proper. A landscape of computation could be the next step in the urban environment (Greenfield, 2006). In effect, the recent proliferation of smartphones, tablet computers, locative services integrated with social media and banking systems could be seen as a hint of what has the potential to be actualized. Most users are enchanted by the smoothness and robustness of the tactile interface, yet in their totality, pervasive technologies bring on an experience of seamlessness and continuity.

SENSATION OF QUALCULATION: THE HAPTIC TURN

How is this world with an additional layer on top of the physical world sensed and perceived? Capabilities of the body are central for the answer. A case for the importance of the haptic sense could be made in the emerging digital urban environment beyond built form. There are several signs that could be utilized for developing the case. First, regarding the manipulation of digital data, many researchers are devising gestural interfaces for manipulation of digital information. Some of these works place gestural control at the heart of access (Thrift, 2011). Gestural game controllers have been commercially available by several makers, and since their inception these devices are increasingly popular. The most pervasive usage of gestural interfaces happened recently with touch-sensitive smartphone screens. In effect, these interfaces do converge to a notion of landscape of movement and touch that is ever-connected and always on (Mistry and Maes, 2010).

A second sign could be the reflection of this notion of location-on-a-landscape being tagged with information content onto the urban realm. The physical world becomes an extension of the informational network: everywhere is addressed and therefore all movement is documented (Sterling, 2009). A third sign could be the availability of a kind of feedback. Lewis utilizes the musician's term 'interactive composition' that is indicative of instruments "that made decisions that responded to a performer" in the context of technological urban life (Lewis, 2007).

Altogether these signs and more could show that the emerging perceptual process in the world of qualculation is haptics, which may not be a new assertion. Tallis argues that the hand has been the major facilitator of human intelligence for a very long time (2003). In 1964, the anthropologist Leroi-Gourhan documented the revolutionary change in prehistoric times that was brought about by the tools the hand used for breaking, cutting, tying and so on (Leroi-Gourhan, 1993).

Touch or tactile sensation is the primary sensory instigator for haptic perception which involves recognition of objects (Gibson, 1966). Somatosensory perception of patterns on the skin surface (such as edges, curvature, and texture) and proprioception of hand position and conformation are combined to give rise to haptic perception. The observer actively touches the world by exploratory movements. Therefore Gibson and others have formulated haptics and body movement as active processes closely linked. Haptic perception is also at work when observers use tools such as sticks or knives to experience with extended physiological proprioception.

Composer and music theorist Trevor Wishart arrived at a similar synthesis as he theorized about listening in the frequency domain (Wishart 1992). Wishart formulated a continuum of sound, as it moves from the scale of smallest sound particles to bodily actions and to landscapes. Wishart's approach is based on a critique of the established notions of musical sound as it is theoried in Western thought. Lattice is an abstract mathematical structure that in its simplest case, it could best be characterized by a Cartesian coordinate system on which only discrete points are inhabitable. Wishart argues that Western music treated musical sound as an object to be placed on this lattice. The dimensions of the lattice respectively define the pitch value, which instrument is played and time. Helmholtz's division of physical acoustics and psychoacoustics strengthened the lattice model (Helmholtz, 1877).

Wishart thus brings forth listening in the frequency domain as it is related to gesture and then spatial motion. The spectrum of sound is a collection of the frequencies present. His account devises a typology of motions beginning with simple cyclical, straight, diagonal and similar types to complex motions. With each motion, the spectrum of the sound produced carries with itself the information about the type of motion. Wishart's theory is among others that take the gesture of the musician and discusses the interdependency of the spectral content in the sound and the spatial motion the gesture generates.[3] Wishart expends these views

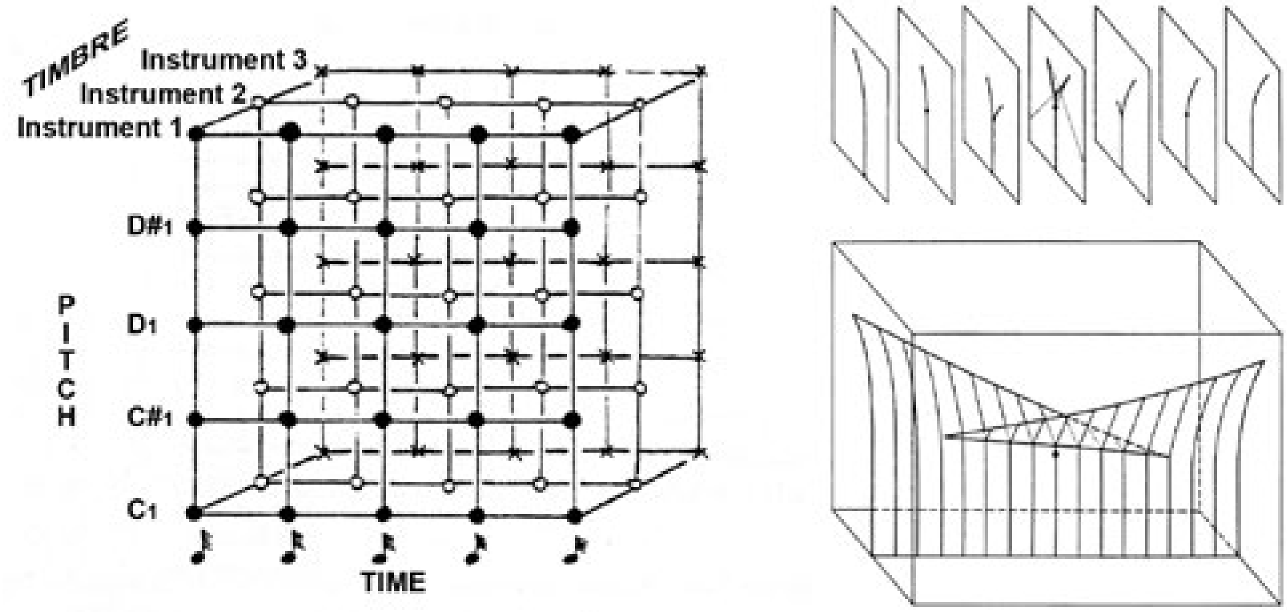

Figure-4:. *Wishart's characterization of the musical lattice space versus morphogenetic bifurcation as predicted by catastrophe theory* to cover a continuum between the spatial motion of the performer and the landscape it takes place in. The physical forces and interaction with these forces and entities are evidently heard within the sound itself: a telephone wire swinging in the wind has information regarding its materiality, strength of the wind and so on.

GESTURAL HAPTICS IN THE ELECTROMAGNETIC FIELD: THEREMIN

It is possible to extend Wishart's notion of physical continuum to the physics of electromagnetic fields. Today, there is an abundance of experimental and commercial gestural control interfaces, digital devices responding to performers playing without actually touching (Cadoz and Wanderlay, 2000). The early electronic music apparatus Theremin could be a predecesor of these devices. Built in 1919 by Lev (Leon) Termen, a Russian professor of physics, Theremin was designed to be an intuitive musical tool. A player can make music by simply moving his or her hands in the air: intuitive understanding of music was thought to be sufficient to play.

To play the instrument, the standing player moves her hands within space around two metal antennas. The distance from the first antenna determines pitch, and the distance from the second one controls the volume. There are two radio frequency oscillators in the instrument: one operates at a fixed frequency, while the other one, which is controlled by the distance of the player's hand to the antenna, works at a variable frequency. Because player's body is connected to the ground, the hand becomes a grounded plate of a variable capacitor in an inductance-capacitance circuit. The difference in frequencies of the oscillators generates an audio signal that is sent to a loudspeaker. The second antenna controls the sound volume with the same principle.

Contrary to the original aim, the overall performing experience of the instrument was reported to be very hard (Glinsky, 2000). In a recent study, the playing styles of two well received performers are compared (Ward et al, 2008). Performers Rockmore and Kavlina are demonstrated to have utilized completely unrelated set of gestures combined with control of their full bodies.[4] Dealing with uncontrolled sounds was an active part of the performance.

In the theremin, the performer is faced with the actual electromagnetic forces, movements of the hand create fluctuations in the electromagnetic field. Instead of a computationally mediated interface, responses of this active electrical circuit is not clipped: if the performer ventures into unstable zones, sounds get out of control. It is this unmediated instrument that could be taken as a model for a design tool that tackles with changes in the temporal domain. Ward et al. use the term 'forceful' interfacing for theremin, in order to indicate the physical interdependency between gestural control and physical responses of the system (Ward et al., 2008). For explaining discrete jumps or breaks, Wishart's use of catastrophe theory and morphogenesis could be utilized: the geometry of cusps on a continuous surface (Thom, 1975).

THEREMINSPACE VS. CARTESIAN GRID: SPATIAL LOGIC OF QUALCULATION

Taking the theremin as a model, a concept could be abstracted to embody the morphogenetic enhancement of the space of interaction beyond the immediate Newtonian physical world: thereminspace. Thereminspace is a gestural space of interaction where the virtual aspects of interplay are an embodied extension of the physical world. Just as the instrument, thereminspace has an inherent sensorimotor haptic continuity.

Thereminspace has several properties. First, interaction is forceful, situated and embodied as a result of being directly coupled physiologically.[5] The responses of the system arise out of the actual physical workings of the system, they are not mediated and mapped from another dataspace. Secondly, heterogeneity is a key component as all the points that make up the thereminspace are different than others. In a lattice space, all the points are essentially discrete and the same. It is the mapping that renders them different for interaction. The mapping could be aligned, transformed or switched off. In thereminspace, the points are defined to vary between themselves inherently as a result of physical characteristics. Third, echoing the way the sound of theremin was characterized as aether music, thereminspace is ever-present in a similar notion (Glinsky, 2000). Thereminspace is all expansive; the space dies out gracefully where it dies naturally, not because it is not mapped beyond the defined ranges. Thereminspace is not calculated per se, even though it rests on and arises out of intense calculations or atomic

***Figıre-5:**. Theremin instruments*

interactions at lower levels. Fourth property is the temporal nature of the experience. Movement in thereminspace can only happen over time, which has a muscular memory for the performer.

In effect, Theremin renders the space of interaction as a heterogeneous and nonlinear landscape. There are steep and jagged mountains where it is cumbersome to maintain continuity, as well as relaxed valleys where travel is effortlessly smooth: not all the points are the same for the performer. The Cartesian grid of the 20th century on the other hand, is based on the idea that all the points in three dimensional space are the same: a turbulence can be mapped onto any subregion of the field any time. Thus in the end the Cartesian grid becomes a void for placing identically substitutable parts. Content and variation becomes a separate layer that can be mapped onto different places on the lattice.

If qualculation is argued to be the primary sense for the emerging urban realm of today and tomorrow, the concept of thereminspace could be used to explicate the spatial expectations that are expected of this realm and culture. Qualculation arises out of a proliferation of discrete calculative layers mostly in the form of computation, yet what the observer or the urbanite experiences is not quantitative but qualitative. The urbanite is not aware of the totality of the underlying processes of calculation that takes place in an airline travel, or in an unobstructed computerized stock-market transaction for example. Even a simple and smooth supermarket shopping trip is laden with an abundance of constantly readjusting calculations regarding logistics details underneat the surface. Participation in these processes has incalculable nonlinear repercussions throughout the network of interconnected subprocesses: buying one product at a price at a given location changes the system of pricing for other products, albeit infinitesimally.

THEREMINSPACE AS A MODEL FOR NEW DESIGN TOOLS

Therefore thereminspace gains more viability over the Cartesian void for explicating the workings of this urban realm. Non-participation in this realm is not an option and citizens' actions effect the system nonlinearly, beyond awareness. The emerging spatiality is not a passive void, where the citizen's actions are substitutable, but an active and responsive one.

In tandem with the spatial logic, design tools for designing the pertinent spaces need to change. The mechanical tools of the architect that were devised over centuries and perfected in the 19th and 20th centuries are being replaced with a myriad of tools: building information modeling, geographic information systems, networked sharing environments, parametric modeling tools, performance analysis and so on. In addition to software, advances in fabrication and production blur the boundary between construction, manufacturing and physical model-making.

Therefore, there is a new challenge for current digital systems: the omnipresent computational landscape is a mediation of the physical world with smart interfaces. These interfaces clip out the unwanted parts of real physical response curves, generating a sense of seamlessness for the user. Various intensities and densities are categorized into predefined classes for making decisions and diversions. However, it could be argued that in a system with predefined classes of events, novelty

Figure-6:. *Gaudi's catenary design model for studying funicular forces*

as the primary component of design activity can not be identified. By definition, emergence of novel events can not arise out of a previously known class of events.

It is yet to be seen whether these developments are further immediations and refinements of the Cartesian void or not. What is absent or largely neglected in the current design tools is the human factor: neither the designer, nor the dweller are still fully situated in the interactivity of the design.[6] The situatedness has to involve a sensorimotor coupling with the designed artifact or design forces.

The funicular design tools Gaudi used for studying complex vault systems is a well-known example for a design tool that is responsive by nature. In Gaudi's model, the act of designing is akin to building. Gravity can not be put on hold to make adjustments. Unexpected failures during design process are of key importance as the material physicality shows its optimal preferrences naturally. As a result, novelty in design emerges but the designer has to engage with the physical forces acting upon the model to make designs which are instantly tested.

Thereminspace could be an enhancement of these principles in new design tools as they take steps into virtuality. Design has to remain an active engagement of designer with the ever-present medium over time. The spatial disposition is heterogeneous as a result of active forces, therefore the tool allows the designer to make qualculative decisions: qualitative aspects are evaluated in a calculative environment. In order to find inspiration for digital design tools producing meaningful work, we might inspect how qualculation plays itself out. After all, it is the logic of society that shapes the tools that shape its environment.

ENDNOTES

1 See Knorr-Cetina (2003), Mirowski (2003) or Graham (2004).

2 For Thrift (2004), the growth of calculation is the last in a list of successive historical steps: mathematical deduction, the exact gridding of time and space, the invention of filing and listing systems and invention of logistics.

3 Smalley discusses a very similar interdependency – which he terms as 'spectromorphology' – more deliberately in the context of conventional musical instruments (Smalley, 1997).

4 It is interesting to note that Lev Termen used similar ideas in the design of further instruments (Glinsky, 2000). Most notable of them was the Terpsitone. The artist moves on a plate filled with antennas and plays by dancing. The movements of the whole body become a modulator of sonic output.

5 Theoreticians of embodied cognition propose the concept of structural coupling, which aims at explaining seemingly separate bodily phenomena – including cognitive and perceptual processes – showing high degree of correlation. Coupled mechanisms producing general outcomes refute the reductionist approaches to physiology and psychology (Varela, Thompson and Rosch, 1999).6 Experimental tools such as the Luminous-Tangible Workbench for urban design are rudimentary searches for tangibility of the designed material to the designer (Underkoffler and Ishii, 1999).

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THE DEFINITION, NECESSITY, AND POTENTIAL OF DRAWING COMPUTATION

Carl Lostritto, Assistant Prof., *Rhode Island School of Design (RISD)*

Drawing is so ubiquitous that the definition of the word, "drawing," often remains unconsidered, flexible, or inconsistent within architectural discourse. The straightforward question, "is drawing dead?" which would seem, on its face, to have an easily measurable answer, becomes a prompt for theoretical debate and scholarly discourse.[1]

If drawing is defined as any representation that exists in two dimensions, digital screens and prints–any image in any format–would be included in the set, and it would be inevitable to conclude that drawing is very much alive and thriving. This definition is often colloquially used in architecture: design media is divided into "drawings" and "models," 2-D and 3-D. One could reduce the set of what constitutes "drawing" significantly by appending descriptive caveats such as, "...which is made predominantly made of lines," or "...which exists on paper." However, upon further interrogation, even "on paper" and "lines" break down into open and debatable terms.

Another way to define drawing is a 2-D system of marks that is built up in a world that emerges through the process of its making. With this definition, most plans and sections would have to be excluded, and one would be forced to acknowledge that drawing is rarely found in architecture.[2]

Marco Frascari comes close to a yet another universal definition of drawing by arguing an emphasis on its salient feature: "facture."[3] Important in his schema is that "drawing" must be relevant as process and product. The drawn object must in some way convey (or betray) the drawing action. This definition could be narrowly interpreted as excluding the digitally produced line, which tends to describe the geometry rather than the act of marking. Frascari does, however, heavily rely on an exploration of hypothetical apparatuses, which fold operation, indirection and translation into a broad consideration of making. This leaves "drawing" open to potentially include computed actions that are manifest as image.

Deanna Petherbrige, an artist, scholar and Professor of Drawing at Cambridge University, also devotes extensive scholarship to the nature of drawing's resistance to definition.[4] She proposes that drawing cannot be strictly defined, but offers, instead, the framing of drawing in terms of that which it "approaches" but cannot become. In Petherbridge's "Economy of Line," she proposes that drawing is best understood in resistance to painting. The salient distinction lies in terms of drawing's emphasis on line relative to painting's reliance on matter.[5] What makes a drawing is a matter of interpretation rather than of medium. A drawing can be made with paint, but it cedes that label as soon as the quality inherent to the paint itself (hue, value, materiality, character of light) dominates over the legibility of line. This framework is consistent with Deleuze and Guatarri's often-quoted exposition on line, which, although taken out of context, reveals the philosophical and linguistic depth that a simple interrogation into the notion of line can yield.

> "Such a line is inherently, formally, representative in itself, even if it does not represent anything. On the other hand, a line that delimits nothing, that describes no contour, that no longer goes from one point to another but instead passes between points, that is always declining from the horizontal and the vertical and deviating from the diagonal, that is constantly changing direction, a mutant line of this kind that is without outside or inside, form or background, beginning or end and that is alive as a continuous variation–such a line us truly an abstract line, and describes a smooth space."[6]

In its most basic state, the drawn line may represent nothing, but it always conveys something and is legible in terms of its structure, no matter how simple. Petherbridge provides ample evidence that lines gain informational capital by entering into territory that allows the suggestion of painting or an experience similar to that of painting without fully betraying the topology of the line. Klee is similarly biased towards loading up lines with character, behaviors and even emotions.[7] When read in contemporary light, Klee and Petherbridge (who despite an active practice as artist and theoretician, does not venture into the waters of digital media and software when elucidating the core of her analysis) articulate line as embedded with information and rules–not a single geometry but a capacity for potential further geometry. Every drawing is linked, therefore, to its past and to the future.

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"Computation" suffers from similar universal ambiguity to that of "drawing." Nearly all architects use computers, but the term is often employed to suggest an intellectual topic of focus, an implication that how and why we engage technology deserves provocation, if not critique. In some contexts, computation is synonymous with digital media. In others it's nearly the opposite, used as a way to distinguish the interrogation of structural operations from the application-fixated domain of software.

This essay proposes that computation and drawing, when considered in isolation, are difficult to engage in polemical fashion, but each provides enough resistance to the other that criticism can become productive and valid. Cammy Brothers, a historian, notes that before and even during the Renaissance, a period unusually associated with the codification of drawing conventions in architecture, drawing was a "space for research."[8] She calls architects to arms in an effort to renew the role of drawing as experimental territory, considered parallel to built architecture and emancipated from it's position as conventional representation. Her view could be interpreted as rejecting the urgency of the question "is Drawing dead?" in favor of a more nuanced, "What should drawing be, now?"

"What should computation be, now?" is an equally valid question, though like the question about drawing, is too brutal to answer universally without violating the heterogeneity of computing culture.

Drawing is not the savior of computing, nor is the converse possibly true, but if computing and drawing are to a suitable degree in tension with one another, their hybridization may prove a productive line of inquiry.

Mitchell and McCullough, in the canonical *Digital Design Media*, implicitly foreshadow the conceptual tension with the historic and colloquial term "drawing" and contemporary computation by avoiding the term altogether. The structure of the book identifies "Images," followed by "Drafted Lines" as topological categories.[9] This is not an omission, but a characteristic rigor with respect to accuracy of terminology. Digital lines are more accurately labeled "drafted" despite the colloquial usage of the term "drawing." The implicit conclusion taken from Mitchell and McCullough's structure is that precisely defining or creating shapes with a computer does not conform to any rigorous and historically consistent definition of drawing. Even pixel-level, 2-D manipulation (including, for example, the coloring of pixels with the use of a mouse or other input device), for Mitchell and McCullough, would appropriately fall under the category of image creation, not drawing.

One way to undermine the prevalence of the pixel, if not eliminate it pixel altogether, is to avoid screens and printers when making and viewing 2-D visual content. Although trivial in the domain of pencil and paper, such a task is a challenge amongst digital interfaces, worlds and output devices. The computational drawings that accompany this text are created through a process that defines lines computationally in the Python programming language and marks paper by controlling a vintage Hewlett Packard Pen Plotter[10]. This apparatus, which is a patchwork of obsolete and new technology,[11] generates commands in the plotter's native machine language, HPGL,[12] without the use of any graphic software interface. Systems for representation on screen are possible, but must be crafted by the author. Such representation–symbolically or abstractly–represents the structure of content before it is translated into marks, and therefore does not necessarily correspond to the eventual appearance of the drawing.

Because of the fidelity possible in the movement of the plotter head and the complexities inherent to the deflection of the paper and bleed of the ink, the effective resolution of the plotted drawings[13] is not possible to convey in a practical way on screen. Each drawing is a project in itself, with unique topological structure, rule-based behavior, and pre-drawing representation.

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To an extent, these drawings can be positioned in the context of generative art, a domain which sees a significant body of work challenging traditional notions of drawing and computing. Chaotic drawing machines[14], 2.5-D models,[15] and the use of fabrication machines as drawing apparatuses[16] are all prevalent project types that are inherently computational and, in some cases, reflective of a considered definition of "drawing." In terms of the drawing as an experience-inducing product, the work presented here fits alongside (and in some cases, was inspired by) these related works. Where they diverge, however, is with respect to their position in a design process. These drawings are intended to shed light on the potential for the construction of media for architectural design. Unlike works of art, their role is seen as intermediary. Drawing in architecture must be projective, somewhere in the middle of a design process. Using drawing as a point of departure, a territory for thinking, is not unusual for architects.

The adage, "draw through a problem"[17] serves a pedagogical agenda in architectural education because, in addition the assumption that the human mind is imperfect territory for internally exploring spatial and formal relationships, the line can convey and serendipitously betray the intended reading of the most primitive elements in architecture–edges, contours, seams and corners.

Some of the drawings presented here heighten the architectural potential of the line by defining it in terms of a physical presence on the paper. Lines gain architectural agency by behaving as though they were material: some lines avoid intersections, gravitate toward other lines, have weight or favor an orientation.

***

With "computing drawing" established as a non-trivial task, and examples offered as objects for interrogation, the question of meaning still remains. Computing drawing might be inherently difficult, but what's it's value for design? Andrew Witt discusses a definition of architecture as the combination of design knowledge and instrumental knowledge.[18] He argues that the skilled use of machines and tools (instrumental knowledge) played an essential role in encapsulating knowledge for architects prior to modernism. A relatively recent near- exclusive emphasis on design knowledge (which Witt defines as logic, order, and relationships) relegates technique to the margins. Witt's categorical distinction and advocacy for the fusion of design and instrumental knowledge is timely given the speed at which fabrication and construction tools are being re-considered by architects. Implicitly, drawing

is essential for Witt's argument as the territory in which instrumental knowledge can become design knowledge (and vice versa).

This brings the discussion of computing drawing to the nature of design process. Creating computing drawings and computing drawing apparatuses can shift the emphasis away from computing for tool-making (instrument mastery, to extend Witt's framework) to computing for media-making. Roland Snooks would seem to support this agenda writing,

> "...in architecture computational methods have been adopted that privilege certainty over open-ended process. This adoption is based on a set of false assumptions regarding the pseudo-objective nature of

> computational design. These systems of parametric variation and optimization are complicit in the automation of design, marginalizing risk, and foregrounding stability and equilibrium. I would argue instead for complex systems of formation that operate through the volatile interaction of algorithmic behaviors and engage the speculative potential of computational processes."[19]

Snooks frames computation with a research ethic that eschews predefined goals. He convincingly and thoroughly elevates generative algorithms above parametric modeling, optimization, and form-finding. Putting aside whether his "catastrophic change" is practically viable within a fractured discipline, the open-ended "designing of process" would seem philosophically consistent with the most foundational values of architecture. If algorithms can operate on those grounds, there's reason to be optimistic about computation as a motive force for research. Snooks describes a paradigm of a design process that leverages unpredictable tactics by placing significant emphasis on the model: "This requires a relentless, iterative torturing of the model...Within this messy feedback, the algorithmic generation of form and organization becomes the input to explicit modeling processes and vice versa."[20] Drawing is glaringly omitted from this process, perhaps because of the weight of convention and their stifling capacity to be associated with tradition. But drawing, and seeing drawing, is coupled with intelligence, as Bruno Latour documents rigorously in Visualisation and Cognition: Drawing Things Together":

"Realms of reality that seem far apart (mechanics, economics, marketing, scientific organization of work) are inches apart, once flattened out onto the same surface. The accumulation of drawings in an optically consistent space is, once again, the 'universal exchanger' that allows work to be planned, dispatched, realized, and responsibility to be attributed."[21]

***

Although the drawings presented here overtly avoid the possibility of application, the question of their life beyond the experience they engender is valid. A few conclusions and projections are possible. First, drawing should respected as a currency of design knowledge. The future implications of this work are likely pedagogical as much as they are generative.

Architects, designers and teachers concerned with research will benefit from visiting drawing as language of discourse even when drawing (or, at least, conventional drawing) is not necessary to achieve built form. This is especially true now that the bar for novel formalisms is nearly unattainable given the confines of the architectural project. Furthermore, computation has evolved beyond that of sub-topic into a territory so central and ubiquitous that "computational design," like "design drawing," requires a conceptual catalyst to assist in its taking new, and more relevant positions in process and discourse.

ENDNOTES

1 At a 2012 Yale University Symposium, "Is Drawing Dead?" (J. Irwin Miller Symposium, Yale School of Architecture, February 11-13, 2012) the explicit, headlining question was addressed with some contention. Implicitly, however, conflicting definitions revolved around the debate.

2 This point was made by Preston Scott Cohen at the "Is Drawing Dead?" Symposium. ("Plan Vs. Drawing" presented at the J. Irwin Miller Symposium, Yale School of Architecture, February 11, 2012)

3 Marco Frascari, Eleven Exercises in the Art of Architectural Drawing. Page 10 (1st ed. Routledge, 2011)

4 Deanna Petherbridge. The Primacy of Drawing: Histories and Theories of Practice. (Yale University Press, 2010)

5 Ibid

6 Deleuze, Gilles and Felix Guattari, A Thousand Plateaus: Capitalism and Schizophrenia. (Minneapolis, MN: University of Minnesota Press. 1996 edition) Page 497-8, emphasis original

7 Paul Klee, The Thinking Eye: The notebooks of Paul Klee. (Edited ny Jurg Spiller. New York, NY: George Wittenborn. 1964)

8 Cammy Brothers, "Experience and Fantasy in Renaissance Drawing." ("Experience and Fantasy in Renaissance Drawing" presented at the J. Irwin Miller Symposium, Yale School of Architecture, February 10, 2012.)

9 Mitchell and McCullough, Digital Design Media, Page 129.

[10] Manufactured between 1988 and 1990, these devices were marketed for engineers and architectural draftsmen with the intent of automating the process of drafting precise technical information on paper. Each plotter contains 512 KB or RAM and a small amount of ROM to store a "demonstration plot." Although expensive, these plotters, which used up to eight disposable pens for each drawing, developed a reputation for inconsistency and slowness. The tip of the pen degraded markedly before running out of ink and the quality of line was highly dependent on the bleed of the ink, which varied by color, manufacturer, paper type and even humidity

[11] A Serial-USB adapter bridges contemporary and vintage ports and a Python library, "Chiplotle" (http://chiplotle.org) developed by Victor Adan and Douglas Repetto, conveniently wraps the generation of HPGL syntax into an object-oriented structure and deployed PySerial to initialize and establish a serial communication connection with the plotters.

[12] Hewlett Packard Graphics Language, HP's attempt to proliferate an industry standard, output language. It preceded the more advanced HPGL/2, which lost prominence to the completing Postscript language. The following code would instruct the pen to draw a horizontal line of length 1000 units from the coordinate position (200,200) on paper using pen number 1: "SP1;PU200,200;PD1200,200;" See "HP-GL Reference Guide" (n.d. http://www.isoplotec.co.jp/HPGL/eHPGL.htm) for complete specifications.

[13] The resolution of the drawing is technically limited by the x and y axis motors. On each axis the pen movement is controllable to about one thousandth of one inch.

[14] Chaotic drawing machines use at least three interconnected parameters to create an unpredictable system. Usually autonomous, these machines sometimes produce a line quality similar to that which can be achieved through drawing by hand. State-of-the-art examples include Bravi, Lorenzo's "Drawbot Children Workshop" and Robert Howsare's apparatus ("Drawing Apparatus by : The Method Case" http://www.themethodcase.com/drawing- apparatus-by-robert-howsare/)

[15] 2.5 (or two and a half) dimensional models are images that are made by generating shapes in a two-dimensional space, which because of the nature of the system, is nearly three-dimensional as a result of a layered condition in which either the later functions "destroy" (or appear to cover) the information that was previously drawn or the shapes are assigned a value that is associated with their effective depth.

[16] Marius Watz's "Grid Distortions" project (http://www.unlekker.net/proj/griddistortions/index.html) is an especially intriguing example of this type of apparatus because the mark left by the laser cutter is dependent on duration and sequence, effectively yielding a drawing at a scale not possible with any other medium

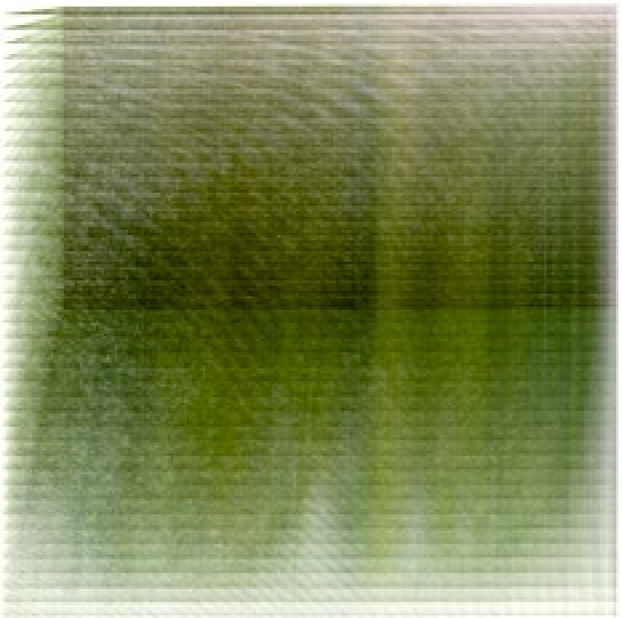
[17] Often attributed to Alberti, this is a common directive by design studio faculty faced with a verbally expressed idea or condition that is either unclear, untested or known to be flawed (or tends to lead to flawed results)

[18] Andrew Witt, "A Machine Epistemology in Architecture. Encapsulated Knowledge and the Instrumentation of Design" Candide. Journal of Architectural Knowledge: Issue 3 (Transcript Verlag; Bilingual edition, July 1, 2012)

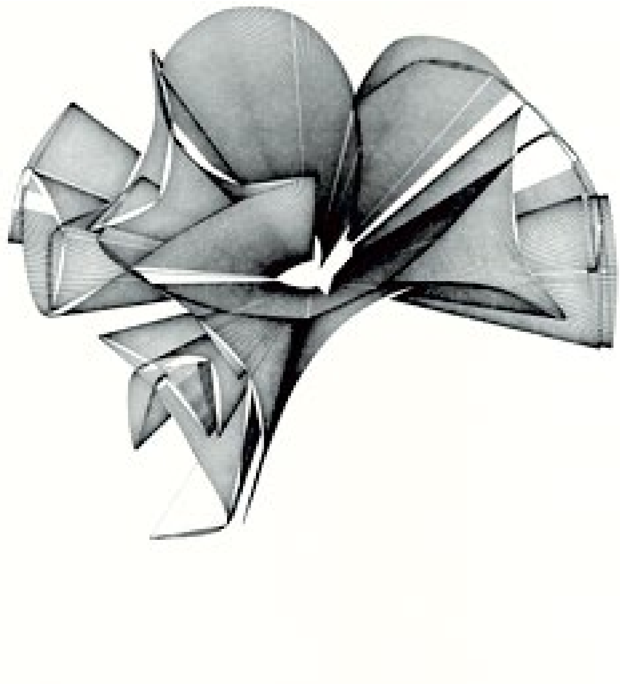
[19] Roland Snooks, "Volitile Formaiton," Log 25 Reclaim Resi[lience]stance //......R2 (Anyone Corporation, Cynthia Davidson, ed, July 10, 2012)

[20] Ibid

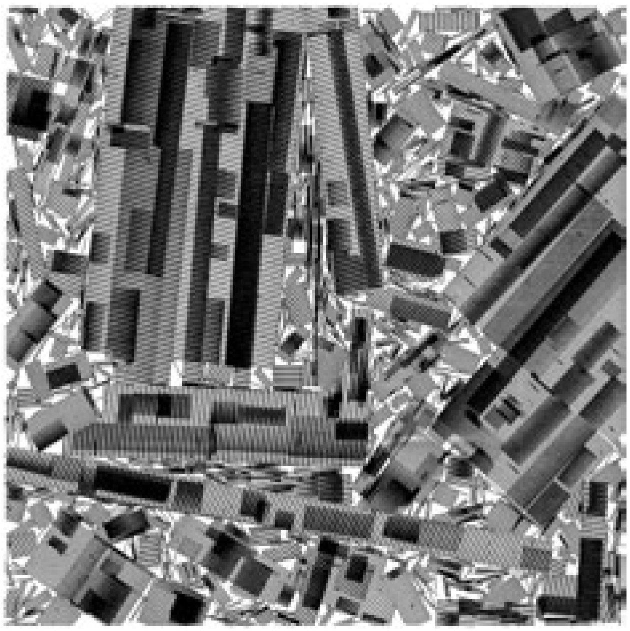
[21] Bruno Latour, Drawing Things Together, in The Map Reader: Theories of Mapping Practice and Cartographic Representation (eds M. Dodge, R. Kitchin and C. Perkins, John Wiley & Sons, Ltd, Chichester, UK 2011)



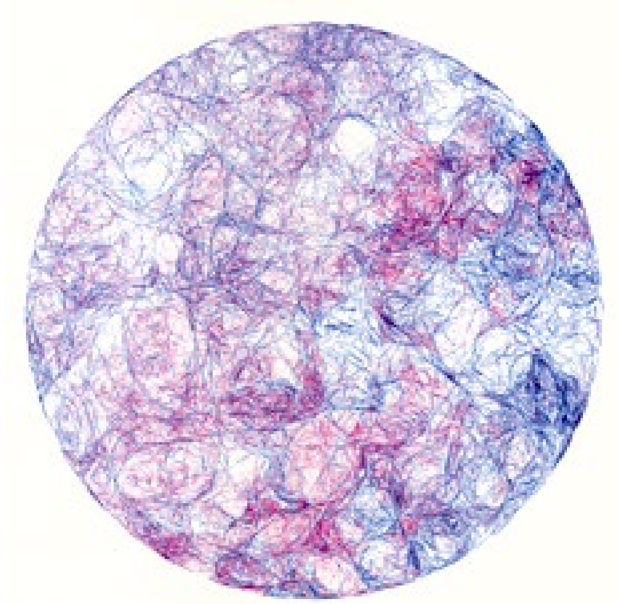
C-003-001 *Method 'C' draws lines in gridded sets with respect to a focal point. Series 003 layers three sets. In two sets the lines are angled towards the focal point. The third set is made of vertical lines. In run 001, a set is drawn with a blue pen. The second set, closely aligned with the first set is drawn with a yellow pen. The third (vertical) set is drawn with a red pen.*



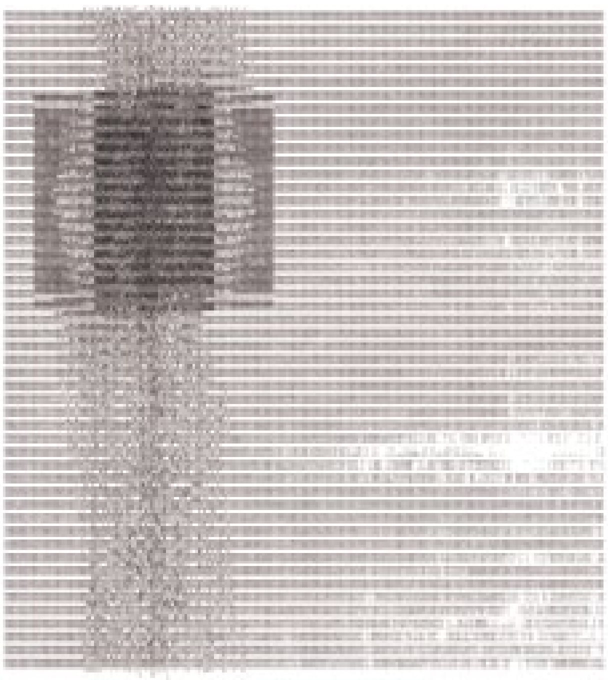
C-004-001 *Method 'C' draws lines in sets with respect to a focal point. In Series 004, a single coarse path is calculated first, within a circular boundary. The path tends to avoid intersections. A finer path with 50 points is generated per each initial point, and forms an interpolated spine curve. Each new point marks the beginning of a drawn line towards, but not ending at, the focal point. Lines stop at any intersection with the path. Run 001 is the result of a 70-segment coarse curve. The plotter is loaded with a highly worn pen.*



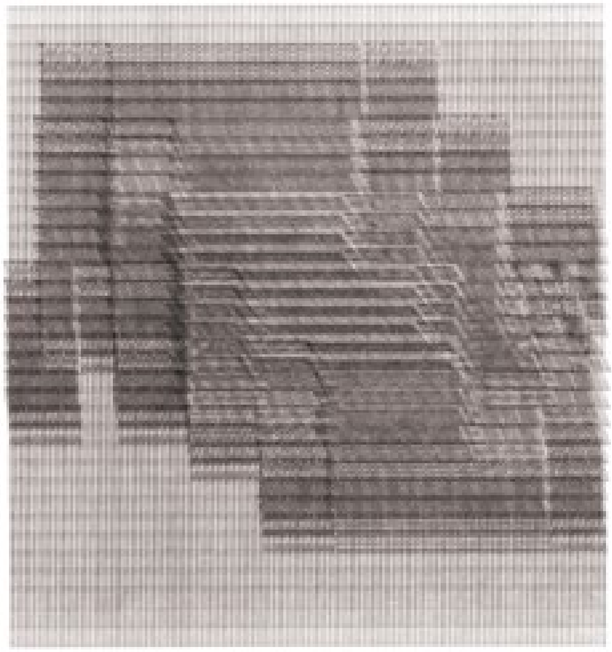
D-001-002 *Method 'D' involves algorithms that treat the paper as space and ink as object. Series 001 draws a line at a random angle that will not intersect any previously drawn line. Then lines of the same length are drawn slightly offset from the previous line. When the next line will intersect any previously drawn line, repeat the process. Run 002 is drawn with around 12,000 lines.*



D-002-009 *Method 'D' involves algorithms that treat the paper as space and ink as object. In series D-002, marks are made by a particle "walking" in a random but generally curving path within a boundary on the page. The invisible particle leaves a dashed trail, which it is never allowed to make contact with. If the particle is nearing collision with its tail, its angular acceleration increases–it steers out of the way. The gaps between the dashes are openings, where the particle may move through. Over the course of the drawing the particle speed decreases, (causing the curves to be tighter and smoother) the proportion of dash to gap decreases. Run 009 adds the variable of a second ink color to further emphasize the axis of time in the making of the drawing. Later marks have an increasing likelihood of being made with the pink, as opposed to blue, pen.*



G-001-036 *Method G involves deploying a lattice to represent the space of the drawing. At each lattice point, six bits are stored. These bits are translated into parameters that define a single pen stroke in the drawing. On the algorithmic temporal axis time zero, the initial state, is composed. Then, in discrete steps forward in time, the bits shift each of six directions based on simple rules designed to simulate fluid diffusion. Series 001 uses a 450-unit wide by 200-unit high triangular lattice. The initial state is composed as a rectangle. The system will eventually will move towards homogeneity, but after only a few dozen steps the initial state, a rectangular area with all "on" values, has been merely degraded. Run 036 is drawn with a worn (to the extent of near failure) pen to allow overlapping lines to register.*



G-003-019 *In the H-series, each abstract lattice point represents not a single line on paper, but a set of lines. This introduces an intermediate scale into the drawing. As patches of lines collectively change angle and length, their overlap with other patches produces an area of consistent texture. Even when only "slightly subject to time," the near-depth effect is dominant, relying on the ambiguity of conflicting meanings of the line: as particle in a field and as mark at the edge of a figure.*

SUNGLASS: A CONVERSATIONAL FRAMEWORK

Kaustuv De Biswas, CEO and Co-Founder of Sunglass.IO

...What evolution moves towards is increasing sentience of all sorts. So throughout life minds are invented all the time.

Kevin Kelly,
Teknoloji Ne İster (What Technology Wants), (2011)

Design technology is neither an *autonomous agent* nor is it a just a *production tool* for pre-defined ideas, rather it is a cognitive apparatus for the designer to create new ways of seeing and doing in intervened or constructed realities. A design tool must be viewed as an inventive playground which allows a human designer to engage with an external system – real or abstract – enabling him to develop, represent and record his understandings of it, often driven by agenda independent of the system. Kevin Kelly in his book "What Technology Wants" suggests that technology creates new species of minds, or ways of thinking that evolution in the biological sense could not reach.

In order to arrive at a framework for a design tool, we must review the two complementary and coincident loops within which the designer operates – First the individual designer engaging with an external system to explore and create (creative cycle) and second, the collective engagement of designers within an ecosystem, cooperatively exploring ideas (cooperative cycle).

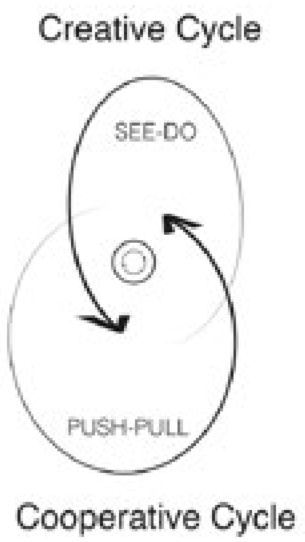


Figure 4.1: *The coincident creative and cooperative cycle in the design process*

SEE AND DO – THE CREATIVE CYCLE

Design is about discovery and discoveries appear in differences. In order to capture or develop an intension or an imagination, the designer interacts with real or abstract material organizations, opportunistically probing into its latent or manifest logics - constantly re-conceiving and re-structuring the evidences at hand, discovering differences and inventing new languages to develop temporal understandings of the material. It is through this bi-directional to and fro reflective reconstitution driven by differences that languages and ideas co-evolve in the mind of the designer.

The material does not have any innate structure in it. It is during the process of seeing and doing that the designer embeds temporal structures (descriptions) in it. If the transformations (**t1, t2 in Figure 4.2**) that appear in the material space are recorded, a language (descriptions and rules) can be constructed retrospectively to capture the process. It is important to note that the language is not memorialized in the material, but only expressed as differences of its state (Sa -> Sb) observed in the process. It is herein that lies greatest rift between design and symbolic computation. The latter demands the world be broken up in consistent, unchanging units or symbols right from the start, whereas in design parts, descriptions and language appear in retrospect to the to-and-fro designer-material interaction.

> Shapes are subtle and devious. They combine to confuse the eye and to excite the imagination. They fuse and then divide in surprising ways. There are endless possibilities for change. How to deal with this novelty while you calculate — neither limiting the alternatives nor frustrating the process — is the test.
>
> George Stiny (Shape, 2006)

Materials can be real or abstract and interactions can happen in various scales. Designers use the innate properties and logics of materials for both calculating shapes as well as employ them as things to think with. However not all material spaces, the properties or their innate logics are naturally observable and any human explorations / investigation involving them must be intervened by some machinery – either translating the properties and logics to make them observable or by evidencing them through an abstract language. Designers have employed material logics in physical, chemical and the biological paradigms as inspirations for form finding [Gaudi, Otto, Fraser] – in the last two decades there has been shift from using the materials itself as calculating devices to deriving inspirations from the innate material logics, as points of departure for formal play. Design Tools must be viewed as a cognitive apparatus to extend human engagement with new kinds

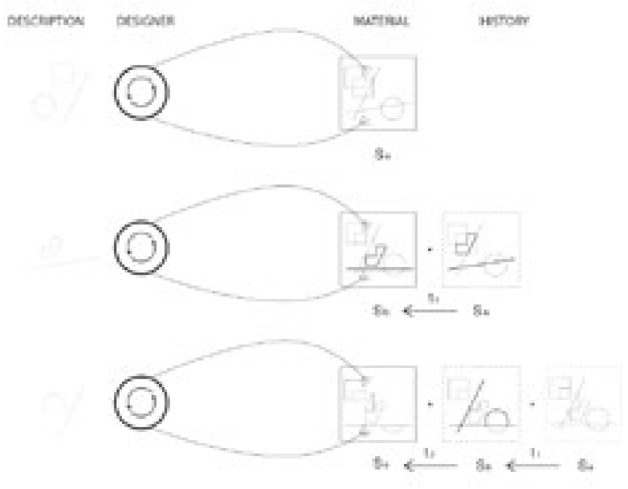


Figure 4.2: *Stiny's Visual Calculation*

of materials spaces, which our biological selves could not sense or comprehend.

PUSH AND PULL – THE COOPERATIVE CYCLE

Objects appear and disappear in collective conversational spaces - design is not an isolated event but a discursive practice – constantly inspired by, compared to, contrasted with, copied from peripheral objects, artifacts and the collective memories (Collective field of seeing and doing, Chapter 3.1). Visual material (objects, artifacts, patterns) unlike symbolic spaces is open to interpretation (high dimensional) and the same material may evoke completely orthogonal languages in mind of the designers (Fig. 4.4) as they create their own temporal descriptions (embedding), transform the material and then release the descriptions (fuse) to see the material context afresh. As the designers co-operate on the same material space embedding and fusing independently, they respond to each other's observed material transformations by recognizing and accentuating it (pull) or recognizing and disrupting it (push). This push-pull bias marks the beginning of a conversation between the collective, with the material context as the medium.

Fig. 4.3: A Conversation

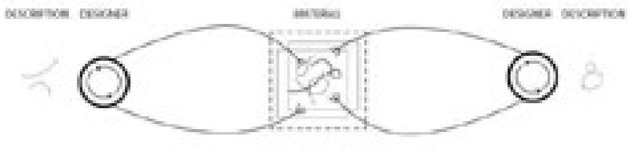


Figure. 4.3: *A Conversation*

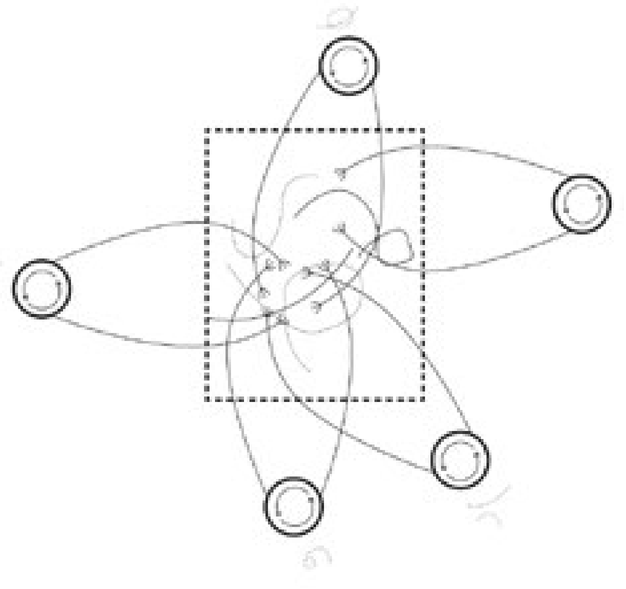


***Figure 4.4:** Many to Many Conversations*

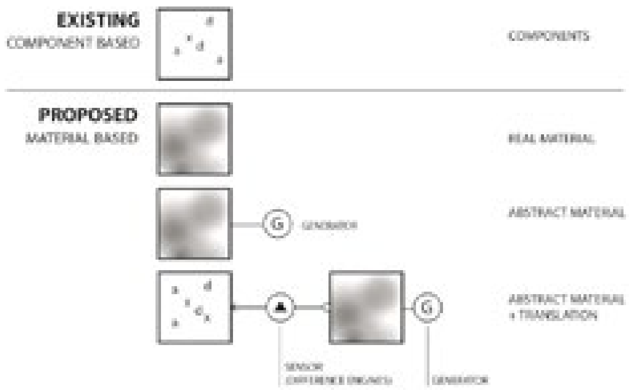


Figure 4.5

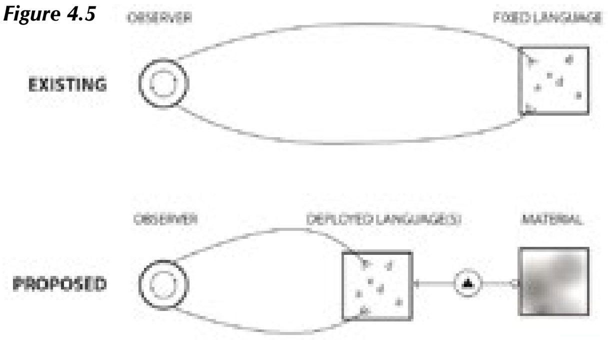


***Figure 4.6:** Decouple descriptions from process (material context)*

The creative cycle of the individual is not a bounded phenomenon but is operational on a backdrop of collective memory and bias. The multiplicities of object-interpretations, their collective superposition and the resultant conversational field between the designers must be embodied within a design tool framework by decoupling description and language from the material context.

1 DERIVING THE SUNGLASS FRAMEWORK

A. Material as unit of interaction and feedback

Contemporary CAD tools are closed toolboxes with prescribed languages / components and the universe of user engagement remains contained within such pre-structured spaces constraining ways of seeing and doing (chap 3.2). The Sunglass framework suggests materials (real or arbitrary property spaces) dimensionless entities as the unit of interaction and feedback. Its only when one wants to transform or record the material properties (seeing-doing) that a language is created or deployed.

B. Decouple language from process

Digital computers are powerful in the sense that they can store (state) and recursively apply rules (process) within preset languages. However storage and recursion by themselves are not enough for building a design system. Contemporary design tools modeled on the Von Neumann architecture, promote strong and singular language-logic coupling forcing the designer to abandon his conceptual fluidity and force fit monotonous set of predefined units of description in order to maintain a consistent, unambiguous world at the cost of completeness - the enterprise of design becomes less of an exploration, more of production. Thus CAD so far has been a success as powerful documentation, data management and problem solving systems, however been impoverished to accommodate the constant structural reconstitution, as a designer shifts and slides between different ways of thinking, generating and deploying arbitrary languages probing for opportunities and wrestling to discover a precipitate language that captures his imagination. The Sunglass architecture is more akin to a difference engine driving parallel and synchronous conversations between designers, materials and languages.

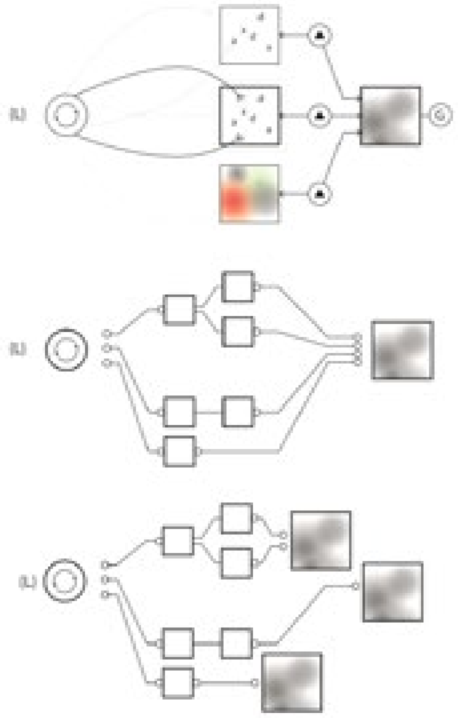


Figure 4.7: *Description Switching and Chaining*

C. Switchable multiple see-do environments.

In the Sunglass architecture, there is a decoupling between a resource (real or abstract material space) and the representation scheme. A representation scheme is analogous to a formal language with a vocabulary and production rules much like current CAD systems – however the difference is the new proposed architecture is the ability to change from one to the other which minimal effort. Secondly, the architecture allows chaining of representation schemes allowing users to find novel combinations at runtime. Finally the architecture casts a design tool in a client-server architecture – much like the world wide web. A client (a browser in a desktop environment, or a mobile app) can request the server for certain resources. The server returns a representation of the resource based on the request details and the client environment. The Sunglass architecture builds on Roy Fielding's (2000) PhD dissertation "Architectural Styles and the Design of Network-based Software Architectures". Fielding described an architectural style for distributed hypermedia systems, which decoupled the state of the client from the server side processes.

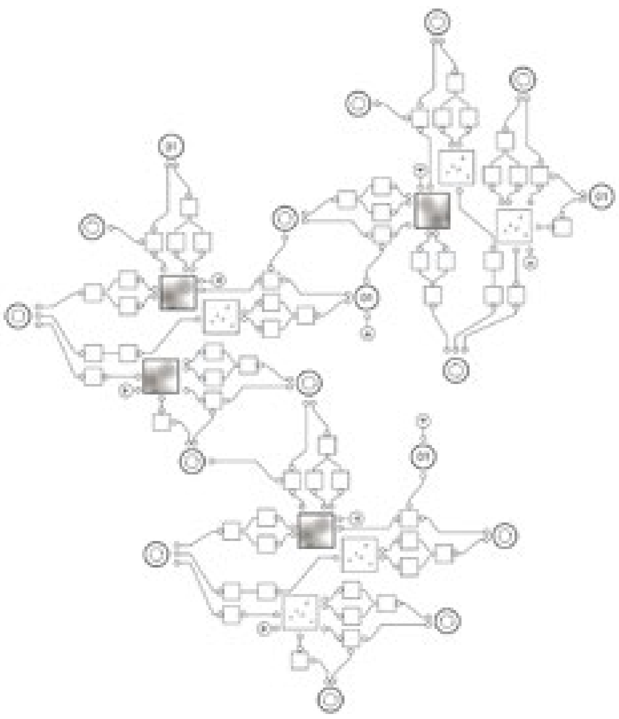
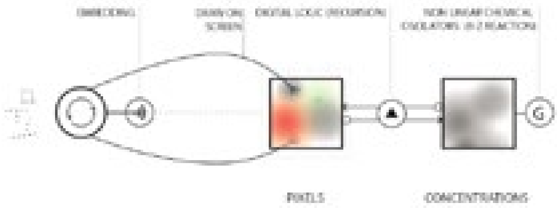


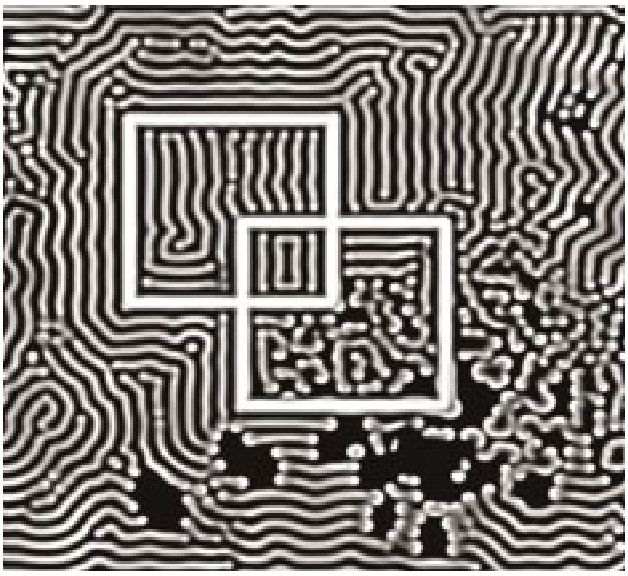
Figure 4.10: *A Networked Model of Human – Machine agency mediated by material contexts.*

D. Collective spaces for engagement

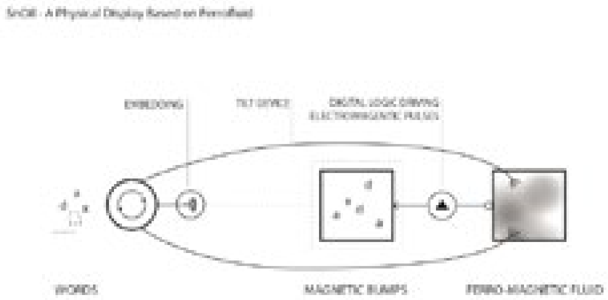
As opposed to the egocentric models of contemporary design tools, Sunglass is a collection of shared spaces in a network, allowing collective engagements. Conversations may be situated within a human or machine agencies mediated by material contexts. It is necessary that these spaces / processes are supported by an asynchronous computing model to release any serialization of events and maintaining mutual independence.

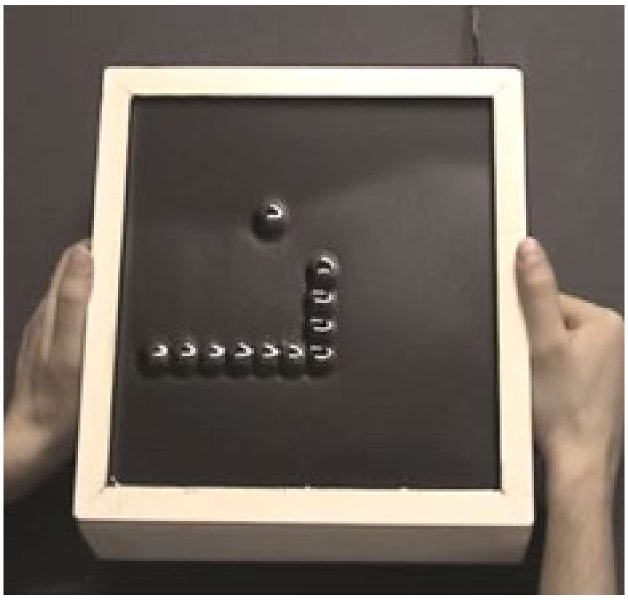
Maxwell's Dream (DeBiswas, Rosenberg 2010): A Sculpture, which allowed groups to collectively play with a magnetic field to paint a pattern in light.



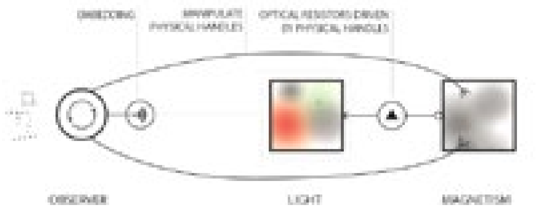


SnOil (Martin Frey, 2006): Playing a game of snake using ferrofluid bumps as interface.

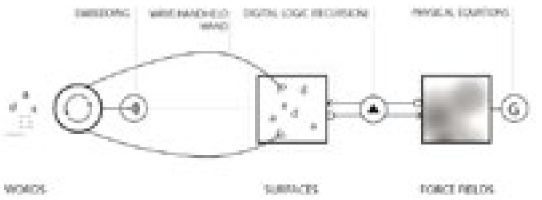


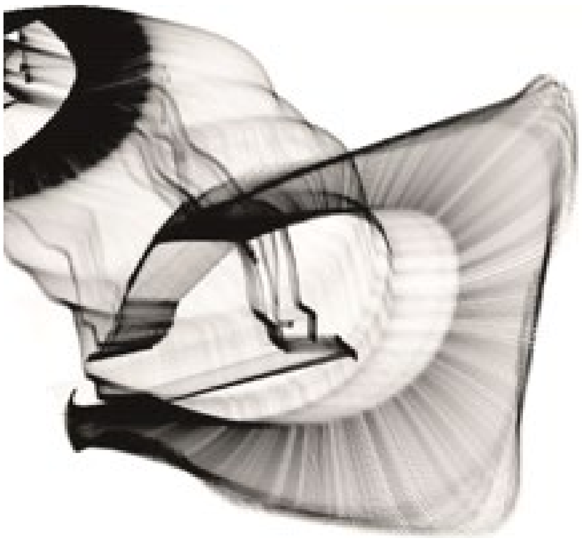


Mediated Paint (DeBiswas 2010): Painting with an abstract / synthetic material (Gray Scott Diffusion Reaction)

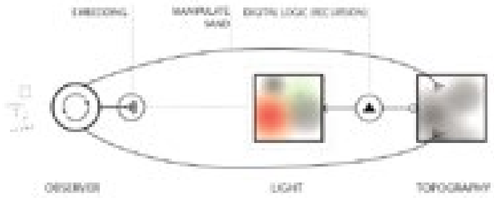


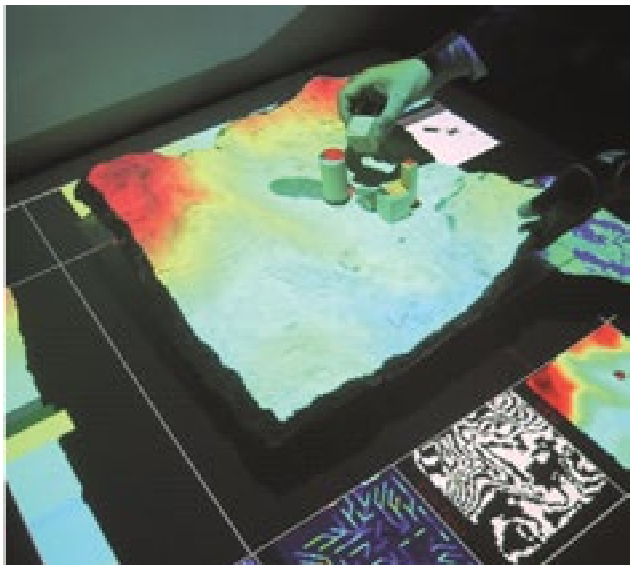
Chemical Morphogenesis (DeBiswas, Tsamis 2010): Generating three-dimensional forms in a synthetic material space (B-Z oscillating equations)



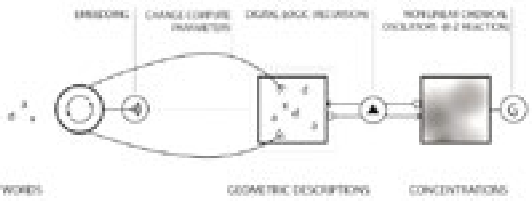


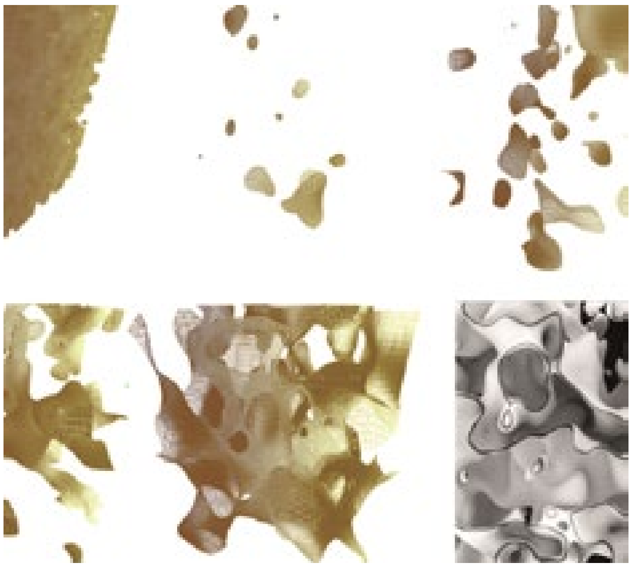
Sandscape (Tangible Interface Group – MIT MediaLab, 2006): Superimposing real-time analysis data on a physical sand-based interface.



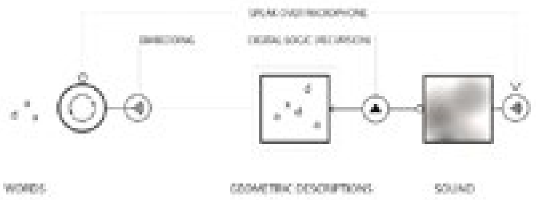


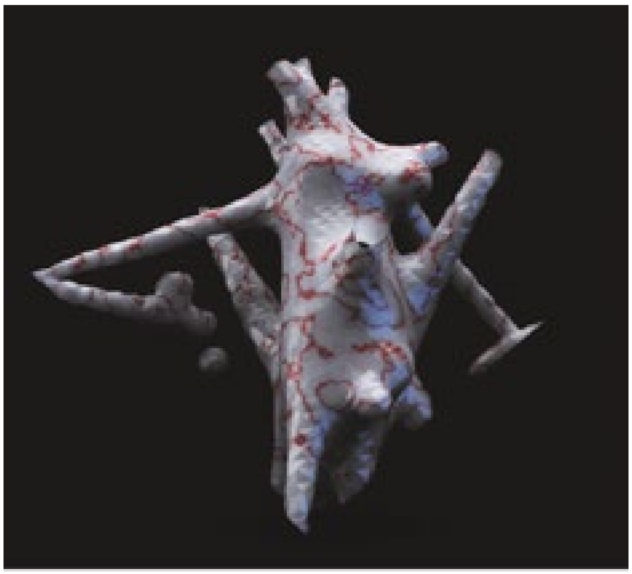
Springy Thingy (DeBiswas, Shen 2007): Drawing in a physics based form-force space where designers would deploy a synthetic springy materials using physical gestures.





Eigene (DeBiswas 2011): An exhibit, which allowed a group to use their voice to collectively shape a visual sculpture.





3 SUNGLASS: INTELLIGENCE-IN-ACTION

Strictly speaking Sunglass is not a model of intelligence, but an apparatus for human engagement with novel environments, with the belief that intelligence arises in such action-reaction spaces - discovering differences through interactions with real or abstract organizations. The following is an account of two primary schools of thought around models of intelligence, followed by a discussion of the Sunglass framework in context.

Intelligence in Description

Action Description

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Turing's seminal paper 'Intelligent Machinery' (Turing 1950) opened up an entire philosophical, psychological inquiry in to the nature of intelligence. In 1956 the Dartmouth Summer Research Conference laid the foundations of the discipline of Artificial Intelligence. In 'Steps Towards Artificial Intelligence' (Minsky 1960) Marvin Minsky summarized the state of art and grounded intelligence in symbolic logic and search. The central motif of this school of thought is that if a problem or a phenomenon is represented efficiently, we can employ techniques (Recursion, e.g. Search, Optimization) to arrive at truths, decisions or solutions. The concept of 'intelligence' was thus severed from physical experience – it became an enterprise of the *disembodied* mind.

> "To solve really hard problems, we'll have to use several different representations. This is because each particular kind of data structure has its own virtues and deficiencies, and none by itself would seem adequate for all the different functions involved with what we call common sense."
>
> Marvin Minsky

In his 'Society of Mind' (Minsky 1986) he lays down the core tenet of his theory of distributed cognition. He suggests that we envision our mind not as a unitary thing but as composed of many partially autonomous 'agents' – a society of smaller minds. Then any 'mental state' can be interpreted as subsets of the states of the parts of the mind. Much like any human administrative organization, Minsky suggests that there are large hierarchic divisions of our mind which specialize in areas like sensory processing, language, long-range planning; and within each subdivision there are multitudes of sub-specialists or agents which embody smaller elements of an individual's knowledge-base, skills and methods. These agents embody small units of knowledge; recognize certain configurations and respond by altering its state. Thus, the total mental state is described by the states of all the 'active' agents.

While the concept of multiplicity is interesting in relation to how designers operate, it is the grounding of such multiplicity in strong classification systems and pre-defined knowledge representation schemes that are problematic. In a recent TED talk, Minsky mentioned that in order to build intelligent machines, the discipline of psychology should be focused on classifying the universe of problem spaces or predicaments that we humans

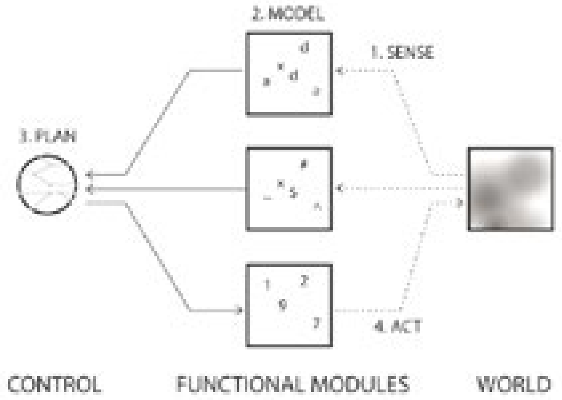

Figure 4.11: *Sense-Model-Plan-Act Model*

encounter and understanding the corresponding strategies of thinking that can be instrumental within each class.

Computations are performed on abstract symbolic world and hence the need for persistent state (strong memory).

Multiple sub-modules with each having a specialized representation scheme.

A central locus of control which understands/ communicates with the different modules to plan and perform actions. Society of Mind releases this but this is true in general for the SMPA (sense-model-plan-act) model, which is prevalent in most experiments in this tradition of thought.

Causal chaining is explicit i.e. we can trace back a certain system behavior to a particular sub-system or module.

Decomposition of intelligence is 'functional', i.e. every sub-module is responsible for delivering a symbolic description of the world up the hierarchical chain of modules based on its function (input->output). The control then processes the propagated input to map actions for the action modules. This causes a large distance between sensing and action.

In his manifesto *A Pattern Language (Alexander 1977)* Christopher Alexander took a similar position of situating design technique in knowledge classification (patterns). He argued that good design is simply a matter of applying core principles. However it is prescriptive and systemized logic does not quite appreciate the nature of intelligence that appears in seeing and doing. Patterns are static pre-set ways of thinking about the

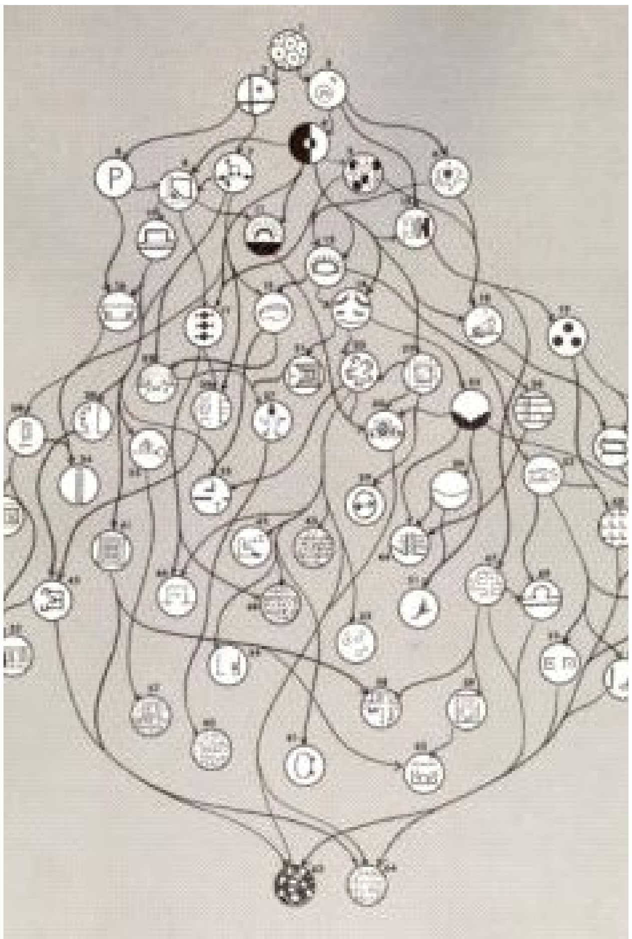

Figure 4.12: *A pattern language, which generates multi-service centers*

phenomenon or evidences at hand, and they discount the spontaneous discoveries of novel patterns and structures that arise during the human experience – design becomes more akin to a diagnosis, and the designer akin to a rule-based expert system like MYCIN (Shortlife 1976). Invention and discovery takes a back seat and instead of artistry, design becomes a clinical and mechanical production.

Intelligence in Action

> "With multiple layers, the notion of perception delivering a description of the world gets blurred even more as the part of the system doing perception is spread out over many pieces which are not particularly connected by data paths or related by function. Certainly there is no identifiable place where the "output" of perception can be found." – Rodney Brooks 1987

Action Description

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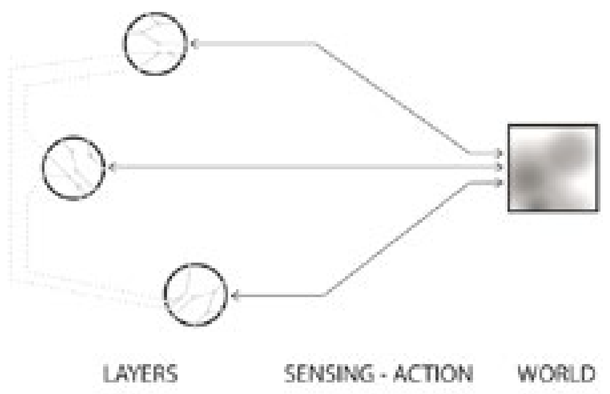

Figure 4.13: *Subsumption Architecture Model*

Rodney Brooks in his paper 'Intelligence without representation' (Brooks 1987) criticized the direction of the enterprise of Artificial Intelligence mentioning that it has retreated into specialized sub-problems (knowledge representation, natural language understanding, vision and even more specialized areas such as truth maintenance systems or plan verifications). Further the developments in these sub-areas are benchmarked against human performance. He asserted that human level intelligence was too complex and little understood to be correctly decomposed into right subpieces. He proposed an approach (Subsumption Architecture) where the real world is its own model, releasing the need for any explicit knowledge representation schemes. Brooks and his team built robots (Creatures), which could carry out multiple goals through constant interfacing (sense and act) with the real world. The fundamental decomposition of his proposed architecture was independent and parallel 'activity producing layers' which all interfaced directly with the world through sensing and action, as opposed to information processing units which interfaced with each other via representations. Though there is central control, they are combined in a fixed topology and there is mechanism via which certain layers can suppress or inhibit other layers (hence the name Subsumption).

> "..the notion of central and p eripheral systems evaporate-everything is both central and peripheral" [Brooks 1987]

1. The real world is its own representation, releasing the need for abstract knowledge representation schemes and symbolic logic.

2. The system has no or minimal state (memory). Brooks creatures refresh (forget weverything) every few seconds and constantly re-sensing the world. Multiple layers/module – each having their own independent sensing and action scheme.

3. There is no central locus of control – parallel layers can suppress or inhibit other layers.

4. Causality is not explicit i.e. we cannot trace back a certain system behavior to a particular subsystem or agency.

5. In this model, the decomposition of agency is by 'activity'. There is no distinction between peripheral systems. Rather the slicing up of an intelligent system into 'activity producing' subsystems. Each activity or behavior producing system individually connects sensing to action without any central control.

6. System can grow incrementally, being fully functional at any point of time, independent of the number of layers.

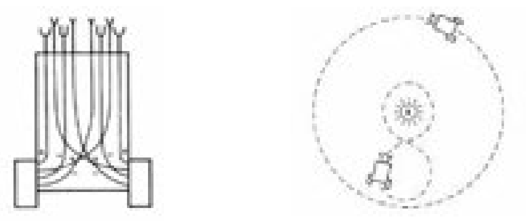

Figure 4.13: *Braitenberg's vehicle and their trajectory around a source*

Fig.4.14: Braitenberg's vehicle and their trajectory around a source

In 'Vehicles: Experiments in Synthetic Psychology' (Braitenberg, 1986) Valentino Braitenberg Although not as sophisticated as Brooks robots (which have augmented finite state machines in modules – hence capable of some storing logics), the vehicles do not have any locus of control, or state and their behaviors are just a continuous reaction to the environment. They *appear* intelligent and it's causally difficult to trace a system behavior to a particular subsystem.

Stiny criticizes preset vocabularies or representations in computation – prefigured units limit both observation and subsequent action. In a commentary on his own book 'Shape' (Stiny 2006), he points out that symbolic logic with its 'complacent appeal to units and primitives and permanent parts' right from the start creates a serious deficiency and becomes an impoverished tool in calculating with shapes – or domains of design where ambiguities are drivers of production.

In 'shape grammars' the designer spontaneously responds to the evidences in the world and embeds a structure on the fly. Through the application of the rules a new world is created, and the structure is released (the parts fuse) allowing the designer to embed again.

Sunglass

Action	Description

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In the domain of design, actions and descriptions coexist – none dominating the other. They are more like strategies that the designer employs to calculate – visual or symbolic – depending on the context.

In the visual paradigm, the designer spontaneously responds to the material evidences through actions - transforming it and leaving traces of what was observed (embedding). These traces can be recorded retrospectively and collectively form a language (vocabulary and rules of production). Stiny's 'Shape Grammar' is a conceptual model of this paradigm and captures the designer's fluid seeing and doing operative cycle, however there are two aspects that remain unaccounted for:

The action-oriented paradigm discounts for any intentionality that is external to the object or material at hand. While a language can be observed in retrospect, it does not reflect 'intensions' of the designer or the 'conversations' in a collective.

The action-oriented paradigm has a posterior stance, looking at the world as it *happened* and not what it *can be*. Without memory devices, containers of thought it is impossible to calculate 'imagined' futures – unless of course the designer has a proverbial flash of the entire future in one go.

In the symbolic description paradigm, the designer recursively assembles abstract worlds, working within a pre-configured language. Starting from Ivan Sutherland's Sketchpad, digital design technologies have been imagined and built in this paradigm leveraging the power of abstraction, recursion and combination. They maintain consistent worlds, applicable for documentation and analysis – however the two important aspects that make this paradigm an impoverished model for design:

The world is never more than what the language anticipates. Design reduced to assembly.

It rejects notions of ambiguity and noise, which are essential for capturing proto-ideas. Designers fix and release structure (embedding / fusing) at will to constantly shuffle between different ways of thinking.

Sunglass framework is an attempt to reconcile the two paradigms by decoupling the material and language, giving the designer access to both for the purpose of seeing and doing.

a. Material as unit of interaction and feedback. (Action-Orientation)

a. Decouple language from process. (Descriptions for leveraging recursion)

a. Switchable multiple see-do environments. (Layers / Decomposition by Activity)

a. Collective spaces for engagement. (Conversational Field)

Over the last year, an ambitious project of implementing the Sunglass framework on a network via state of the art client/server technologies has been initiated. A beta tool has been already deployed in the public domain with several thousand designers (architects, product designers) working on shared collaborative spaces on the Internet. There is a long way to go but there has been tremendous excitement and encouragement around it. This implementation of Sunglass views the entire network of designer as a unified network – a global brain expressing and suppressing cultural desires through artifacts and objects.