while (true)

COMPUTATION AND TIME: DYNAMICS OF STILLNESS

by Afsheen Rais-Rohani

Bachelor of Architecture
Southern California Institute of Architecture (SCIarc)
June 1993

Submitted to the Department of Architecture, School of Architecture and Planning
In partial fulfillment of the requirements for the degree of Master of Science in Architecture Studies
at the Massachusetts Institute of Technology
June 2002

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Abstract:

As the use of digital technologies and computation becomes prominent in Architectural design, there arises a need to transpose the creative process into that new medium intact. The goal of this thesis is to investigate the possibilities for this transition and to allow for the emergence of a poetics. A Poetics of Computation.

Thesis Supervisor:

William Lyman Porter, FAIA
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I would also like to thank my parents for understanding me, despite all that I have put them through.

Finally, I’d like to dedicate this thesis to the memory of my late uncle, A. Rais-Rohani, who left us just two weeks earlier, whom I loved dearly.
Overview
As in the classical psychological separation of nature/nurture, in computational design, the experts are undergoing a similar bifurcation. On the one hand there are designers who begin with some primitive three dimensional geometry, and through manipulations (morphings) transform the geometry into a more fluid, complex entity. These external forces can range from gravity, site conditions, and wind, to the architectural program and infrastructural requirements.
On the other hand, there is the generative, genetic approach through which the design goes through a constructive growth process. Inspiration for such projects can range from plant growth, embryology, and chemical/biological processes. The starting point for this process can be outside of geometry. For example, character strings can take the process a considerable distance before even being translated into lower dimensional geometry. This is why the second approach can potentially yield richer outcomes.
The main difference in the products of these two approaches therefore, is in the geometric complexity -topology- of the produced artifacts.
Three exercises will be demonstrated in this thesis. The first two will respectively follow the above mentioned approaches and the third exercise will combine the first two results.
This third process is best described through a condition found in nature. Take a plant under water. The plant itself is currently going through a growth process, and at the same time, the flow of water is moving this structure based on its various parameters (direction of flow, amount of turbulence, viscosity, etc.)
Although the third exercise symbolizes this convergence by way of process and geometric/material investigations, exercise two already enters into that shared space, looking both to the inside and outside of itself.
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Introduction:

The separation of computational design techniques put forth in this thesis is an artificial one. It is of great importance to keep in mind that this categorization stems from the authors immediate experience in the field of design within the past thirteen years. It is needless to say that many designers who do work with computers in the field of Architecture would not fit neatly into categories outlined here. The use of computation for purely engineering purposes have not been considered here. For example, from the point of view of this thesis, the computer work at the office of Frank Gehry and Assoc. is not considered as part of computational design. The reason is simply because computers do not play an instrumental role in the creative process. Of course, the value of that work is not being judged, but that according to the distinctions necessary for this thesis, that work falls outside of its range. At the same time, there may be techniques touched upon which are shared.

The main distinction here is that the computational process is being viewed as instrumental to the creative process rather than being primarily a tool for technical optimization. It is helpful to think of the categories outlined in this thesis as philosophical rather than technical differences. The categories act as a starting point for the following exercises and more often than not, they begin to depart from their initial trajectories.
A page filled with handwritten notes and diagrams. The content seems to be related to scientific or technical topics, possibly involving computation and time. The handwriting is dense and includes various symbols, arrows, and diagrams. The page is not completely legible due to the handwriting style and density of notes. It appears to be discussing concepts such as 'waves' and 'time', with references to 'future generations' and 'past'.
II. **Dynamic, external forces**
   Background: kinetic/interactive, spatial dynamics

   Computer simulations; Programming with python and Mathematica

Interleaf:
   Architectural wall for modulation and filtration of light.
Still image through several rotating etched acrylic panels.

Layering transparencies; Reflectivity and motion
Interactive, responsive, and kinetic architecture is located in the dynamic category. Essentially, these systems act as animations in that at each given moment only a slice of time is revealed. The existence of each moment is bound to a temporal linearity. Through this trajectory in time, a larger pattern forms itself, transcending its individual parts.

The following project, due to its canonic movement, expresses a duration rather than a single slice of time. At any one moment the observer witnesses many instances of the same object.

Computer simulation of a simple array after multiple transformations; reversible.
This exercise has been developed in three stages:

i. Computer generated simulations.

ii. Electronics components:
    interface with mechanical/pneumatic/magnetic output.

    Sensors as input.

iii. Component fabrication
A working prototype capable of driving up to eight motors using one pic.

The pic is programmed to actuate the motors when the light intensity exceeds some level (adjustable).

After the program is loaded onto the board via a serial connection from the laptop, it can stand alone, holding the instruction set internally.
The wall

Made of tiled components, these modules stand independently. The specifications of these walls do not radically shift the construction of the higher levels of the project. While this is true, the phenomenal presence will be radically altered by replacing the primitive tiles (the building blocks) which are simple geometric modules.
Transformation stages of a wall using cube modules as primitive.
Sample blocks

i. the simplest module is a square or circle. An opaque module arrayed within the framework (structure) of the wall.

ii. the component within itself remains opaque and simple, wood, metals, plastics, but the geometry at the local scale changes.

Each module at this scale can be a lense (negative - enlarging) or( positive - reducing )filtering and altering the perception of the observer.

Each module can be a micro ecosystem. Hydroponics, aeroponics), materials:organic growth ( moss, algae, liquids, ferrous liquids,..... the wall, influenced by the environmental conditions, heat barometric pressure, humidity,cold,.....can change ex. mediums responsive to each parameter.... Each module changes based on its specific makeup.
The resulting pattern in the overall wall changes constantly as each individual component varies over time.
Controls:

1. Mechanical/Pneumatic controls: modules are controlled by motors, pumps, getting instructions from microcontroller.
2. Magnetic controls: As needed, each module can be controlled by magnets which can effect the parameters of each wall locally through receiving electric pulses.

The wall itself is placed within a larger field (recursively). These walls are simply placed on a grid. The walls themselves have rotational freedom around their vertical axes.

At this level also each individual wall is interchangeable allowing for alternate conditions to be composed.
- a. the walls, as noted above, can have rotation along their vertical axes.
- b. the walls have vertical lift reacting to proximity of observer. This quality will bring about an additional layer of global pattern formation based on occupation while the rotation of walls are based on large scale planetary relationships (day and night, seasonal...)
Over time, the walls self-organize themselves.
By responding to larger planetary forces rather than human [herding] dynamics, something other can begin to enter.
The larger field actuates in different modes based on the time of day and seasonal change.
Plan view of walls organizing into larger patterns

A section cut through the structure of the wall.
As the walls rotate, clusters appear temporarily.
Inter-leaf

An architectural devise for modulation and filtration of natural light, this wall project studies a range of possibilities to transform and transfigure our interior spaces.

Natural light (THE SUN), is the prime actuator of this instrument. The instrument itself is made up of multiple rotating aperatures / lenses embedded within one another, both controlled and powered by this light to transfigure the interior spaces we inhabit.

Through this process of filtration the quality of light and shadow will change throughout the day as the resultant of vast relational positioning of the nested aperatures.

The operation of this machine will allow for new conditions to be experienced by the observer.
In at least one sense, the concept of an architecture machine goes back centuries - to attempts by classical Greek and Roman designers, and later, Renaissance artists, to come up with "laws of beauty" and geometric rules and relationships that would automatically translate into aesthetically pleasing structures.

The chief figure responsible for laying down the rules for art and architecture in fifteenth-century Italy was Leon Battista Alberti. Attuned to the regular forms hidden within nature, Alberti based his rules on the geometric concepts of proportion and ratio. Within his design for a building, for example, a certain proportion would be repeated over and over again on varying scales. Large arches would sweep over smaller but still perfectly proportioned arches, and the pattern would continue down to the smallest details.

Ivars Peterson
mathematical mystery cruise
While this system evolves, much attention is given to modularity and constructability. Issues such as pre-fabrication techniques will be taken into account. The constructive nature of the process will allow for the physical realization of such environments, giving it the possibility of being actualized.

Natural structures and growth processes, giving rise to plants, mineral formations and biological complexity at different scales, have provided the setting for the arising of man, who in turn has constructed a layer over and throughout the organic film on which he lives (our cities). The formation of modern cities or any city for that matter are but a recent development given geological-time.

Computational growth, in fact, is more in tune with natural growth, and in most cases natural growth can easily be described as a computational process. Here we are, humans in this instant of geological time, experimenting with but a very narrow field of possibilities.
This is an experiment which intends to apply a set of possibilities that can play themselves out in a parallel universe, so to speak. A different iteration giving rise to a different spatial possibility altogether. Of course this process can also be tuned to intersect current conditions but the intention in this thesis project is to test an entirely new condition with an abstraction of the pre-existing layer as a base. This abstraction can represent, natural forces, and/or pre-existing man-made layers.

It is inevitable that eventually our world is going to reform itself and not only through appropriating new technologies onto, and embedded into traditional architectures. Through this process, these new advances drastically change the built environment and consequently our environmental and spatial experience.

To achieve this objective, I have divided the process into 3 distinct but simultaneous and parallel developments with rhythmic interpollenations between them.
background and transformations of images through viewing and aperture ratings
1. site
The first step is to develop a site. this site in itself is a field condition created using simulations of natural forces. The site is an abstraction; a field of forces changing over time. A dynamical system which will guide and alter what inhabits it.

2. structure
Within the generated site, a structure(s) is developed. This structure has its own internal logic. This growth is externally effected by the position it is located on the site. The structure grows according to natural principles. In this case it may begin with the growth of a spine from which ribs will grow as secondary structures which are in turn filled with tertiary materials to create enclosures. At every level.

3. program.
Simultaneously with the formal development of the structure, a programmatic development must also take place, checking itself periodically with the developing structure where they mutually impact one another. The approach is like growing a body with distinct organs where each organ would develop and grow according to its related programmatic requirement and find its appropriate position within the rest of the project.
The modular quality of the project allows a mass production of this part of the component which in turn is hooked to a single photo-sensor.

The board sends signals to a number of servo motors which run the aperatures along their rotational trajectory.

the prototyping of the materials has been completed using the laser cutter, milled aluminium parts and a steel stand fabricated in our metal shop.

After the board has downloaded the program through a serial port from the desktop, it can store it for future use and can stand independently and operate in remote mode.
This instrument, due to its self-similar geometric construct [nested cavities] requires a general solution to the question of actuation, yet at the same time an architecturally inspired material investigation is necessary to bring to light the full potential of the machine.

The potential for a volumetric presence of this multi-layered wall system is demonstrated in the models on facing page.

In essence this system can operate as a foundation for a 3D display of a specific kind where it reflects the actions of its surroundings through a time lapse. Every layer becomes active at different times of the day and the accumulative result constantly transforms over time.
Prototype 0002

Reflective embedded 3D display prototypes -- mock_up 002
An enlarged sample of an instant, showing the transition into night while the apparatus is installed on the interior part of the threshold condition.

The layering is both sedimentary and catastrophic.

While the layers accumulate linearly, three elements negate liquid zones for the temperature activated cavities running in and out of sedimentary layerings of the object.

The glass cavities are held in place by acrylic layerings. The acrylic layers are connected by stainless steel rods allowing for shifts within the interior cavity formations.
Prototype showing tiling possibilities and modularity of individual interleaf components.

This example shows the modules without the kinetic actuators. In raw form, the individual panels can act as filters creating a much more subtle effect in lighting through the daytime.

Each individual panel is tuned to a different time scale, allowing for the completed instrument to act as a calendar. This calendar will align itself twice annually to the relation between the sun and the earth.
For Alberti design was governed by rules derived from a vocabulary of elements combined with a set of relationships between these elements. This design structure provided a kind of grammar within which the designer worked. Later artists, including Leonardo da Vinci, incorporated and refined these ideas in their own works.

While it is possible to see how useful and fruitful these ideas can be in the design process and how the process can be mechanized, the other half of the creative equation - imagination - is much more elusive. How do humans modify their stored, observation-based representations of the world to create something that does not yet exist and then, when possible, act on the world to make the dream come true?

The intention in the development of this proposal, is to find new ways in utilizing computation to allow for the design of meaningful structures, spaces, and ultimately for new typologies to arise while retaining architectural rigour. The intention here is to, so to speak, shift from the alchemy to the chemistry of design.

Ivara Peterson
Mathematical Mystery Cruise
As our understanding of the world and reality shifts by new scientific discoveries, architecture remains relatively un-effected.

Because of these unchanged surrounding conditions, the mass population is not directly impacted and faced with these new evolving sensibilities.

Since we live our lives surrounded by our immediate dwelling (home, work), syncopated by intervals of urban experience as transitive zones, we in fact physically inhabit a world constantly conditioning us to view it in specific ways. By inhabiting new spaces, our lives, views, and understanding can be drastically effected and changed.
Through this process I intend to create a condition where one is immersed in an entirely new relationship with his surroundings. There is a continuity between the larger context and the individual structures developed at different points on the site.

a. Site forces -- external
b. Logic of inner growth
c. The resulting outcome from a and b.
Working prototype of leaning wall.

In the following three images, the range of motion is visible.

The wall leans away from any object moving in proximity. As two bodies approach the wall from opposite directions, they cause the wall to twist. The twist causes the wall to move away from both bodies in proximity.
twisting

leaning
The correct materials can verify the architectural potential in computational design.
III. Monadic; Internal differentiation

Background: genetic space.
i. logical unfolding of generative structures.
ii. Geometric mappings of these systems.

Computer programming with C/GL.
Endowed by an internal logic, and primarily independent of external, environmental influences.

Ex. Embryological growth: the process of gastrulation and arising of individual organs and the nervous system, gastrulation

In this scenario, primitives are pre-geometric abstractions:

This example is constructed upon one of the simplest possible conditions. Three basic primitives - a, b, and c - with only one of those primitives branching - a->bc.

Based on these initial conditions, there exists a total of six possible combinations (see diagram on facing page).
BRANCHING SYSTEM

1L  a -> b -> c
     ^     |
     |     v
     c -> a

2L  a -> b -> c
     ^     |
     |     v
     c -> a

3L  a -> b -> c
     ^     |
     |     v
     c -> a

1R  a -> b -> c
     ^     |
     |     v
     c -> a

2R  a -> b -> c
     ^     |
     |     v
     c -> a

3R  a -> b -> c
     ^     |
     |     v
     c -> a
Each of these six sub-systems grow with slight variations based on the particular character which is branching. The facing diagram displays the first twelve generations of each sub-system and their corresponding representations in bar codes.

I worked on this project with xkavya in 1997. The project reached its limits simply because we were not utilizing programming to its full extent. It remains however, the best way to introduce the following section.

The bar codes act as the first movement towards a geometric mapping.

The following pages illustrate the next level of mappings. In this case one of the systems is mapped using a polar coordinate system.

Each mapped generation then becomes a structural section of a resulting surface which will sit on the structure.
2. Mappings in 2-dimensional space.
This information can be viewed as sectional data which, in the following stage will be connected to form volumetric enclosures and surfaces.
The development of algorithms to generate logical structures and growth processes, identifying primitives and their possible meaning in terms of programmatic, organizational, and infrastructural requirements.

The first system in this series is built on the growth and transformation of three primitives (a,b,c) with only one of those primitives branching. This setup allows for a total of six possible permutations.

generation 9 in system -z
2. Mappings in 2-dimensional space: This information can be viewed as sectional data which, in the following stage, will be connected to form volumetric enclosures and surfaces.
Generation 1 to Generation 16

The development of algorithms to generate logical structures and design processes, identifying primitives and their roles and meaning in terms of programmatic, structural, and infrastructural requirements.

The focus of this series is built on the growth and performance of three primitives (a, b, c) with only one of those primitives branching. This setup allows for a total of six possible permutations.

3. Surfacing the resulting structure, interlocking, or primitive paths.

After assembling laser cut n's, use either flattened/unfolded geometry to put together skin and refine manually, refine, refine.
Generation 1 through 10 CW

Mapping using NURBS
(non-uniform rational b-splines)
Generation 11 and 12 CW
Beyond 12 generations, the system becomes extremely difficult to follow manually and almost impossible to map. It was necessary to write a computer program to automate this process. The computer program allows for an unlimited number of primitives. The main challenge was to implement deletion rules. The difficulty was in that the program could recognize a single character within a string and replace it with any number of characters, but the reverse required many lines of new instructions. The solution came from the logic of branching within the growth enabling nested sets in later generations.

This program is written in C /openGL.
(see appendix)

The first generation of this code generated character strings from the bottom up on a two dimensional plane.
Flat view through two layers.
Multiple layers of the same system in 3D space
The second iteration of the program: character strings growing in parallel planes within a three dimensional environment.
animation stills: parallel systems rotating in space
animation stills: parallel systems rotating in space
Horizontal strings of characters represent individual generations. Growth is increasing vertically.
The most inherently natural mapping (in this case a tree) from the growth of the system has been used to generate the geometry.
Still frames of plant under flowing water after a storm, from Solaris, a film by Andrei Tarkovsky

facing page: three dimensional mapping of the system with three primitives and one branching rule.
facing page: The environment in which this structure exists has properties which brings the whole project closer to a combination of both internal growth and environmental forces.
facing page: progressive moments of this structure moving in time.

In this case, the environment has gravitational controls, viscosity, and the left mouse click activates and alters damping of joints throughout the structure. This damping allows the structure to exhibit some natural behaviours.
IV. Co-existence
L-systems: structural growth.
Proportional extractions into phenomenological space
-physical models.
This last exercise acts as a catalyst, a simultaneously abstract and literal realization of my ideas. It is abstract in the sense that it houses two different geometric coordinate systems within the same space, and it reflects a map rooted in philosophical notions. It is literal in that it indexes a beginning for a physical Architectural project. The model simultaneously operates at the level of object, at the level of viewing instrument, and as a model for something larger than itself. The moving image aims at capturing the process of its making, and it also attempts to capture views of the entity as it would exist at a different scale. While simulating an optical space, it attempts to describe a coexistence of two geometric coordinate systems within a singular space, and it has also served as a rich grounds for a materials investigation. The major factors behind the model are multiple:
1. an iterative process to evolve a structure to inform the proportional ratios between the parts of the model.
2. Using pre-existing software for a thorough analysis of the result based on a method other than its original construction. This second step acts as a filter to extract new information. in other words, the physical model maps only certain properties of the computational model.
3. Investigation into properties of transparency, translucency, reflection, refraction, and defraction.
Lindenmayer system, or L-System, was introduced in 1968 by the biologist Aristid Lindenmayer, primarily conceived as a mathematical theory on plant development. In the 'bible' of L-Systems, "The Algorithmic Beauty of Plants" (ISBN 0-387-97297-8) - or ABOP for short-, Lindenmayer and Prusinkiewicz wrote:

"The central concept of L-systems is that of rewriting. In general, rewriting is a technique for defining complex objects by successively replacing parts of a simple initial object using a set of rewriting rules or production."

An L-system is a rule like description of a 3d form. It contains descriptions of parts and how they should be assembled together.

The description is applied to itself a number of times (e.g., recursion levels) so fractal and recursive forms are very easy to describe in an L-system. By increasing the recursion level the form slowly 'grows' and becomes more complex.

The computer model is generated using this program.

An L system file format is completely structured. The file is a standard ASCII text file with a defined order for passing parameters from the text file to the program which acts on those parameters to create an output file.
Orientation Commands

+ Turn left up and around vector
+(x) Turn x left up and around vector
- Turn right up and around vector
-(x) Turn x right up and around vector
& Pitch down around left vector
&(x) Pitch x down around left vector
^ Pitch up around left vector
^(x) Pitch x up around left vector
< Roll left (counter clockwise) around forward vector
<(x) Roll x left (counter clockwise) around forward vector
> Roll right (clockwise) around forward vector
>(x) Roll x right (clockwise) around forward vector

Movement Commands

F Move forward and draw full length
F(x) Move x forward and draw full length
Z Move forward and draw half length
Z(x) Move x forward and draw half length
f Move forward full length
f(x) Move x forward
z Move forward half length
z(x) Move x forward
g Move forward full length
g(x) Move x forward
. Don't move

Special Orientation Commands

| Turn 180 deg around up vector
% Roll 180 deg around forward vector
$ Roll until Horizontal
~ Turn/Pitch/Roll
~(x) Pitch down around left vector
t Pitch x down around left vector
t(x) Pitch up around left vector

Structure Commands

[ Push current state
] Pop current state
{ Start polygon shape
} End polygon shape
Increment / Decrement Commands

"    Increment length by 1.1
"(x) Multiply length with x
'    Decrement length by 0.9
'(x) Multiply length with x
;    Increment angle by 1.1
;(x) Multiply angle by x
:    Decrement angle by 0.9
:(x) Multiply angle by x
?    Multiply thickness by 1.4
?(x) Multiply thickness by x
!    Multiply thickness by 0.7
!(x) Multiply thickness by x

Additional Commands

c    Increment color index
c(x) Set color index to x
@    End of file
#    Comment
The parameters which are passed to the program are:

- The number of recursions (Line 1)
- The default angle used for orientation commands (Line 2)
- The default line thickness used for drawing (Line 3)
- Axiom (Start string) (Line 4)
- Rule 1 (1st Substring which acts on axiom) (Line 5)
- .
- .
- Rule N (Nth Substring which acts on axiom) (Line N+4)
- "@" (End of Rules Marker) (Line N+5)
First transformation. The focal distances from the face of the model (image below) is determined by sectional information (image on the left).
Perspectival studies to determine placement of optical lenses.
The initial distance the lenses have from the model is determined by the proportions derived from the model on opposite page.

The end points of the L-system structure extruded along the z-axis.
Each location marks a crossing of two or more members derived from the L-systems structure.
The model before final assembly
The final model before full assembly
Saul Griffith, a PhD student at the media lab taught me how to cast optical quality lenses. After casting about one hundred of them, I was able to make around fifty flawless pieces for the model.

facing page:
The casted set of lenses after frame assembly
Light studies of individual panels. These panels reflect and deflect light (somewhat like a beam-splitter) as they rotate along their z-axis.
Still images from defractive rotating partitions
opposite page:

the first study model
Frontal shot; looking through to the facade from outside
Image sequence from exterior of model.

The observer looking in.
Looking towards the face. The three zones are visible
1. Outer zone with rods holding optical components
2. Thick skin (habitable) with frozen perspective inside it. It acts as foundation for structure of optics.
3. Inner zones: cartesian planes holding conic spiral structure.
End layers of laser cut block slide back about the cone

40 layers of laser cut acrylic embedding two 3 dimensional etchings of proportional system

Rods supporting the lenses spiral back to the apex of the cone.

Optical cast lenses
V. Conclusion

As new technologies are continually developing, their influence in design is also expanding. I sense a great danger in this trend. The influence of computation within the field of design does not necessarily have to come at the cost of the loss of meaning. Years ago, I was introduced to methodologies in design which now fall under the category of computation. At that time however, computers were just not around (1990-91). I feel very lucky to have been introduced to this, what is now called computational design, from a philosophical standpoint. Computation is an ancient idea. This seed was planted in me by my teachers in the past and I am greatful for it. It is important to realize computation is taking place everywhere from the microscopic to the macroscopic scale, inside of us, and also outside us. In my opinion, what is important is to understand why computation is significant. what is behind it?

A computational process can be a revelatory device.

I hope that the work recorded here will be continued by some other and be pushed to the next level.

I feel it is extremely important to remove the earth (man) from the center once more and replace it with the sun, as it is in reality.
References:

all images by author unless otherwise marked