Algorithmic Sustainable Design: The Future of Architectural Theory.

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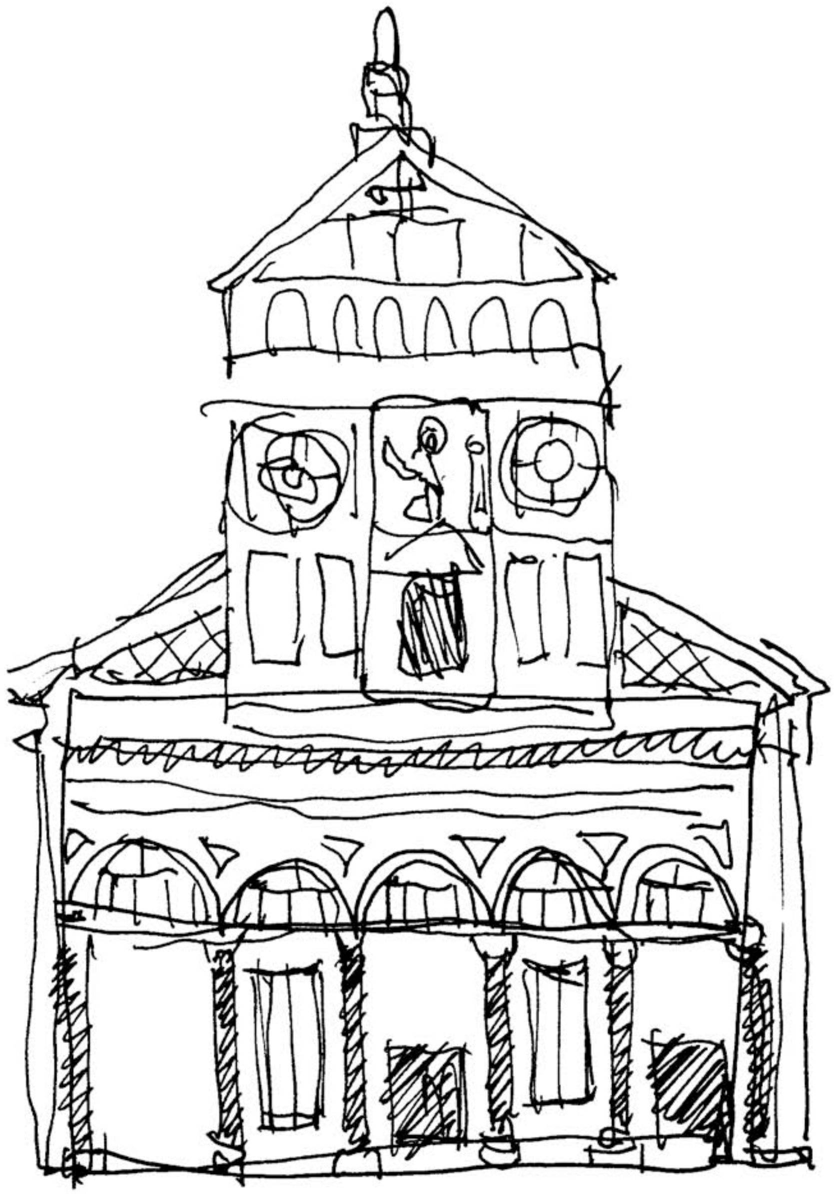
Lecture 5
5.1. Architectural harmony.
5.2. Alexander's theory of centers.
5.3. Design as computation.
5.4. Computational reducibility.

5.1. Architectural harmony

Compute the architectural harmony

- GOAL OF COMPUTATION: improve coherence of the design by successive steps
- Mathematical model of "harmony" given in my book "A Theory of Architecture"
- Harmony estimates density of symmetries, connections, scaling coherence, universal scaling, universal distribution, etc.



San Miniato al Monte, Florence

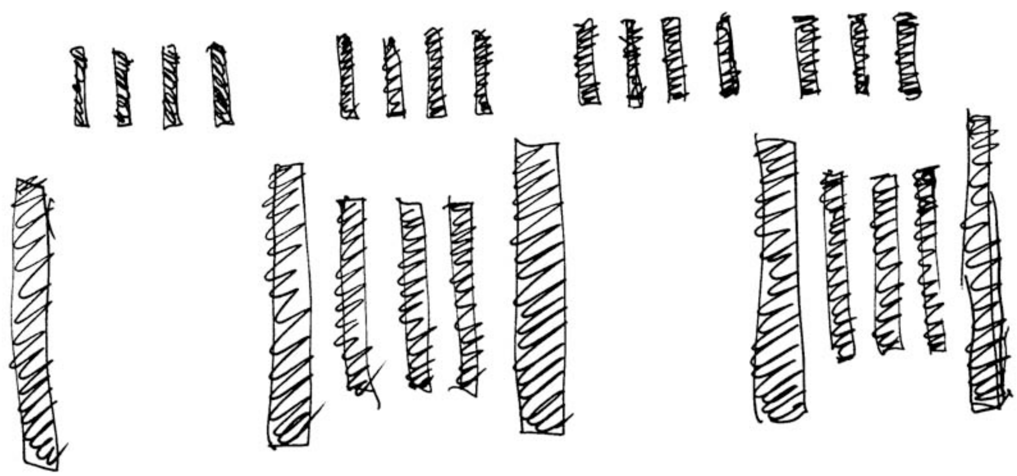
Estimate the harmony

- Reflectional symmetries on all scales = 2/2
- Translational and rotational symmetries on all scales = 2/2
- Scaling symmetries = 1/2
- Geometrical connections = 2/2
- Color harmonization = 1/2

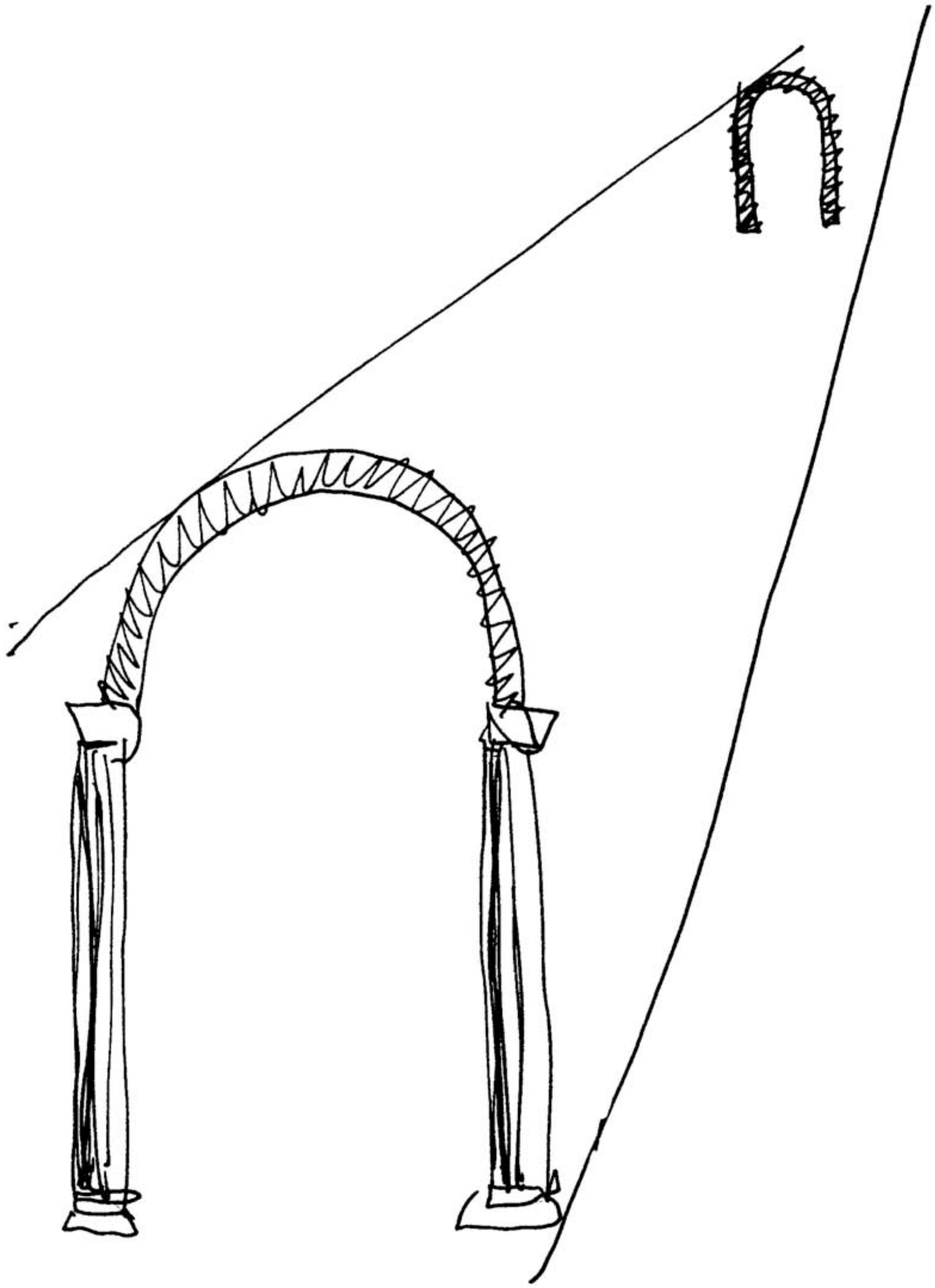
- Sum to get **total harmony = 80%**

Method of estimation

- Simplest estimate for each property seen in obvious design characteristics:
- NONE = 0
- SOME, NOTICEABLE = 1
- A GREAT DEAL = 2
- Each of the 5 components of the architectural harmony adds up to give a percentage measure



Translational symmetries

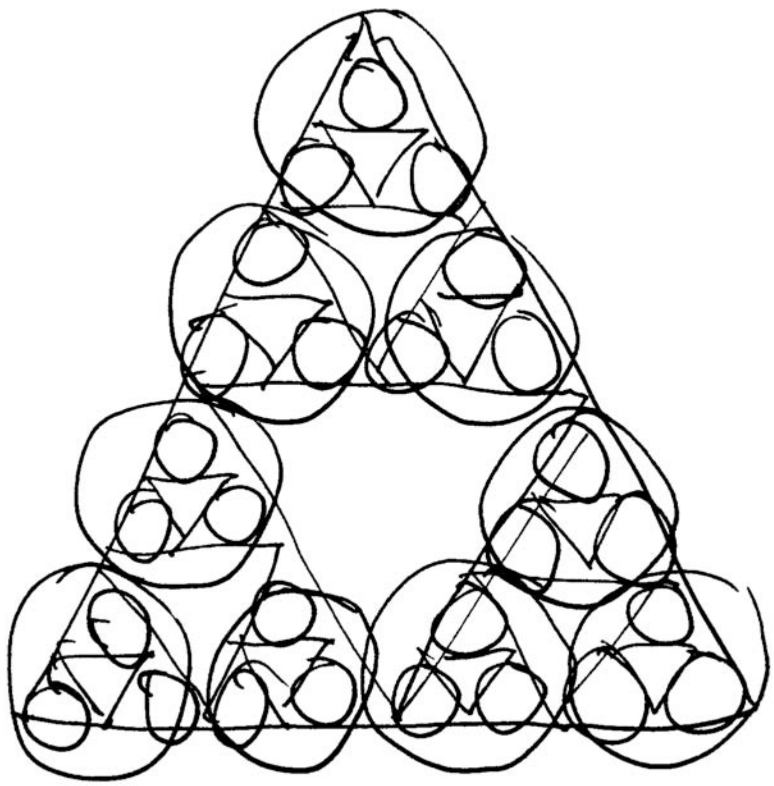


Scaling symmetries

5.2. Christopher Alexander's theory of centers

A "center" as a focus

- Basic notion describing the ordering process in nature (and in architecture)
- The geometry of mutually reinforcing focal points
- Independent from patterns already obtained via interaction between geometry and social structure



Recursive points of focus (circles) in the Sierpinski gasket

Focus and condensation in fractals

- Self-similarity and the universal distribution require that the details in fractals are not uniformly distributed
- Smaller scales focus in particular regions of a fractal where subdivision occurs

The theory of centers

- A "center" is a visual field that is the focus of a region
- The region that focuses on a "center" can be of any size
- Centers help to tie the space together by reinforcement

- Recursion leads to fractal properties

Centers — structure-void duality

- Two types of centers: "defined" and "implied" (my own terminology)
- Either a well-defined structure in the middle is surrounded by a looser boundary, or a void is surrounded by a structured boundary
- Mathematically, these two types are dual to each other

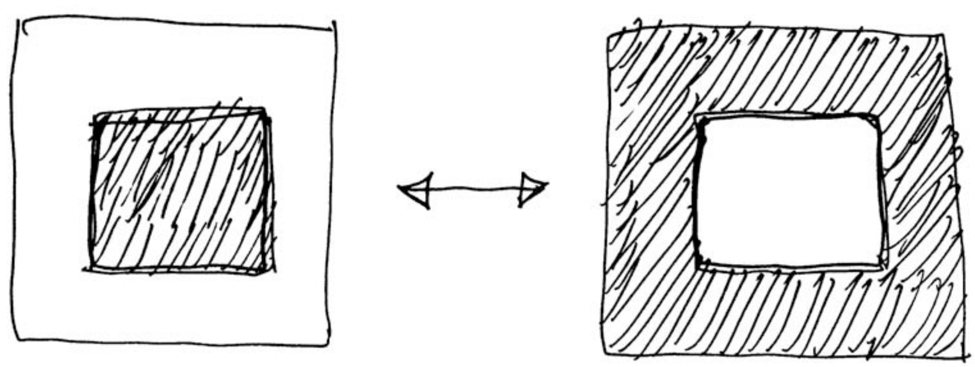
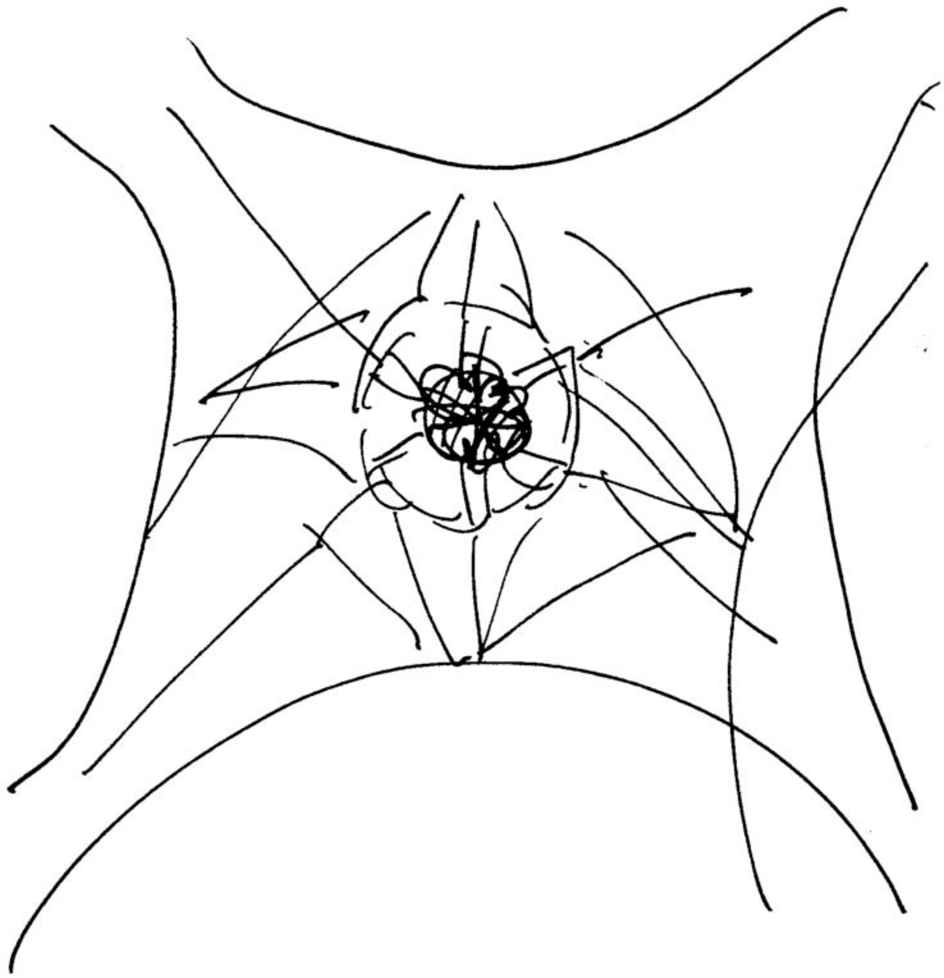


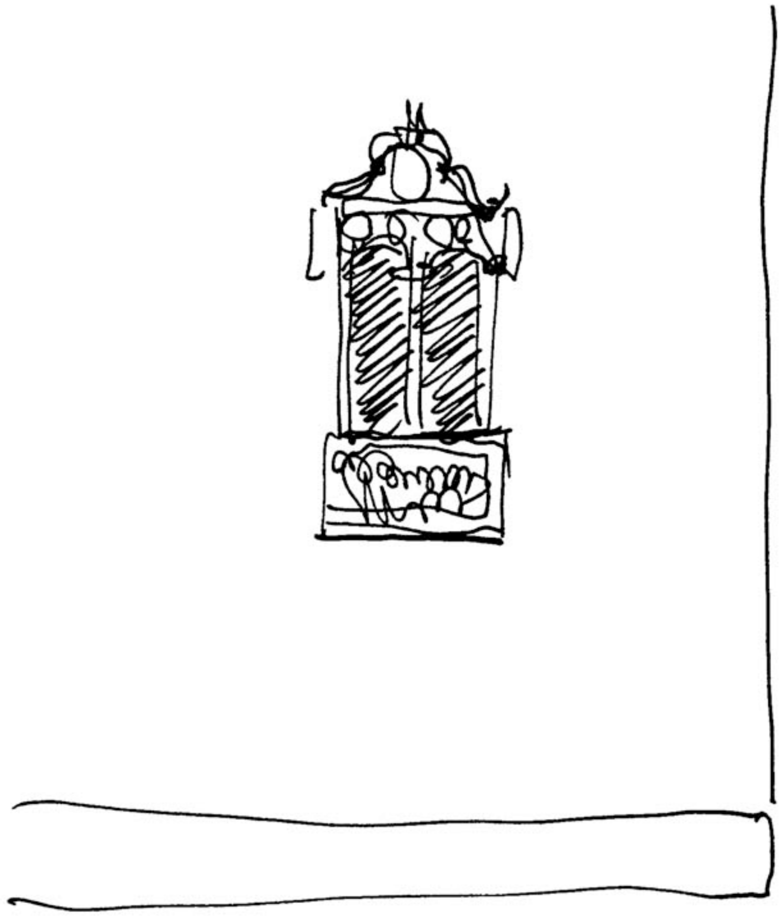
Figure-ground duality

A. "Defined" or "explicit" centers

- A region in which something right in the middle focuses the structure
- The focal point draws attention to the actual center of a region
- Examples: fountain or sculpture in the middle of plaza; window or door centered in the middle of a wall; light fixture in the center of a ceiling; medallion in paving



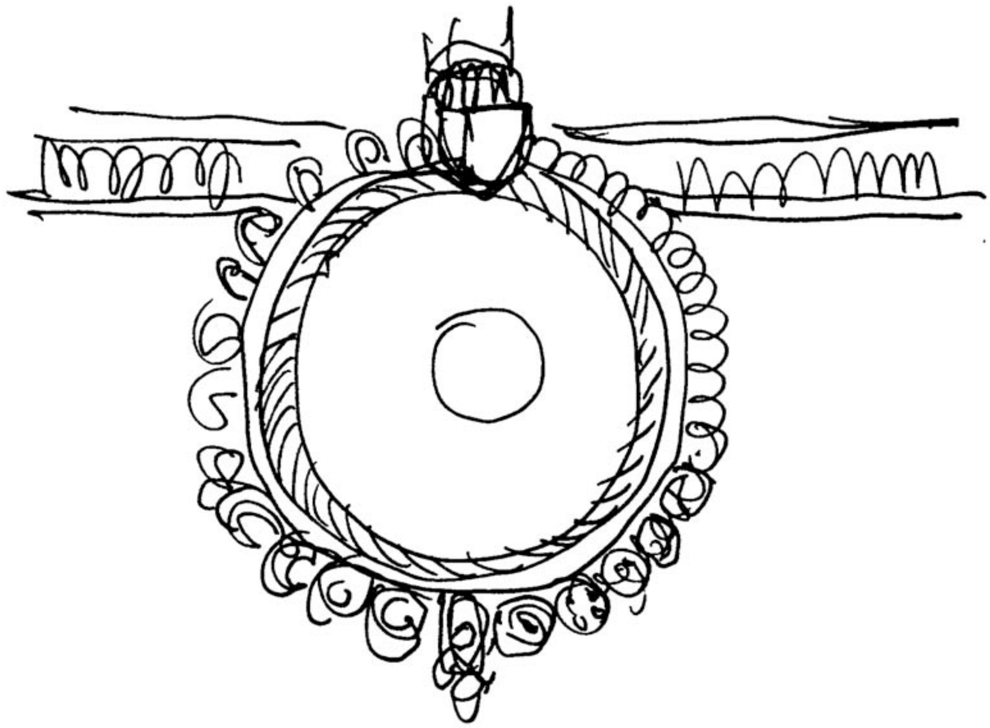
Medallion is focal point of ceiling design



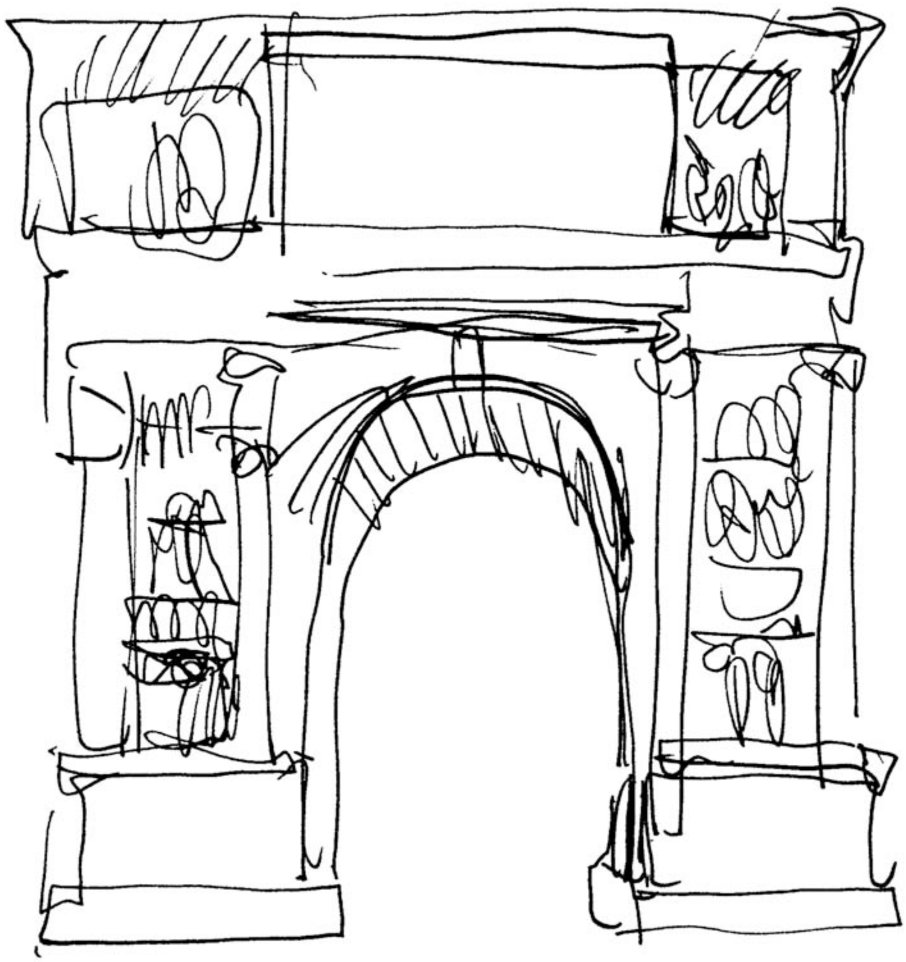
Window is focal point of plain wall

B. "Implied" or "latent" centers

- A region that focuses on its central point, but where the middle is empty
- Surrounding structure is helping to focus attention towards the interior
- This is a boundary effect — the boundary is focusing on the implied center
- Examples: courtyard enclosed by decorated walls; cloister; decorated arch



Highly ornamented window frame focuses on center



Monumental arch focuses on passageway

Geometrical focus

- Both “defined” and “implied” centers are the foci for their surrounding structures
- “Defined” and “implied” centers can overlap, thus helping each other
- In a coherent design, all the centers cooperate to reinforce each other
- Smaller centers combine to form larger centers — recursive property

Algorithm for generating centers

- Create both strong “defined” and “implicit” centers on a particular scale
- Place/create smaller centers so that they are nested within larger centers
- Use symmetries to make centers cooperate so they support each other geometrically

- Success means that centers blend together

Adaptivity and asymmetry

- We are encouraging the formation of a high density of local symmetries, not an overall symmetry
- ASYMMETRY arises from adaptation, usually seen on larger scales
- But there needs to be a reason for asymmetry, not just personal whim

Alexander's first algorithm

- "**Every time you create a center on a particular scale, make sure that it reinforces the centers on the immediately smaller scale, and the centers on the immediately larger scale**"
- From Alexander's "The Nature of Order", Book 1

Alexander's second algorithm

- "**Begin by visualizing the whole. Then identify the scale that is the weakest, or is missing. Create or intensify a center on that scale. The new center must reinforce all existing centers on its own scale, as well as follow rule 1.**"
- From Alexander's "The Nature of Order", Book 3

Example: find a weakness

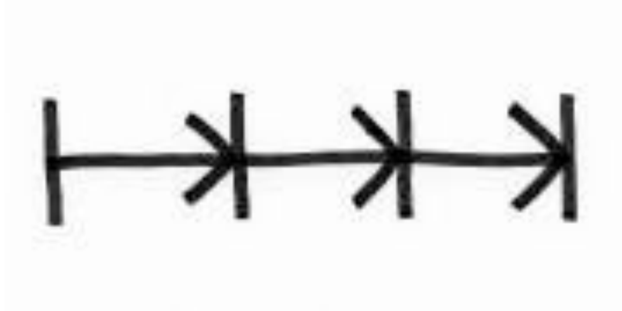
- Problem: some part of your design feels wrong
- Don't just adjust that piece, but look at that SCALE in the entire design
- Ask: WHAT IS THE BEST CENTER THAT REINFORCES THIS SCALE?
- Solution: implement that center, rather than adjusting the original faulty piece

Starting from weakness

- Usually start from the site, which may contain a weak system of centers
- Apply successful transformations
- Each step creates new centers, or reinforces existing weak centers
- All centers reinforce each other to create a coherent whole

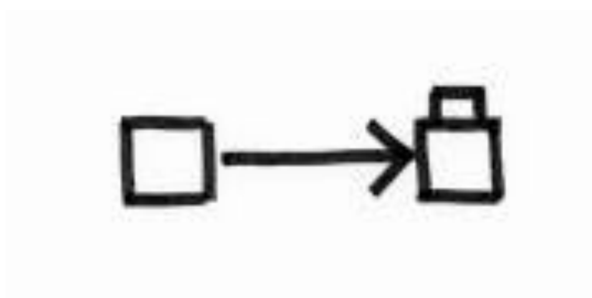
The first set of Leitner diagrams

- Helmut Leitner uses simple visuals to grasp the center-generating transformations
- **1. Stepwise**
- **2. Reversible**
- **3. Structure-preserving**
- **4. Design from weakness**
- **5. New from existing**

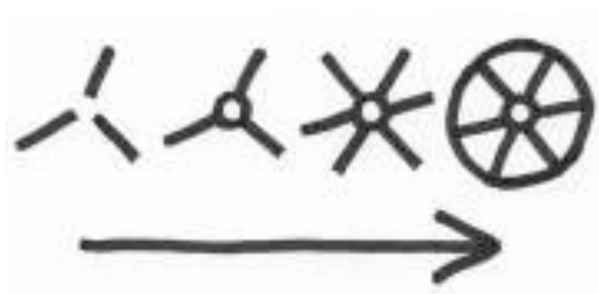


1. Stepwise: *Perform one step at a time*

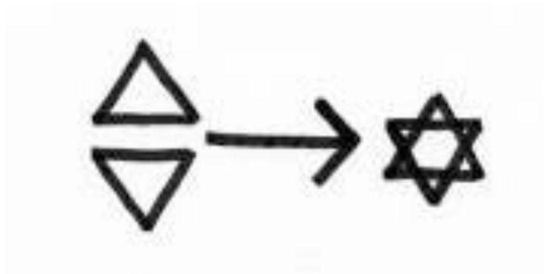
2. Reversible: *Test design decisions using models;"trial and error"; if it doesn't work, undo it*



3. Structure-preserving: *Each step builds upon what is already there*



4. Design from weakness: *Each step improves coherence*



5. New from existing: *Emergent structure combines what is already there into new form*

Future software

- With time, we can program these rules
- Pattern recognition is a problem of major interest in computer intelligence and vision
- Model for estimating the coherence or "life" of structures is developed in "A Theory of Architecture"

Incompleteness theorem

- Software will never substitute for a human designer
- "Living structure" is not possible just from a mathematical algorithm
- Not enough cognitive capacity!
- Computer algorithm is interesting and will be very useful for saving effort

Universal distribution merges to become a field effect

- Centers obey universal distribution: few large ones, some of intermediate size, many smaller ones
- Achieving harmony, however, blurs the identity of each center
- Coherence is a "field effect" — the secret of our greatest architecture

5.3. Design as computation

Sequence of steps

- Christopher Alexander views successive steps of adaptive design as steps in a complex computation
- Take initial condition as defined by the site, and by successive steps transform it into the final coherent design
- Computation of finite number of steps

Algorithms are recursive

- Algorithm is repeated until a desired level of harmony in achieved, or until the resources run out

- With each succeeding step, coherence of total design is improved
- Next step locates (makes obvious) new bottleneck to coherence

What is our algorithm?

- Alexander's first and second algorithms
- 1. Identify the weakest or missing center that forms a bottleneck in the harmony of the configuration
- 2. Intensify that center
- 3. Act both locally and globally

… but there are more

- These are just two of several algorithms acting together
- More process principles are needed for computation
- Process concepts are not yet as well developed as structural concepts
- Refer to Leitner's first set of diagrams

What are the constraints?

- 1. Brief of project (a) — functions
- 2. Brief of project (b) — human needs
- 3. Biophilic considerations — human feelings of wellbeing
- 4. Patterns from a Pattern Language
- 5. Connecting to the surroundings

Patterns as complex socio-geometric "centers"

- Socio-geometrical ways of behavior
- Repeated rediscovery of useful configurations in buildings and cities
- Classified in Alexander's book: "A Pattern Language"
- Come from participatory design
- Not a pure geometrical concept

What are the programming tools?

- **1. Alexander's 15 fundamental properties**: provide the "code" in which the algorithm is written and implemented (next lecture)
- **2. Process principles**: to be developed more
- **3. Connecting concepts**: universal scaling, universal distribution, wide boundaries, architectural harmony, centers, etc.

Goal of computation

- Goal is not what one would expect!
- Algorithm does **not** compute the typology of the building (e.g. house)
- Algorithm computes **harmony**, and each step proceeds by improving the harmony
- Function of building lies in the constraints!

Formal decomposition

- Algorithm broken up into specific computational loops (in theory)
- But this decomposition does not even touch the implementation problems!
- How do we achieve "living structure"?
- Not only geometrical harmony
- Need to incorporate patterns

High-level description

- Algorithm: larger main loop computes architectural harmony
- Several nested secondary iterative loops act as constraints:
- — project brief; patterns from "A Pattern Language"; universal scaling; universal distribution…

Non-adaptive architectural design

- A drawing based on images has nothing to do with an adaptive building
- An adaptive design must be computed!
- Human mind is the best pattern computer
- The number of computations is proportional to the complexity of the desired result
- There can be no shortcuts to final form

Most design is memory-based

- No computation at all
- Retrieval from a memory bank
- Even if architect is convinced he/she is being totally innovative, design is usually coming out of subconscious memory
- Harmony-seeking computations are rarely applied by architects in the industrial world

Good and bad memory

- Stored proven patterns are good
- Evolved over generations, tested and survived by adaptive selection
- But recycling of faulty design patterns gives bad designs
- Therefore: **need periodic checks for the correctness of stored patterns**

Algorithmic checks

- Coherence and cooperation of different elements among different levels of scale
- Analogous to the coherence of a fractal
- Alexander's fifteen fundamental properties help achieve living quality
- Global-local geometrical property

Emergence

- A very simple algorithm acting on the smallest scale generates a complex pattern with long-range geometrical features
- Complex geometrical properties are emergent
- They are not obvious in the initial code

Alexander's harmony-seeking process is more than emergent

- Emergence is only a two-way process
- Smaller components cooperate to create a larger whole — link small with large
- Harmony-seeking computations have an additional element — three-way process
- Whole interacts with an even larger external entity — **small, with large, with outside**

5.4. Computational reducibility

How much computation?

- General misunderstanding of how much work is required to create a complex system
- Design generates complex systems
- Everyone wants shortcuts
- Some shortcuts compromise system coherence and functionality

Computational processes

- All processes can be viewed as computations (Stephen Wolfram)
- Both human and natural processes
- Form develops by changing its state on various different levels
- Life continuously changes materials of organism, but maintains form template

Computational reducibility

- Adaptive systems evolve, with each step being a computation
- In simple physical systems, we don't need to duplicate the amount of computational effort, but can shortcut to final state — i.e., use a formula
- Simple case is COMPUTATIONALLY REDUCIBLE

□

Computational **ir**reducibility

- In irreducibly complex systems, there are no formulas for finding the final state
- Computation of final state requires the same effort as the system has gone through to create itself — no reduction
- Stephen Wolfram's "computational irreducibility"

The reducibility fallacy

- Design that is adaptive needs to compute a large number of steps
- The algorithm is usually recursive
- Such a process is COMPUTATIONALLY IRREDUCIBLE
- It is therefore impossible to make a top-down design so that it is adaptive

General procedure

- Decompose design problem into more tractable subunits or components
- Decomposition is dictated by experience
- Employ known methods (relying upon precedent) to evaluate subroutines
- Re-assemble partial results into final result
- Initial decomposition determines re-assembly

General procedure (cont.)

- Require selection criteria to be able to eliminate false positives
- How do you recognize false steps?
- Again, this relies upon precedent
- Process is successful if large scale structure is adaptive, not if it is strange or irrelevant

Conclusion: computational equivalence

- Classical and traditional architects follow part of our algorithm for design
- From computational irreducibility, **all adaptive design algorithms are computationally equivalent**
- Any inequivalent algorithm cannot be adaptive