Algorithmic Sustainable Design: The Future of Architectural Theory.

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Lecture 7

A. Biologically-inspired computation.

B. Genetic algorithms.

C. Computation versus memory retrieval.

D. Evolutionary regression.

A. Biologically-inspired computation.

- An algorithm that follows or mimics biological processes
- Computation guided by biological constraints towards adaptivity
- Algorithm uses biological sensors to endow the configuration with “life”

Process of optimization

- Biological systems optimize themselves via selection
- What is being optimized is either physical form, or behavior, or both
- Evolution is therefore a computation with bio-geometrical constraints on the underlying structure

Example: laying out the plan of a new building

- Suppose we are going to build on a green site, or on an existing lot
- Walk the lot and identify the centers
- Totally emotional, not mathematical
- Use sensory feedback to fit building components into the site
- ***Influenced by every detail already there***

Best initial fit

- Match typological elements “entry”, “main rooms”, “windows”, etc. with where emotion and intuition tells us they belong
- Compute the project’s morphology using cognitive resonance — using our own body’s exquisite biological sensors
- Mark the site with sticks, flags on posts, cardboard panels, chalk on ground, etc.

Participatory design

- These steps are more accurate when taken with the participation of a group of people — *an on-site charrette*
- Architects working together with eventual users make decisions ON THE SITE
- Reach a consensus about shapes, paths, placements, and configuration

Radical propositions

- 1. ***Consider everything existing on the site*** — don't just wipe everything clean
- 2. ***Make value judgments*** about which existing elements are life-enhancing
- 3. Save those and discard the rest
- Decide to keep a tree, a large rock, but remove some earth and older structures

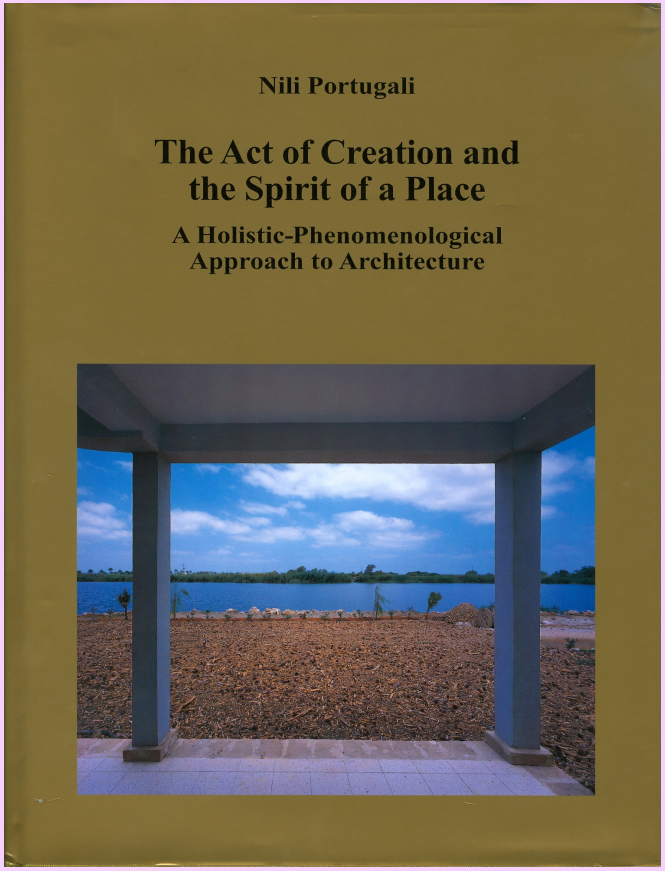
Preparing the plan

- Tens of millions bits of information influence the plan subconsciously!
- Less information available in the office
- The entire building, or set of buildings, *is conceived on the site*
- When on-site design is finished, *measure the physical markers on the site to accurately draw the first plan*

Method as formulated by Nili Portugali (Tel-Aviv, Israel)

- Adaptive design method used by Christopher Alexander and his students
- Building *grows out of* the site, and is not *imposed* upon the site
- Plan is first encoded on the site itself
- — using low-tech markers and props!

"The Act of Creation and the Spirit of a Place"



Step 1

- Identify the main centers of the site:
- — focal points of geometry
- — focal points of activity
- These centers reinforce each other
- Imagine performing each activity in the building already erected — where does it *feel* to be the best spot for it?

Step 2

- Identify the main and secondary entrances to the site
- Establish the most natural connection to the existing surroundings: roads, buildings, etc.
- Use Alexandrine patterns to define approach and entry so that it is enticing

Step 3

- Internal paths arise from linking the localized activity centers
- *Sequence*: centers first, paths second
- Define the paths while actually walking on the site
- Approach from the outside involves one or more paths

Step 4

- Decide on the rough boundaries of each center of activity
- Those boundaries are now beginning to fix the geometry of the plan
- Choose the entry point for each center
- This determines the path structure more accurately

Step 5

- Decide where to place structures
- Structures are there to accommodate the activity and geometrical centers, not the other way around!
- The most intrusive structures go up in the least attractive parts of the site: Alexander's **Pattern 104**, "*Site Repair*"

Step 6

- Stake out the useful urban space
- Decide outdoor activities: walking on a path; sitting outside — and reinforce them
- Coherent urban space is defined by walls, and is not just external left-over space
- Chapter 2 of "*Principles of Urban Structure*" — 20C ruined urban space!

Step 7

- Lay out the future indoor spaces
- Use all the appropriate patterns from Alexander's "*A Pattern Language*"
- Finally, only now decide on the walls!
- Once this preliminary work has been done, proceed to develop the building

Unexpected form

- What are the indications of success towards an adaptive design?
- Examined back in the office, the plan feels RIGHT, and it also looks rather UNEXPECTED — a positive quality
- This means that it is an *evolved* design, but not an imposed design
- Could not have been made up

“Unexpected” but not “absurd”

- I distinguish between our unexpected designs and the absurd forms of contemporary architecture
- Evolved design in perfectly adapted, not made up arbitrarily!
- Absurd forms do not adapt to anything, not even to the program brief!

Proceed into design

- Make a list of the project's relevant socio-geometric patterns from Alexander's "*A Pattern Language*"
- Derive new patterns needed by the project, if those are not yet developed
- Look to precedent, tradition, successful solutions under similar circumstances

Then combine the patterns

- Combinatoric method from Chapter 8 of "*Principles of Urban Structure*"
- Combine patterns acting on smaller scales together hierarchically into higher-level patterns
- Link all scales together through the patterns acting on different scales
- Do not privilege the largest scale!

Proceed into design (cont.)

- Decide on your form language
- Tectonic and ornamental vocabulary
- Adopt a pre-existing form language suited to the locality (memory), or create your own form language
- Make sure to use a rich form language — otherwise design cannot be adaptive

Calibrate the form language

- Chapter 11 of "*A Theory of Architecture*" shows that a rich form language will never contradict the pattern language! (Otherwise, discard)
- Express all tectonic elements in the chosen form language
- Pay special attention to smallest scales

Now design the building

- Follow recursive rules for creating centers (*lecture 5*)
- Previous sequence of seven steps for laying out the ground plan reflects the general approach on all scales
- Adaptive emotion-based computation continues all the way down to the smallest scales of ornamentation

B. Genetic algorithms

- An algorithm is a list of instructions
- An algorithm can evolve using a Darwinian processes that selects for success
- Start with an algorithm that works
- Introduce random variations in the code
- Millions of new variants won't work
- One variant may work, and could be better than the original algorithm

Monsters from genetic algorithms

- Darwinian process of selection can indeed generate monsters — Chapter 10 of "*A Theory of Architecture*"
- Occurs when you select forms for "cuteness" or "strangeness", not for adaptivity to human needs
- Is the system evolving towards a higher intelligence, or into a monster?

The key here is selection

- In contemporary architecture, selection is usually based on generating forms that induce anxiety!
- Anxiety is misinterpreted as the thrill of exciting new forms, but it actually affects our body negatively
- Adaptive design solutions don't give the same thrill that triggers anxiety

Selection in design

- My friends and I apply selection criteria based on human needs and sensibilities — result generates a feeling of wellbeing
- Our selection criteria are the following adaptive CONSTRAINTS (*lecture 5*):
- — ***pattern languages; universal scaling; universal distribution; centers; fifteen fundamental properties, etc.***

Incomprehensible complexity

- Computer scientist W. Daniel (Danny) Hillis has bred sorting algorithms
- These genetic algorithms are faster than any written by human programmers
- HILLIS DOES NOT UNDERSTAND HOW THEY WORK!
- Their complexity is as long as themselves

Collective intelligence

- Traditional design methods have evolved through Darwinian processes
- Now stored in built memory as part of the traditional environment
- Their complexity equals their code
- No shortcut to understanding how they work — Chapter 10 of "*Principles of Urban Structure*"

Correctness of traditional architectural and urban typologies

- Evolved solutions — they work even if we don't understand exactly why
- Known to solve all problems of a particular type, and to always give an adaptive solution
- These proven results of evolved algorithms must be preserved for use!

Algorithmic ambiguity

- Let's invent a new design algorithm…
- But just because an algorithm gives output, that does not mean its output represents any valid results
- Results may be nonsensical, or toxic
- Validation criteria must come from OUTSIDE the algorithm itself

Rule of thumb

- Design computations must be validated by checking against EVOLVED SOLUTIONS
- Traditional design gives results known independently to be correct
- Use these as a check before proceeding to more innovative design problems for the contemporary world

C. Computation versus memory retrieval

- MY CLAIM: ***Most design relies upon a stored memory bank***
- Even when designers thinks they are being most innovative, subconsciously, they are still drawing upon memory
- It is therefore crucial to have a bank of evolved solutions to draw from!

Example: some famous architects

- Ludwig Mies van der Rohe, Daniel Libeskind, and Frank Gehry all have their own very narrow design style
- Each re-cycles the same image-based design elements in every building
- Their claim to "innovation" occurred in the very beginning — after that, they rely upon their stored vocabulary

Process of memory retrieval

- A trivial mathematical explanation
- Previous results of computations using an algorithm are stored in memory
- Table of products lists entries in a 2-D array
- Look up the result — no computation involved, only recall
- For example, 3 x 5 = 15

Multiplication table

x	1	2	3	4	5
1	1	2	3	4	5
2	2	4	6	8	10
3	3	6	9	12	15
4	4	8	12	16	20
5	5	10	15	20	25

Memory is liable to corruption

- Using two coordinates, locate product in memory array: (3, 5) = 15
- But informational virus can invade the memory bank
- Virus replaces data with copies of itself
- Virus uses memory to propagate — computations that rely only on memory make copies of the virus

Multiplication table corrupted by the data virus “5”

x	1	2	3	4	5
1	5	5	5	5	5
2	5	5	5	5	5
3	5	5	5	5	5
4	5	5	5	5	5
5	5	5	5	5	5

False results

- Computation accesses the correct data position (cell) in memory
- No algorithm is involved
- But memory is corrupted by virus
- *Output is wrong*: 3 x 5 = 5

Check result by using algorithm

- Problem: $S = 3 \times 5$
- Write product as a sum $S = 5 + 5 + 5$
- Add the first two numbers $S = 10 + 5$
- Repeat process until you have only a single digit
- $S = 15$
- This is the answer

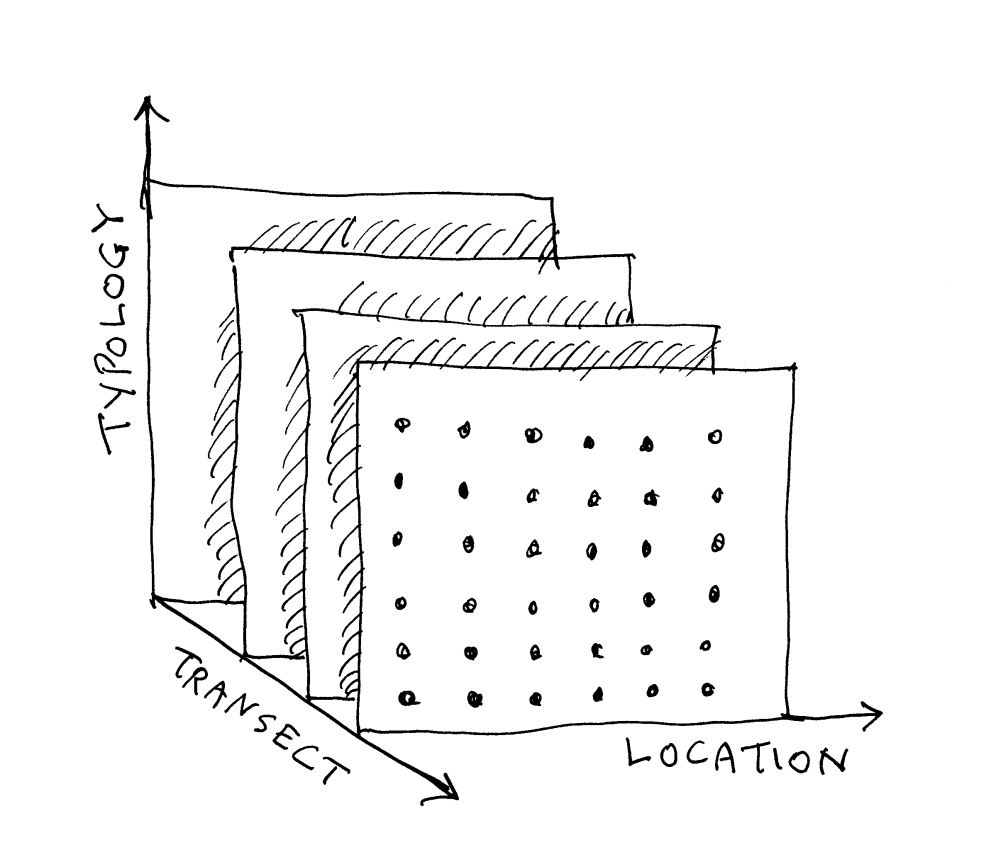
Set up the two memory banks needed for adaptive design

- Memory bank 1 contains typology
- Memory bank 2 contains socio-geometrical patterns in the sense of Christopher Alexander
- Set up architectural memory bank 1 — *a three-dimensional reference system containing evolved solutions*

Architectural memory bank 1

- **First axis is *urban density***: use the Transect system of Andrés Duany and Elizabeth Plater-Zyberk, labeled T1 to T6
- **Second axis is *world location (which includes a form language)***: Algeria, South-Eastern USA, Nigeria, Scotland, etc.
- **Third axis is *functional typology***: school, bank, church, apartment building, house, store, factory, etc.

Architectural memory bank 1



Urban density: Transect system

- Classification of different urban density
- T1 = natural (nature preserve)
- T2 = rural (farmhouses)
- T3 = sub-urban (mixed-use, not sprawl!)
- T4 = general urban (small town)
- T5 = urban center (dense urban fabric)
- T6 = urban core (the densest part of cities)

World location: local culture, climate & materials

- Form language — language of building developed alongside spoken language
- Evolved via trial-and-error over many years and fine-tuned by generations of users and builders
- Form expression of typologies shaped by culture, climate, local materials

Architectural memory bank 2

- The Alexandrine pattern data base — separate memory bank solely for patterns
- Universal architectural pattern typologies
- Largely independent of culture, climate, local materials
- Correct solutions depend upon geometry, evolved along with human physiology

Adaptive design that draws from evolved memory banks

- Define your project in terms of a specific coordinate in 3-D memory
- (x, y, z) = (Transect of urban density, world location, functional typology)
- Look up the unique address in Memory 1
- Recall the relevant patterns for use from Memory 2, then design adaptively

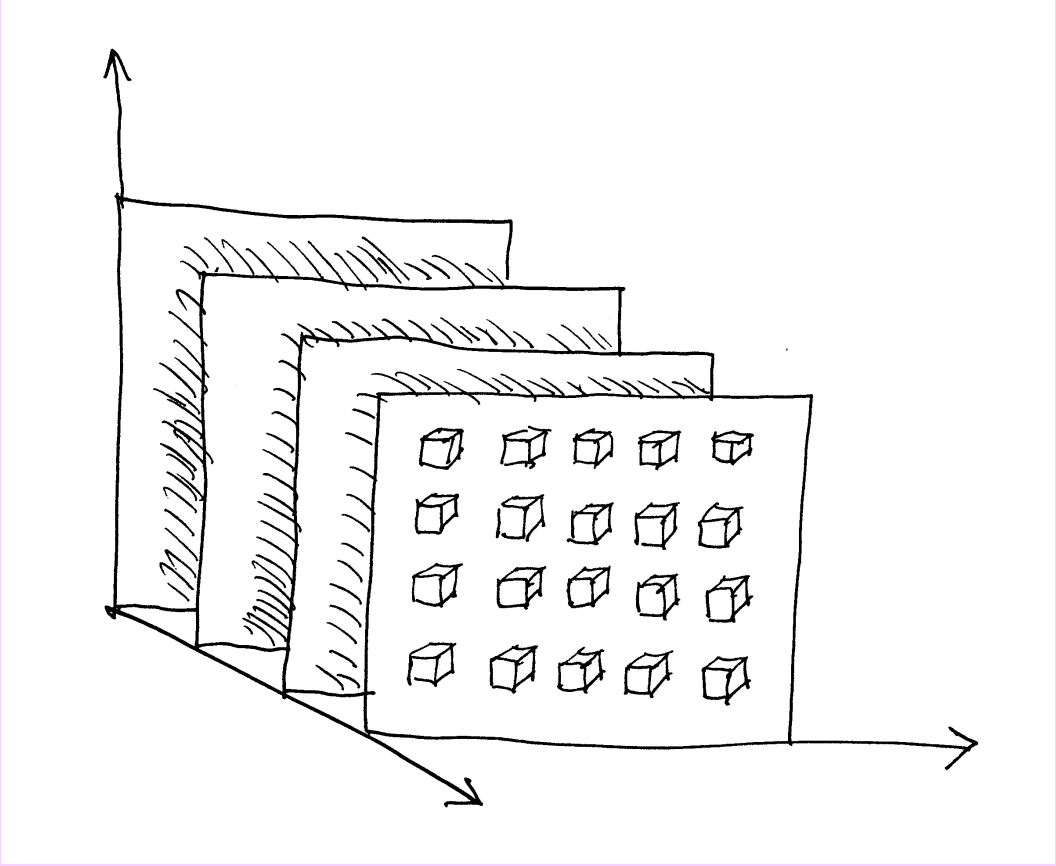
Healthy evolution of architectural memory bank 1

- Solutions can change over time
- One typology can merge into another
- Urban density usually changes in time
- Underlying culture in the same place changes, influenced by others
- Solutions adapt to changing conditions

Corruption of memory banks!

- Viruses invade architectural memory 1 and substitute for the architectural data cells
- Memory bank 1 entries now contain only glass or concrete cubes
- All buildings, in any urban density, all over the world, simply replicate the virus
- ***Pattern memory bank 2 is wiped out — erased because it is a viral antibody!***

Architectural cube virus



Non-adaptive result from corrupted memory bank 1

- Go to position (*x*, *y*, *z*) = (*T2-rural, eastern Pakistan, schoolhouse*)
- Memory cell is glass and concrete box
- Go to position (*x*, *y*, *z*) = (*T5-urban center, coastal Japan, apartment*)
- Memory cell is glass and concrete box
- But result is not adaptive to either task!

The need for adaptive algorithms

- Architects should apply algorithms that adapt structure to human needs
- Simple algorithms connect pattern languages to form languages
- Process successfully generates adaptive design, and corrects irrelevant forms that have corrupted memory

Use an algorithm, or memory?

- Use a proven memory bank that archives *evolved* solutions
- Often just as good as computing a new solution
- When architectural memory banks are corrupted, however, we need to re-compute the solutions all over again
- Pattern languages prevent corruption

D. Evolutionary regression

- It is very easy to evolve a system backwards, thus reversing its development
- Simply reverse the selection criteria, and a Darwinian process takes care of the rest — it is still adaptation!

The blind Mexican cavefish *Astyanax*

- Fish originally lived outside caves, and evolved a well-developed eye
- Its outside relatives have good eyes
- *Astyanax* in caves has lost its eyes
- Backwards evolutionary adaptation to light-less cave environment

Jan Michl (Oslo, Norway)

- Most design is in fact ***redesign***
- A sequence of corrections, additions, modifications, improvements, refinements
- Adaptive design of artifacts is quintessentially Darwinian
- Selection is a “process of tinkering”
- Design as innovation is only a myth

Evolution of tools and artifacts

- Designers never begin from a clean slate
- Function depends upon *existing* form
- The slogan "form follows function" really means "form follows ***purpose***"
- The formalist ***purpose*** is simply to impose new criteria for selection

Function never precedes form!

- The ***purpose*** of Bauhaus designers was to promote a palette of industrial materials and a narrow stylistic vocabulary of sleek, shiny forms
- Unconcerned with the actual function of artifacts, buildings, or cities
- Modernist designers validated their ***purpose*** by referring to fictive demands of the "Spirit of the Age"

More by Jan Michl

- "*The modernist artistic visions were inflicted on the captive audience of the socially weak sections of the population*" — no selection there!
- Governments and the media embraced the allure of the avant-garde
- We adopted the non-adapted modernist style because it was IMPOSED on us!

Forward evolution of books

- Biological evolution created mechanism of the eye-brain system
- Typography evolved over several centuries to optimize information transfer
- — *serif fonts (Times); black ink; matte soft-white paper; 12 point font size, etc.*
- Minimizes the brain-information interface
- Maximizes information transfer rate

Backwards evolution of architecture books

- Use sans-serif fonts (Helvetica)
- Use light gray instead of black ink
- Use too small a font size (9-10 point)
- Use highly glossy paper — too reflective to focus on
- Use unusual page formatting to show off fashionable typographic "style"

Ease of reading is degraded

- No paragraph breaks — confusion of textual and logical subdivision!
- No paragraph indents — ugly!
- Photos are intentionally blurred!
- Yet, these negative characteristics have proliferated — they define a highly successful *antipattern*

Selection over a few decades

- The Bauhaus style introduced sans-serif fonts with the “machine aesthetic”
- Selection criteria imposed by architects, authors, publishers, and a public fascinated with the “new look”
- Style takes precedence over legibility
- Obvious in recent architecture books

One example among many

- One recent book on architectural theory by a world-famous architect, co-authored with a world-famous philosopher, has holes punched in it!
- Book is intentionally illegible
- Highly praised, and recommended as course textbook in our elite universities

Architectural images have also evolved backwards

- Architectural renderings as vague translucent screen shots — no detail
- One cannot grasp the overall forms
- "Competition project style" combines *reflective* with *transparent* surfaces
- But their optical properties prevent the eye from focusing — cannot see them!

Another example among many

- Lectures by a world-famous architect
- Illustrated with blurry monochrome brown photos of the famous architect, intentionally made grainy
- Book would probably not sell if the photos were clear and focused!
- Only the fashionable “style” sells

Information obtained only through pain

- Contemporary architecture books intentionally or unintentionally strain the eyes of the reader
- Yet students have to study them for their courses
- Is this regression an oversight, or is it causing pain to reinforce power?

Conclusions

- Algorithmic design that is adaptive relies upon emotion — uses the human computer
- Architecture schools teach rationalization for each design decision — but that's not computational!
- It is really the rationalization of a ***style***
- True computation results in unusual and unexpected (not "absurd") configurations