A Mathematical Model of Beauty for Sustainable Urban Design

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A Mathematical Model of Beauty for Sustainable Urban Design

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Content (four parts)
- Review of Alexander's life works as a whole
- Fractals or living structures emerged from big data
  - Head/tail breaks
  - Natural cities
- A mathematical model of beauty
  - Beauty for individual centers
  - Beauty for the whole
- Sustainable urban design (adaptation + differentiation)

Part 1
Review of Alexander's life works as a whole

On Alexander's work
- "...Five hundred years is a long time, and I don't expect many of the people I interview will be known in the year 2500. Christopher Alexander may be an exception."
- "Could very well be the most read architectural treatise of all time."
- "A single-handedly trying to destroy the trillion dollar construction industry"
- "Exceptionally influential among Americans who are thinking about the design of their environments"
- "Undeniably an extraordinary piece of literature"
- "A revelation"
Modern Architecture

- Modern (and post-modern) architecture is based on coming up with a picture or image and then constructing it, usually out of components and modular parts.
- This way of doing architecture is essentially governed by mechanistic worldview.

Mechanistic worldview

- The mechanistic idea of order can be traced to Descartes, about 1640.
- If you want to know how something works, you can find out by pretending that it is a machine.
- However...
- It was because of this kind of Cartesian thought that one was able to find out how things work in the modern sense.

Two devastating results

- The first was that the "I" went out of our world-picture. The picture of the world as a machine doesn't have an "I" in it. The "I", what it means to be a person, the inner experience of being a person, just isn't part of this picture.
- The picture of the world we have from physics, because it is built only out of mental machines, no longer has any definite feeling of value in it: value has become sidelined as a matter of opinion, not intrinsic to the nature of the world at all.

Beauty is NOT just in the eye of the beholder

- The statement of good architecture is true or false rather than only a matter of opinion.
- Beauty exists in the deep structure.

A dead tree is more alive than a modern building

- A Vision for Architecture as More Than the Sum of Its Parts

Pictures by
Manuel & Niko
A. Salinas

Published
November 12, 2013
Ulrich R. S. (1984), View through a window may influence recovery from surgery, Science, 224, 420-422.

Alexander’s major works among many others
- Notes on the Synthesis of Form (1964)
- A City Is not a Tree (1965)
- A Pattern Language (1977)
- The Timeless Way of Building (1979)
- The Oregon Experiment (1975)
- The Nature of Order (Book 1, 2, 3 and 4) (2002-2005)

What if 师傅 died?

A city is not a tree
A city is a complex network


Discovery versus invention

- Christopher Alexander
- Benoit Mandelbrot
- Thomas Edison
- Steve Jobs

A Pattern Language (253 patterns)

The Oregon Experiment

The Timeless Way of Building

- The quality without a name

Impact of pattern language

- Ward Cunningham
The failure of pattern languages

Which one is more alive or beautiful?

Again...

Wholeness, life and beauty (Maggie’s circle)

Fifteen geometric properties

The Nature of Order

The major thesis of the book

- The order (or harmony or coherence) in nature and in what we build or make are essentially the same.

A structure with or without a center


A paper with or without a tiny dot

20 latent centers for a paper with a dot


A network perspective on the wholeness


Fractal versus Euclidean patterns

Conclusion – Part 1

- Alexander’s life works as a whole for creating a new way of doing architecture, or.
- A new scientific underpinning for architecture and urban design.
- A new cosmology – a new conception of how the physical universe is put together, which is organic with the ‘self’ inside.
- We must abandon Euclidean geometric thinking, and adopt instead fractal or living geometric thinking.

Part 2

Fractals or living structures emerged from big data

Head/tail breaks

Cantor set (1874)

Koch curve (1904)

Randomized or statistical Koch curves
Generative fractals – fractal sheep

“Pretty pictures but pretty useless”

Mandelbrot set – Julia sets ($z = z^2 + c$)

Hidden order: Watts Towers
Hidden order: Watts Towers (detailed looks)

Internet and WWW

Euclidean and fractal geometry in perspective (I)

Euclidean and fractal geometry in perspective (II)

What is BIG data?

The notion of natural cities

- Natural cities refer to objectively or naturally defined and delineated human settlements, or human activities in general on the Earth’s surface, using massive geographic information of various kinds, and based on head/tail breaks.

90% of world’s data generated over last two years

Openness and transparency
Head/tail breaks leads to a new definition of fractal. A structure is fractal if scaling pattern of far more small things than large ones recurs multiple times. Head/tail breaks can be an efficient and effective visualization tool. Head/tail breaks is more natural than natural breaks. Scaling or fractal is more normal than normal distribution.
Part 3
A mathematical model of beauty

A mathematical model of beauty (beautimeter)
- A mathematical model of beauty or wholeness, which captures
  - (1) not only Christopher Alexander’s definition of wholeness, which is recursive, (2) but also human intuitions on beauty;
  - for understanding (1) not only why a design is beautiful, (2) but also how much beauty the design has.

Euclidean versus fractal geometry

The Nature of Order (30 years in the making)
- The order in nature and in what we make or build are essentially the same.
Many great thinkers in design

- Jane Jacobs - *The death and life of great American cities*
- Ian Mcharg – *Design with nature*
- Christopher Alexander – *A city is not a tree, A pattern language*

After 30 years of dedicated work, Alexander came to a solution to good designs.

- What is good? Or how good is good?
- What is order? Or how order is order?

Order vs disorder

- sequence, arrangement, organization, series, succession;
- grouping, classification, categorization, codification, systematization
- "alphabetical order"
- untidiness, disorderliness, mess, disarray, chaos, confusion;
- clutter, jumble;
- a muddle, a shambles
- “he hates disorder”
To measure the degree of hidden order
- A mathematical model of wholeness is developed, and it is composed of two parts.
- A hierarchical graph in which nodes represent individual centers, and links point from small centers to related large centers.
- Degrees of beauty for the individual centers based on PageRank scores.
- Degree of beauty for a whole derived from PageRank scores using head/tail breaks.
Conclusion – Part 3

- Alexandrian order or living structure differs from regularity in Euclidean geometry or normality in Gaussian statistics.
- We developed a mathematical model of wholeness or beauty to understand (1) not only why a design is beautiful, (2) but also how much beauty the design has.
- The case studies illustrate that the computed degrees of beauty capture fairly well (1) our intuition or the sense of beauty, and (2) Alexander’s definition of wholeness.

Part 4
Sustainable urban design (adaptation + differentiation)
The next step for sustainable urban design

The timeless way of writing

2D plan of the Eishin school – living structure
Conclusion – Part 4

- Sustainable urban design must be achieved through unfolding rather than assembly
- Two basic unfolding processes or wholeness-extending processes: local adaptation and global differentiation
- Local adaptation implies more or less similar things, or autocorrelation (first law of geography)
- Global differentiation implies far more small things than large ones (scaling law)
- Two types of coherence: locally and globally

Thank you very much!