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Lecture 2

Geometric Recursion and Fractals.

A. The Sierpinski gasket.
B. Perforation, bending, and folding.
C. Anti-gravity anxiety.
D. Architecture of the horizontal.
Introduction

• Constraints make design easier by narrowing down choices
• There are several constraints that guide design to adapt towards innate (biologically-based) human sensibilities
• Universal scaling is a necessary but not sufficient condition for adaptive design
A. The Sierpinski gasket

• Start with an equilateral triangle
• Subdivide its sides into 1/2, and draw 3 triangles inside the original triangle
• Now subdivide those smaller triangles into 1/2, and repeat the process
• Geometric Recursion
Sierpinski gasket
Sierpinski gasket (cont.)
Cut out down-pointing triangles
Mathematical, natural and architectural fractals

- The Sierpinski gasket is an exact fractal with an infinite number of decreasing scales.
- Its scaling factor is 2, not 2.72, so it does not precisely follow universal scaling.
- Triangles are a very specific geometry — we are not proposing triangles for the shape of buildings or cities.
Scaling by factor of 2
Two types of fractals

• All fractals depart from uniformity
• *Perforated* fractals cut out smaller and smaller pieces (gaskets, sponges, sieves)
• *Accretive* fractals add smaller and smaller pieces to build up fine structure
3-D accretive fractal castle

• Start with a thick square slab
• Add four smaller square slabs on top of the corners
• Repeat on smaller scales (scaling factor 3)
Scaling symmetry creates coherence

• Similar shape when a fractal’s particular details are magnified
• The brain handles more information encoded in a fractal than if random
• Key to fractal information compression
• Fractals in nature have similar but not identical features under magnification
Self-similarity
Physiological wellbeing

• Self-similarity endows visual coherence — important to human perception
• The brain evolved to handle self-similar natural structures
• We react with alarm at structures that exhibit no scaling coherence
Fractals in architecture 1

- The Cosmati family of mosaicists and floor builders created a series of Sierpinski pavements in 12-14C Italian churches.
- African villages have naturally fractal plans, not triangular but circular.
- Islamic tile patterns are intrinsically fractal, showing high degree of self-similarity.
Plan of Ba-ila, Zambia
(documented by Ron Eglash)
Ethiopian silver cross
Western arrogance!

- We can learn from vernacular architecture
- Unfortunately, the West exports non-adaptive, absurd design styles and typologies tied to industrialization
- These erase sustainable local traditions
- Massive media coverage in league with globalization convinces the rest of the world to abandon their culture of building
Fractals in architecture 2

- Manueline Portuguese architecture consists of accretive fractals
- Smallest details are most effectively used on regions closest to users
- Structural information is never lost by zooming into the area of detail
- Sometimes detail is distributed all over — Hindu temples with sculptures
Detail focused in small region
Minimalist modernism is not fractal

- Only the largest scales are defined
- Maybe one or two scales are present — enormous gap between scales
- No intermediate scales to tie the form together according to universal scaling
- *No scaling coherence*
Postmodernist & Deconstructivist buildings are not fractal

- Opposite problem of minimalist style
- Too many things going on in too many different scales — no scaling hierarchy
- Scale of free-flowing forms is ambiguous
- Nothing is self-similar, because designs deliberately avoid symmetries
- *No scaling coherence*
Adaptive buildings

- The human body has a hierarchy of scales, from 2 meters down to 1 mm
- Adaptation to human use and senses generates substructures and details
- Adaptive buildings connect through a scaling hierarchy to the microscopic structure of the natural materials
B. Perforation, bending, and folding

• Morphogenetic development in architecture
• Architectonic elements necessary to define a scaling hierarchy
• Physical model helps to visualize how fractals are generated by stresses
Three processes

• **Perforation**: windows, doors, arcades
• **Bending**: departing from straight lines creates structure on smaller scales
• **Folding**: crenellation, pilasters, fluting on columns
Perforation: semi-permeability

• In adaptive architecture, biology, and urbanism, boundaries are not absolute
• Semi-permeable membranes let something through while keeping other things out
• Arcades & bollards: let people through while keeping cars out
• Window grille or Mashrabiya: lets air and light through while keeping people hidden
Perforation: arcade
Perforation: bollards
The “push-pull” model — *Pull*

- Pulling uniformly along a line breaks it at regular intervals (sealing wax on rubber)
- Tension generates perforations — gaps on smaller scale
- Eventually leaves only points
- Examples: colonnades, arcades, monumental axis outside Egyptian temples
Tension perforates; eventually separates line into points.
Horizontal tension

- Pulling first separates smooth wall into mostly vertical window and door openings
- Uniform lateral tension separates wall into sections with vertical cuts — arcades
- Further tension separates all wall pieces into columns — creating a straight colonnade
- (This model questions curved colonnades)
Horizontal tension subdivides
The “push-pull” model — *Push*

- Push a line along its axis so that it folds uniformly
- Generates meanders — new fractal scale
- Compression will eventually bend the whole line to create a curve
- Examples: Circus at Bath; circular plazas surrounded by coffee tables and café alcoves; temple interiors
Compression creates meanders, then overall curve
Horizontal compression

- Generates smaller structures
- Folding occurs along lines orthogonal to the direction of compression
- Pilasters, thick door and window frames, ceiling beams
- Departure from smooth, straight wall or ceiling
Horizontal compression folds
Folding: space-filling

• Folding a line is the first step to filling the space slightly

• Meanders create articulations on new, smaller scales

• The boundary of successful urban space needs those smaller scales — which accommodate human activity nodes
Folding: walls
Fluting on column drum
Bending: adapts to volume

- Bending creates a boundary for space
- Domes are best for ceilings, giving the most positive sense of psychological enclosure
- Domes are also more structurally stable
- Urban space needs semi-enclosure on its perimeter, achieved by the surrounding building façades
Folding on dome
Implications of vertical push

• Vertical compression creates folding
• Folding creates horizontal bulges
• There are no horizontal gaps, since those would be generated by vertical tension
• No natural mechanism for vertical tension!
• Buildings that show horizontal gaps are perceived as unnatural, and create anxiety
Vertical push generates morphological features
Gravity influences curvature, thickens capitals and bases.
Biophilic constraints on the “push-pull” model

• Human physiological sensors orient us with the vertical and horizontal axes
• Diagonals generate distress, except when symmetry creates an implicit vertical axis
• BOTH PUSH OR PULL CAN ACT HORIZONTALLY
• Because we evolved with gravity, ONLY PUSH CAN ACT VERTICALLY!
3. Anti-gravity anxiety

- Anti-gravity pulls building upwards
- Vertical tension breaks façade, cutting it and separating it into horizontal windows
- Pull creates horizontal gaps and slits between horizontal slabs
- Vertical tension can pull entire building off the ground — maintained by minimal supports (not columns, but stretched pilotis)
Anti-gravity design pulls building upwards
Not rooted to the earth

- Vertical pull lifts building up, like a space ship
- Building pulls away from humanity
- Something alien — appears to want to detach from life on earth
- Columns are the opposite of pilotis
Pilotis are stretched cylinders

- Pull cylinder uniformly
- If it is elastic, it will stretch
- Cylinder will also narrow in diameter
Columns are compressed cylinders

- Push cylinder to create column
- Pressure widens capital and base
- Further pressure can buckle column
- Serpentine column
Perverse application of “pull”

• Universally applied to world architecture
• Consistent application of our “pull” rule
• Stretching creates horizontal gaps on many different scales — sometimes fractal?
• BUT IN THE ONLY DIRECTION THAT CAUSES ANXIETY — VERTICAL
Anti-gravity generates anxiety
Poverty of conception

• Some vertical “pull” designs show subdivisions on smaller scales
• But vertical “pull” buildings are mathematically one-dimensional
• Any fractal structure is 1-D, because subdivisions are only in one dimension
4. Architecture of the horizontal

• The British philosopher Roger Scruton first described this idea in a 1980 BBC talk (reprinted in “The Classical Vernacular”)

• This method kills design on the vertical dimension, by simply moving the plan up

• Buildings become stacks of horizontal slabs

• The “Domino” house by Le Corbusier
Absurd design idea

• “The plan is the generator” — Le Corbusier writing in his propaganda pamphlet “Towards a New Architecture”

• Draw a ground plan, then translate it upwards to define the building’s volume

• Design method taught in all architecture schools today
Vertical “pull” design has become the world standard
End of 3-D design

• Lifting ground plan to define building eliminates 3-D design altogether
• No façade for human beings to be able to relate to — no adaptivity to senses
• Reduces architecture to 2-D, and just the ground dimensions that are not perceivable!
• Spaces in actual building not designed!
Multi-storey parking garages

• Lend themselves to horizontal slab typology
• Anti-gravity anxiety is one reason why they destroy the urban fabric
• Solution: surround them with real façades
• Older parking garages had stores on ground floor, and fronting the street on all sides
Venetian blinds

- All details contribute either towards anxiety or wellbeing in the built environment
- Illustration of anti-gravity anxiety from minor elements such as window shades!
- Venetian blinds fit into windows that are wider horizontally — anxiety
- Older louvres were embedded into vertical frames — pleasing
Anxiety-inducing horizontals enclosed by vertical frame
Garages in suburbia

• The garage opening is a horizontal gap
• Widespread architectural typology, most prominent feature of today’s house façades
• Contributes to dead feeling of suburbia
• No attempt made to frame a garage opening or to provide a canopy or roof, which would improve the design
Typologies that induce anxiety

• Many building and urban typologies that induce anxiety in the viewer were introduced in the early 20th century
• Those typologies have become standardized
• Standardized typologies are copied without even thinking about their consequences
• Our built environment has become deadening and we don’t realize why