Scaling Law and Tobler's Law for Characterizing Asymmetry in Geography

Presentation · March 2018

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Scaling Law and Tobler's Law for Characterizing Asymmetry in Geography

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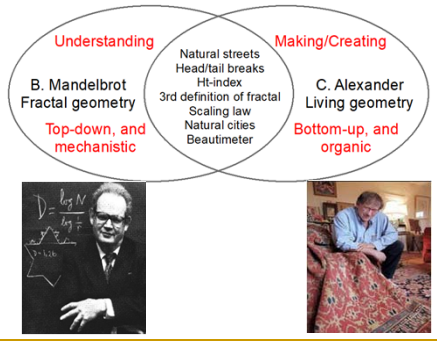
http://giscience.hig.se/binjiang/

Two geometries of asymmetry



The geographer (in the 17th century)

by Dutch Artist Johannes Vermeer in 1668–1669

The geographer (in the 20th century)

The geographer (in the 21st century)

The wholeness of the talk

- Two fundamental laws of geography or any living structure: Scaling law + Tobler's law
- Asymmetry (symmetry breaking + wholeness-enhanced transformaton) underlies geographic forms and processes
- The 3rd definition of fractal (scaling law + head/tail breaks) helps reveal asymmetries
- Living structure or wholeness as a new asymmetric structure and mechanism
- Ubiquity of asymmetry or living structure

Geography – science about the Earth's surface

- How it looks – geographic forms or urban structure
  - Scaling law – far more small things than large ones
  - Tobler's law – more or less similar things
- How it works – geographic processes or urban dynamics
  - Nonlinear processes like stock prices
- What it ought to be – design and planning
  - Differentiation
  - Adaptation

Jiang B. and Ren Z. (2018), Geographic space as a living structure for predicting human activities using big data, *International Journal of Geographical Information Science*, x(x), xx–xx http://dx.doi.org/10.1080/13658816.2018.1427754

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Scaling law – spatial heterogeneity

- There are far more small things than large ones, across all scales ranging from the smallest to the largest in geographic space or the Earth's surface or any living structure.
- Importantly, the scaling of far more small things than large ones recurs multiple times rather than just once at different levels of scale.

Jiang B. (2013), The image of the city out of the underlying scaling of city artifacts or locations, *Annals of the Association of American Geographers*, 103(6), 1552–1566.

8

Tobler's law – spatial dependence

"everything is related to everything else, but near things are more related than distant things."

- Nearby things tend to be more or less similar or related

Waldo Tobler in front of the Newberry Library, Chicago, November 2007

(1930–2018)

Tobler W. (1970), A computer movie simulating urban growth in the Detroit region, *Economic Geography*, 46, 234–240.

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These two laws complementary each other

- Scaling law:
  - Spatial heterogeneity
  - Interdependence
  - Far more smalls than larges
  - Available across all scales
  - Scale-free, long tailed
  - Disproportion (80/20)
  - Complexity
  - Non-equilibrium
- Tobler's law:
  - Spatial homogeneity
  - Spatial dependence
  - More or less similar things
  - Available in one scale
  - With scale, short tailed
  - Proportion (50/50)
  - Simplicity
  - Equilibrium

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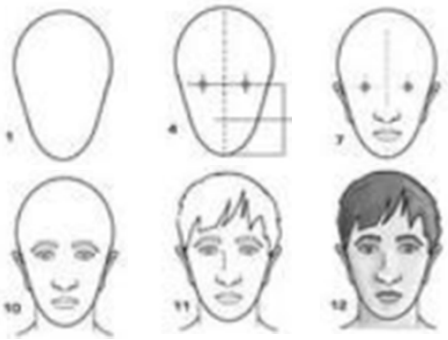
Differentiation and adaptation



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Symmetry versus asymmetry

- Nature and society are full of different types of symmetry.
- Symmetry is often linked to patterns, order, beauty, and complexity.
- Symmetry can recur at different levels of scale, e.g., global symmetry, local symmetry, and between the global and local.
- Aymmetry are far more common than symmetry in geography, hence the title of the presentation.

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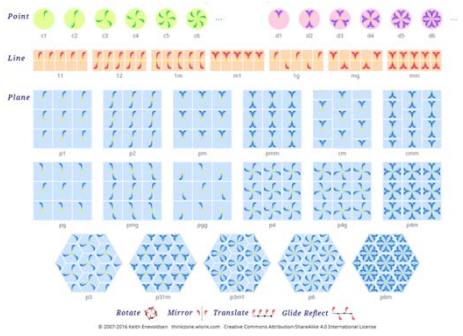
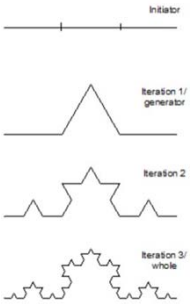
Translate, reflection, rotate, and glide reflection

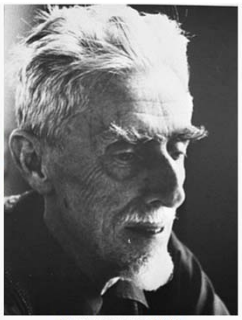


Dilation symmetry



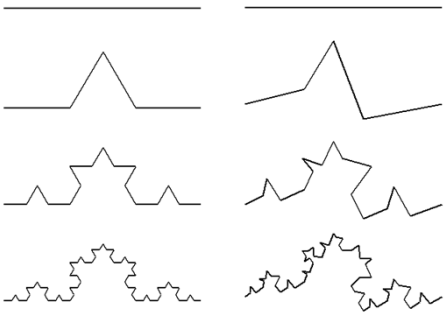
Wade D. (2006), *Symmetry: The ordering principle*, Wooden Books: Bloomsbury, USA.

Dilation symmetry

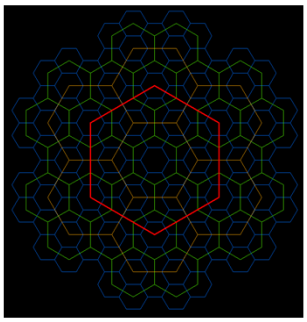


M. C. Escher in 1971

Symmetry > Asymmetry

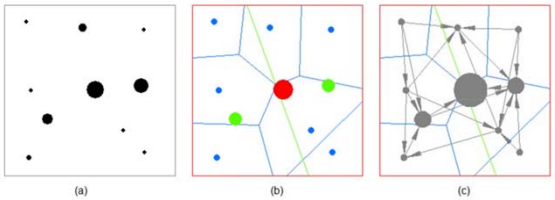


CPT: Rotate, translate, reflection and dilation



WALTER CHRISTALLER
1893–1969

A topological representation (asymmetry)



Jiang B. (2017), A topological representation for taking cities as a coherent whole, *Geographical Analysis*, xx(x), xx–xx, DOI: 10.1111/gean.12145.

Asymmetry in London's hotspots

Jiang B. (2017), A topological representation for taking cities as a coherent whole, *Geographical Analysis*, xx(x), xx–xx, DOI: 10.1111/gean.12145.

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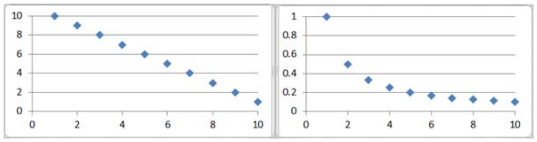
The 10 numbers experiment

										neck
1	2	3	4	5	6	7	8	9	10	5.50
										3.00
linear		proportional (50/50)			more or less similar					1.50
1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	1/10	0.29
										0.61
nonlinear		disproportional (80/20)			far more smalls than larges					



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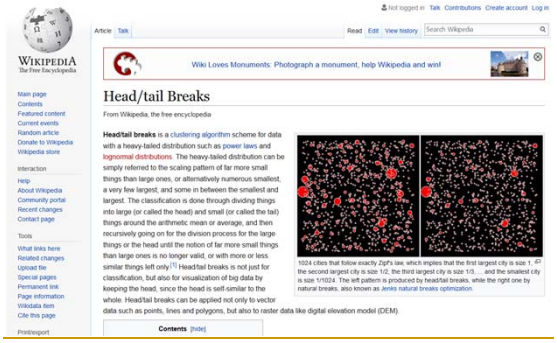
https://en.wikipedia.org/wiki/Head/tail_Breaks



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What are head/tail breaks and ht-index?

Recursive function Head/tail Breaks:

Break a whole into the head and the tail;
// the head for those above the mean
// the tail for those below the mean
while (head <= 40%):
Head/tail Breaks (head);

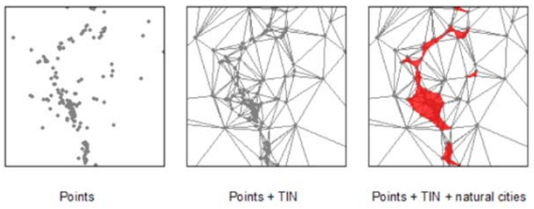
End function

Ht-index = # of iterations + 1

Jiang B. (2013), Head/tail breaks: A new classification scheme for data with a heavy-tailed distribution, *The Professional Geographer*, 65 (3), 482–494.
Jiang B. and Yin J. (2014), Ht-index for quantifying the fractal or scaling structure of geographic features, *Annals of the Association of American Geographers*, 104(3), 530–541.

22

Natural cities from social media



Jiang B. and Miao Y. (2015), The evolution of natural cities from the perspective of location-based social media, *The Professional Geographer*, 67(2), 295–306.

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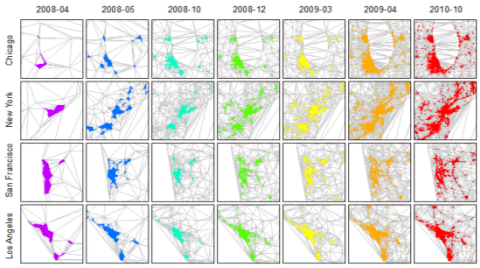
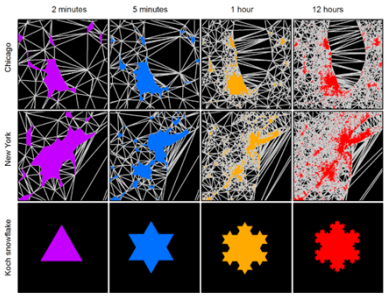
Evolution of natural cities (Brightkite)



Jiang B. and Miao Y. (2015), The evolution of natural cities from the perspective of location-based social media, *The Professional Geographer*, 67(2), 295–306.

24

Fractals emerged from big data (Twitter)



Jiang B. (2015), Head/tail breaks for visualization of city structure and dynamics, *Cities*, 43, 69–77.

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Head/tail breaks thinking

- AT&T
- Britinica
- National mapping agency
- Governments/CNN
- Skype
- Wikipedia
- OpenStreetMap
- Social media/WikiLeaks

Centralized mindset, top-down **Decentralized mindset, bottom-up**

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Head/tail breaks thinking

- AT&T
- Britinica
- National mapping agency
- Governments/CNN
- Skype
- Wikipedia
- OpenStreetMap
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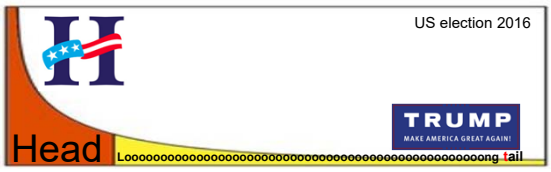
Centralized mindset, top-down **Decentralized mindset, bottom-up**



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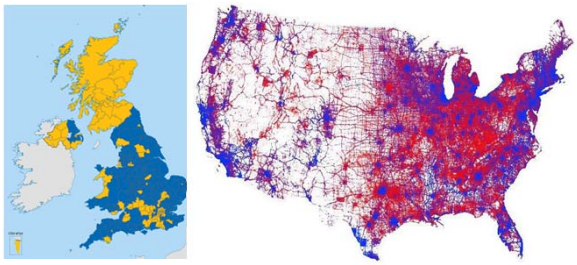
Brexit and US election 2016



The victory of loooooooooooooong tail!!!

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Euclidean and fractal geometry in perspective

Using Euclidean geometry

Applying fractal geometry

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Euclidean and Gaussian vs Fractal and Paretian

Regular + fraction
Euclidean and Gaussian: more or less similar things

Irregular + fractal
Fractal and Paretian: far more small things than large ones

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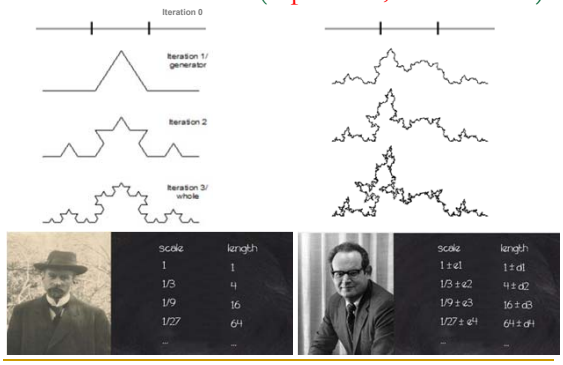
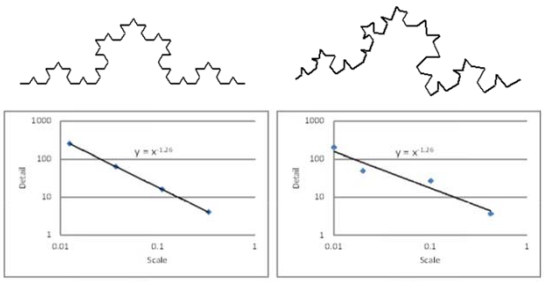
First two definitions (top-down, mechanistic)



Power law behind the first two definitions

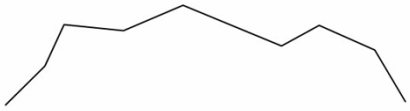


Ma D. and Jiang B. (2018), A smooth curve as a fractal under the third definition, Cartographica, x(x), xx–xx, https://arxiv.org/abs/1802.03698.

Power law behind the first two definitions

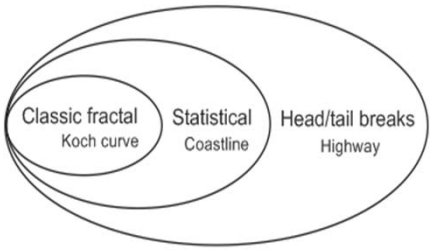
The third definition (bottom-up, organic)

- A set or pattern is fractal if the scaling pattern of far more small things than large ones recurs at least twice, or with ht-index at least greater than three, e.g., $x_1+x_2+x_3>x_4+x_5+x_6+x_7$, and $x_1> x_2+x_3$.



Jiang B. and Yin J. (2014), Ht-index for quantifying the fractal or scaling structure of geographic features, *Annals of the Association of American Geographers*, 104(3), 530–541.

Implications of the third definition



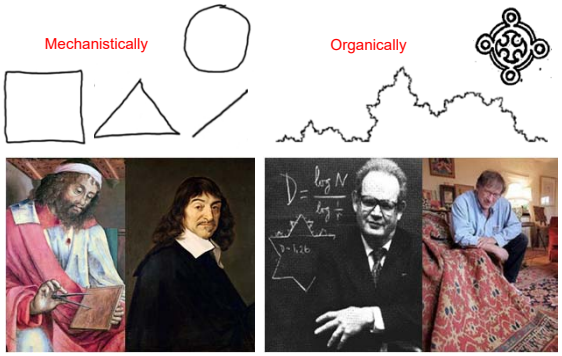
All geographic features are fractal given the right perspective and scope.

Jiang B. (2015), Head/tail breaks for visualization of city structure and dynamics, *Cities*, 43, 69-77.

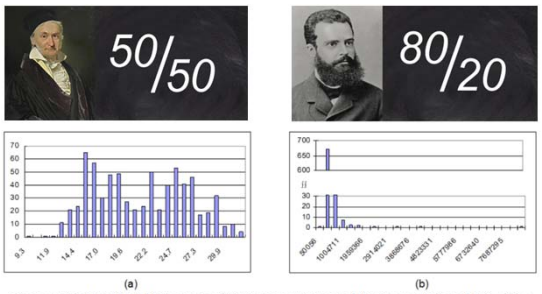
Paradigm shift geometrically

Mechanistically

Organically



Paradigm shift statistically



(a) (b)

Figure 1: (Color online) Histograms of (a) the temperature, and (b) the population of U.S. cities (Note: the two distint distributions indicate respectively Gaussian-like and Paretian-like distributions.)

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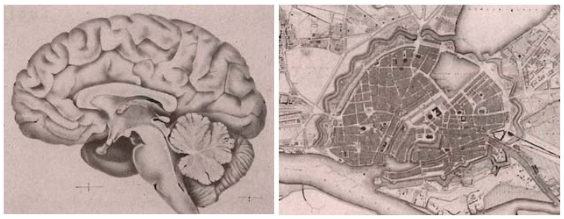
City as a fractal or living structure



(Hamburg circa 1850)

Johnson S. (2002), *Emergence: The Connected Lives of Ants, Brains, Cities, and Software*, Penguin Books Ltd: London.

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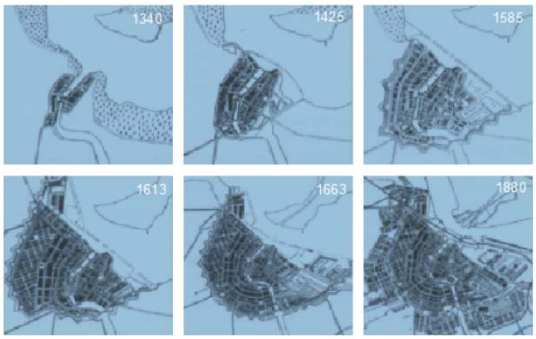
Amsterdam – fractal or living structure



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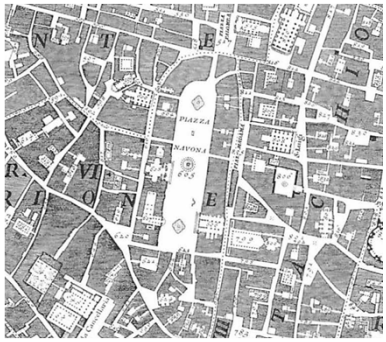
The Nolli Map as a living structure



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Venice – fractal or living structure

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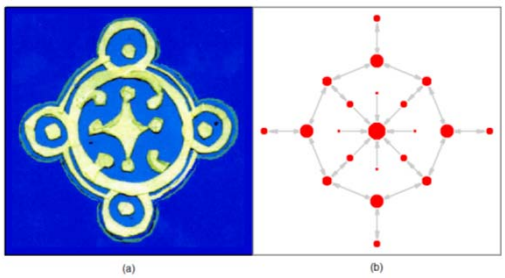
The ornament and topological representation



(a) (b)

Jiang B. and Ren Z. (2018), Geographic space as a living structure for predicting human activities using big data, *International Journal of Geographical Information Science*, x(x), xx–xx http://dx.doi.org/10.1080/13658816.2018.1427754

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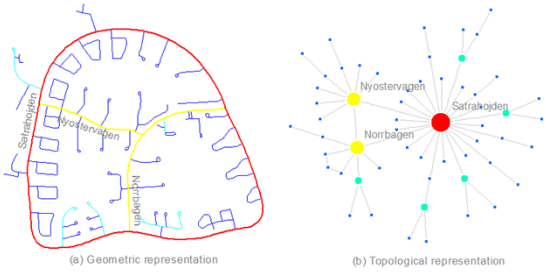
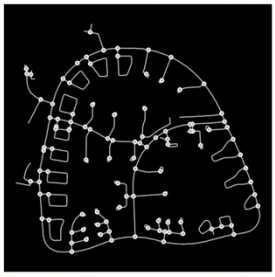
Geometric versus topological representation



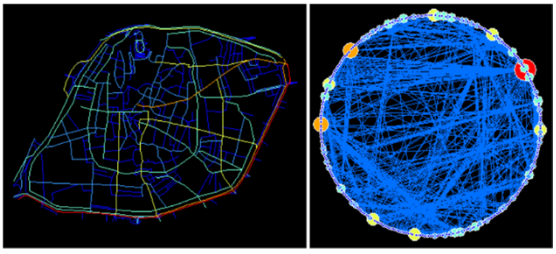
Jiang B. and Claramunt C. (2004), Topological analysis of urban street networks, *Environment and Planning B: Planning and Design*, 31(1), 151–162.

Transition from the geometric to topology

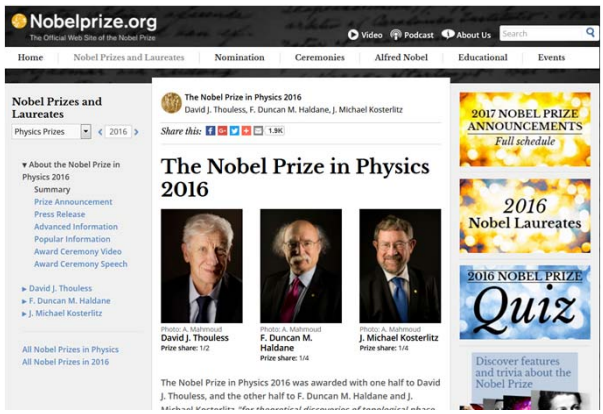


https://twitter.com/binjiangxp/status/952890181262114817

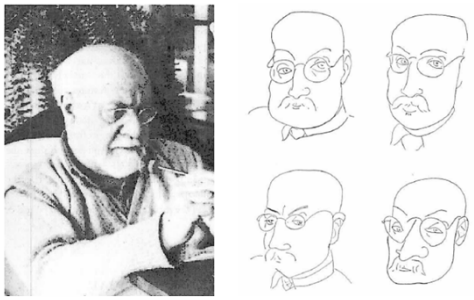
Revealing living structure of cities



Jiang B. (2015), A city is a complex network, in: Mehaffy M. W. (editor, 2015), *Christopher Alexander A City is Not a Tree: 50th Anniversary Edition*, Sustasis Press: Portland, OR, 89–100.



Exactitude is not truth (Matisse 1947)



Matisse H. (1947), Exactitude is not truth, in: Flam J. D. (1978, editor), *Matisse on Art*, E. P. Dutton: New York, 117–119.

Another example of inexactitude

On exactitude in science (Borges 1946)

... In that Empire, the Art of Cartography attained such Perfection that the map of a single Province occupied the entirety of a City, and the map of the Empire, the entirety of a Province. In time, those Unconscionable Maps no longer satisfied, and the Cartographers Guilds struck a Map of the Empire whose size was that of the Empire, and which coincided point for point with it. The following Generations, who were not so fond of the Study of Cartography as their Forebears had been, saw that that vast Map was Useless, and not without some Pitilessness was it, that they delivered it up to the Inclemencies of Sun and Winters. In the Deserts of the West, still today, there are Tattered Ruins of that Map, inhabited by Animals and Beggars; in all the Land there is no other Relic of the Disciplines of Geography.

Suarez Miranda, *Viajes de varones prudentes*, LibroIV, Cap. XLV, Lérida, 1658

Borges J. L. (1946), On exactitude in science, In: Borges J. L. (1998), *Collected Fictions*, Translated by A. Hurley, Penguin Books: New York, 325.

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On exactitude in the big data era

- *...We don't give up on exactitude entirely; we only give up our devotion to it. What we lose in accuracy at the micro level we gain an insight at the macro level.*
- *... Harnessing vast quantities of data rather than a small portion, and privileging more data of less exactitude, opens the door to new ways of understanding.*

Mayer-Schonberger V. and Cukier K. (2013), *Big Data: A revolution that will transform how we live, work, and think*, Eamon Dolan/Houghton Mifflin Harcourt: New York.

50

Living structure or wholeness

- *I propose a view of physical reality which is dominated by the existence of this one particular structure, W, the wholeness. In any given region of space, some subregions have higher intensity as centers, others have less. Many subregions have weak intensity or none at all. The overall configuration of the nested centers, together with their relative intensities, comprise a single structure. I define this structure as "the" wholeness of that region.*

Alexander (2002-2005, Book 1, P. 96)

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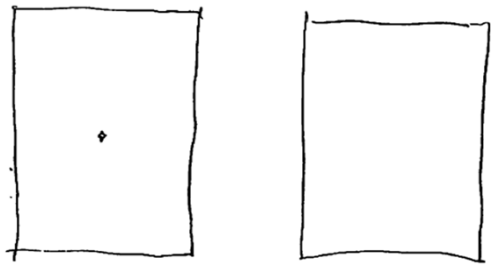
The physical character of living structure



Alexander C. (2002-2005), *The Nature of Order: An essay on the art of building and the nature of the universe*, Center for Environmental Structure: Berkeley, CA.

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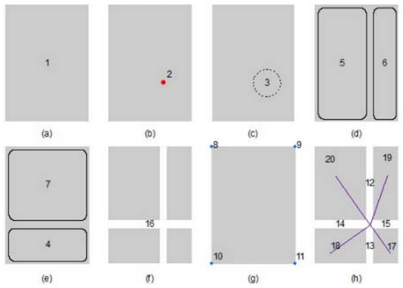
Cognition of a paper with a tiny dot



Alexander C. (2002-2005), *The Nature of Order: An essay on the art of building and the nature of the universe*, Center for Environmental Structure: Berkeley, CA.

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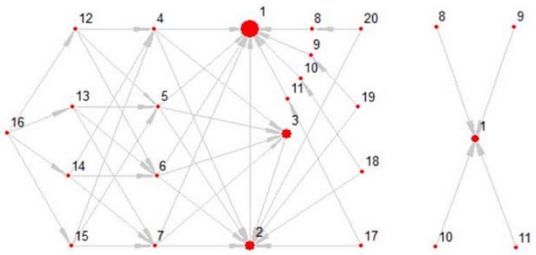
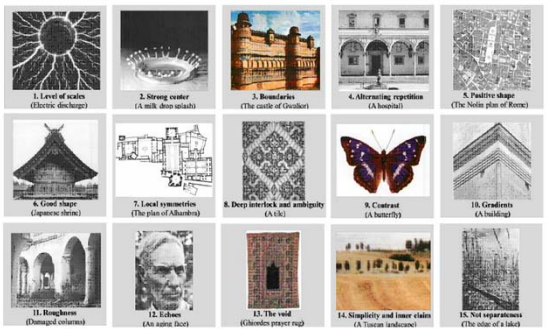
The living versus dead structure (physics)



Jiang B. (2016), A complex-network perspective on Alexander's wholeness, *Physica A: Statistical Mechanics and its Applications*, 463, 475–484.

54

Alexander's 15 fundamental properties



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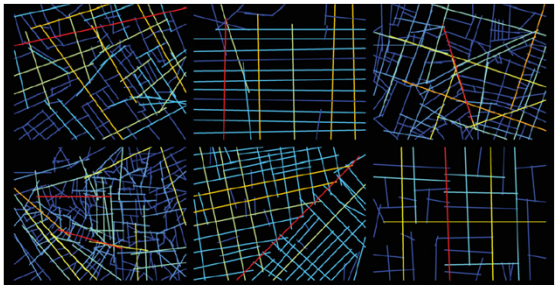
The image of the city out of fractal or living structure



Jiang B. (2013), The image of the city out of the underlying scaling of city artifacts or locations, *Annals of the Association of American Geographers*, 103(6), 1552–1566.

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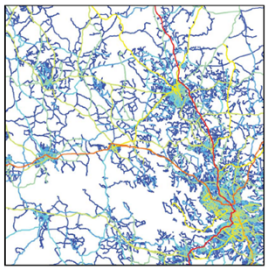
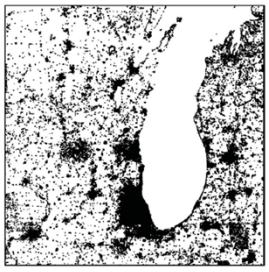
Perception of structural beauty

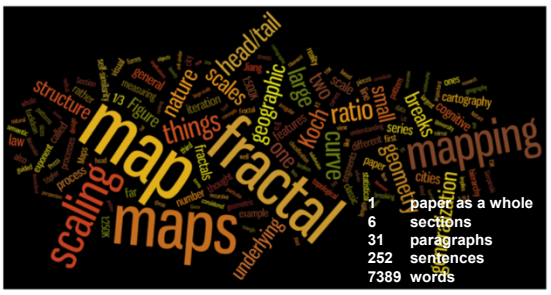




Jiang B., Liu X. and Jia T. (2013), Scaling of geographic space as a universal rule for map generalization, *Annals of the Association of American Geographers*, 103(4), 844–855.

57

The paper as a living structure



Jiang B. (2015), The fractal nature of maps and mapping, *International Journal of Geographical Information Science*, 29(1), 159–174.

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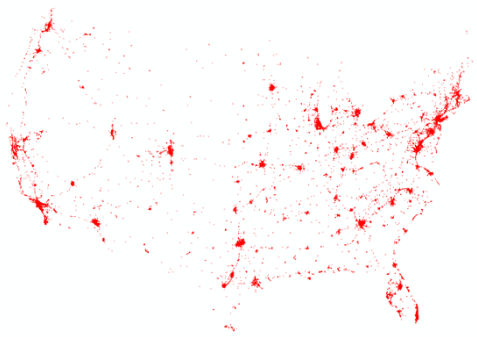
Faaaaar more small cities than large ones



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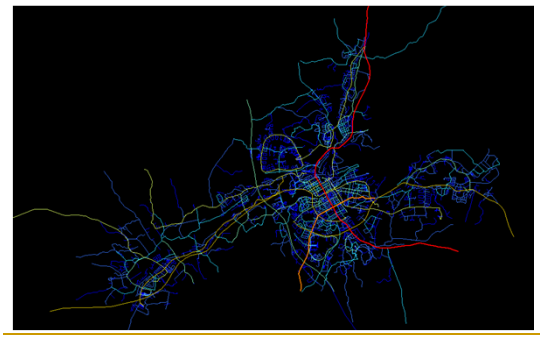
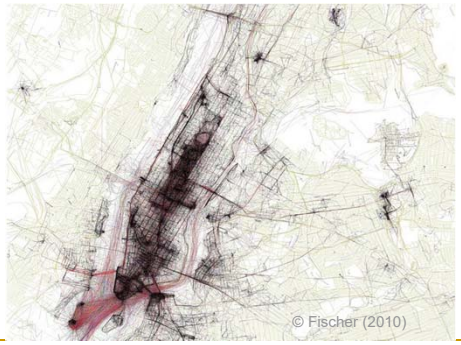
Faaaaar more short streets than long ones



60

Faaaaar more low density locations than high ones



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Faaaaar more low buildings than high ones

62

Faaaaar more ordinary people than the extraordinary

63

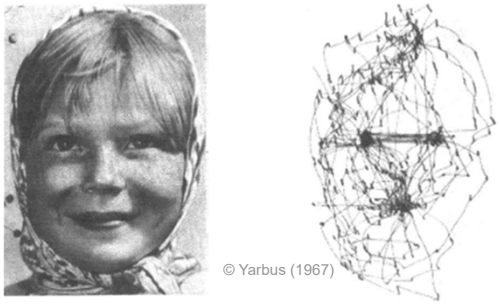
Faaaaar more small stars than large ones

64

Faaaaar more ocean (70%) than land (30%)

65

Faaaaar more low attentions than high attentions



66

Mirror of the self test

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Structural beauty versus structural ugly (I)

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Organized complexity (beauty) disorganized complexity (ugly)

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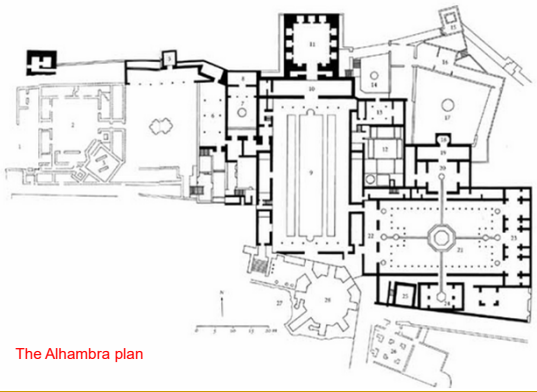
The Alhambra plan



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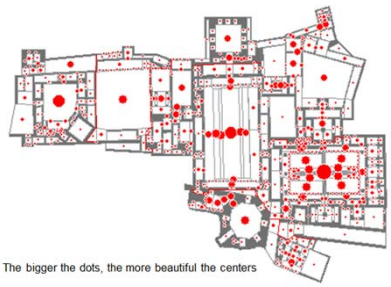
A mathematical model of living structure



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71

http://www.buildingbeauty.org/

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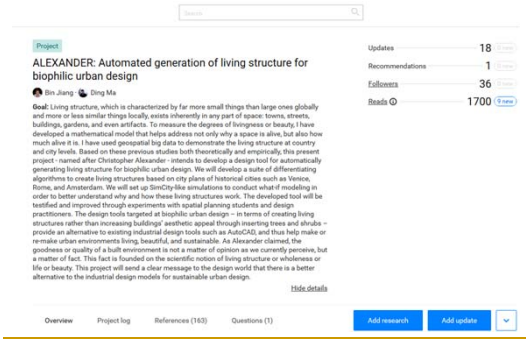
CAD – truly design rather than drawing

73

https://www.researchgate.net/project/ALEXANDER-Automated-generation-of-living-structure-for-biophilic-urban-design



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Conclusion – wrap up concepts

- 2 geometries: fractal + living geometry
- 2 laws: scaling + Tobler's law
- 2 principles: differentiation + adaptation
- 2 world pictures: mechanistic + organic
- 2 statistics: Gauss + Pareto
- 2 geometries: Euclidean + fractal (or living)
- 2 ways of thinking: topological + scaling
- 3 issues: looks + works + design
- 3 definitions of fractal (3rd definition)

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Conclusion – findings (I)

- All geographic features are asymmetric or scaling or fractal or living, given the right perspective and scope.
- Wholeness-enhanced transformation as a fundamental mechanism not only of geographic forms, but also of processes.
- Scaling law is available across all scales ranging from the smallest to the largest, and it states that there are far more smalls than larges in geographic space or living structure.

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Conclusion – findings (II)

- Tobler's law is available in one scale, and it states that more or less similar things tend to be nearby or related.
- In line with these two laws, differentiation and adaptation are two design principles, or wholeness-enhanced transformations, for making or re-making cities to be sustainable.
- Given its making/creation nature, living geometry is more profound than fractal geometry for creating beautiful asymmetries.

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Thank you very much!

(questions and comments?)

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