The spatial signature of convergence and divergence in two cities

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Towards Modelling Spatial Dynamics in Urban Systems

Understanding

- Generative experiments (Hillier and Hanson, 1984)
- Integration is static and choice is dynamic (Hillier et al., 1987)
- Cellular automaton with agent modelling (Batty, 1991)
- Changes in the shape of cities (Hillier & Hanson, 1993)
  - Demand and supply agent model (Krafta, 1994)
- Centrality as a process (Hillier, 1999)
  - Self-Organization and the City (Portugali, 2000)
- Centrality and extension (Hillier, 2002)
  - Multi-layer agent model (Krafta et al., 2003)
- Self-organisation in organic grid (Hillier, 2004)

Add hoc models in architecture and urban design

Modelling

MODELLING SPATIAL DYNAMICS IN URBAN SYSTEMS
HYPOTHESIS

Cities are Simple!

A city is “a network of linked centres at all scales set into a background network of residential space. We then show that this universal pattern comes about in two interlinked but conceptually separable phases: a spatial process through which simple spatial laws govern the emergence of characteristically urban patterns of space from the aggregations of buildings; and a functional process through which equally simple spatio-functional laws govern the way in which aggregates of buildings becomes living cities. It is this dual process that is suggested can lead us in the direction of a ‘genetic’ code for cities.” (Hillier, 2009)

http://otp.spacesyntax.net/methods/urban-methods-2/interpretive-models/

Cities are Complex!

“The tension between chaos and order often keeps cities on the edge of chaos—a situation that enables cities to be adaptive complex systems and withstand environmental changes.” (Portugali, 2012)

“Chaos is aperiodic long-term behaviour in a deterministic system that exhibits sensitive dependence on initial conditions” (Strogatz: 323).

Let V be a set. The mapping f: V → V is said to be chaotic on V if:

1. f has sensitive dependence on initial conditions,
2. f is topologically transitive (all open sets in V within the range of f interact under f),
3. periodic points are dense in V. (Devaney 50)

“A chaotic map possesses three ingredients: unpredictability, indecomposability, and an element of regularity” (Devaney: 50).


“Cities [are] problems in organized complexity”


To understanding cities we need:

1. To think about processes;

2. To work inductively, reasoning from particulars to the general, rather than the reverse;

3. To seek for "unaverage" clues involving very small quantities, which reveal the way larger and more "average" quantities are operating.
Cities show an autonomous behaviour in their growth and differentiation mechanisms. These mechanisms reinforce a self-organised parts-whole structural unity by which planned grid structures are deformed and adapted to match natural growth patterns.
We start from Space  looking for regularities in the geometry of street networks

Angular choice

Metric choice

On order, structure and randomness: *where do urban systems fall?*

Metric Mean Depth MMD Radius 1000metric

Normalised Angular integration Radius n
Searching for clues in the historical growth patterns of Barcelona and Manhattan

Goal/purpose/rule

Assumption

\[ Y = 99.877e^{0.1622x} \]
\[ R^2 = 0.9657 \]

A model can be outlined from the process of growth and structural differentiation in cities

Condition

Input

Mapping and externalising growth dynamics in historical growth patterns

Output

Expansion affordances Space to expand people to occupy
Will determine whether positive or negative dynamic changes

simulations and short term predictions
PRINCIPLES OF THE SYSTEM

Positive feedback

- addition
- Subdivision

Reinforcing feedback

- deletion
- mergence

Urban System

- edges
- middle
Looking for generic trends in the historical growth of urban street networks

Angular integration maps (radius 500 meters)

Angular integration maps (radius 2000 meters)

Severity of transition from one synchronic state to another given structural and distribution indicators

- Higher angular integration values
- Log normal distribution curve
- Mean/median values
Looking for generic trends in the historical growth of urban street networks

**Manhattan**

**Linear and nonlinear fit solutions**

- **Deformity** $R^2 = 0.80$ Natural logarithm fit
- **Fractal D** $R^2 = 0.53$ Linear fit

**Nonlinear fit solution**

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<th>Estimate</th>
<th>ApproxStdErr</th>
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**Barcelona**

- **Deformity** $R^2 = 0.95$ Linear fit
- **Fractal D** $R^2 = 0.83$ Linear fit

**Nonlinear fit solution**

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<tbody>
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<td>$b0$</td>
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$f(x) = X_0 \times \text{Exp}(X_1 \times (\text{year} - \text{year}_0))$

where the parameters initial values are;

- $X_1 = 0.013, X_0 = 159$ for Manhattan
- $X_1 = 0.006, X_0 = 90$ for Barcelona
Looking for invariances in the transformations of street networks

Method/Product

Asynchronising structures
Mapping transformations in-between synchronic states of the growing system

A dynamic model
That implements generative rules
Asynchronising structures
Mapping transformations in-between synchronic states of the growing system

Extract an invariant that marks growth patterns

Infer invariants from urban growth patterns

State A

State A+1

State A+2

State T = transformation (A, A+1)

Make assumptions on how they contribute to urban growth
Generative growth is a bottom up activity. Given the condition of spatio-temporal configurations in the street network, a generative mechanism operates to allow for the emergence of new elements and patches.
CHOICE IS THE GENERATOR

The superstructure marked by cumulative changes in choice is the generative structure of growth (The origin of cities)

Cumulative changes in choice recorded between 1260 and 2000

Barcelona

recorded between 1642 and 2000

Manhattan

where configurational changes are more likely to occur, elements tend to attach to new spatial structures
A matrix of maps plotting changes in integration (radius 500m) over time
CHANGE TRANSFERS

Waves of change in integration values transferring from the core of Barcelona towards the edges

Preferential attachment

Angular choice is generative globally

PRUNING

Once the growing structure reaches its maximum boundaries, patches with low local integration will tend to disappear.
Higher values mean high integration
radius 800
Colour range 3colours at 130

Manhattan (current state)  Manhattan (gaps filled)

There is a top-down process which ensures through a mechanism of self-organisation the maintenance of a part-whole structural unity. This process repeats a fractal structure that has certain metric proximity within itself and between its parts. The overall distance between patches approximates one and half the radius that defines them.
DISTANCE CONSERVATION BETWEEN PATCHES

Clusters were derived directly from MMD radius 1000 metric

Divergent Cities Conference

Cities grow naturally wherever an emergent bottom-up activity is possible

Cities deform to differentiate the uniform grid either by intensifying the grid where more through-movement is expected or by pruning weak local structures.

In a process of preferential attachment, city structure records a certain memory wherever integration change takes place and recalls this memory to attach to new elements.

This process is continuously updated once the system reconfigures its local settings.

The system is apt to fit within a certain distribution and tends to conserve metric distance between patches.

Structural differentiation aims to adapt the grid to match organic city structures.

Spatial structures in cities can be considered as independent systems that are self-generative and self-organised.
Is space predictive of urban form and function?

Or

Is space the materialised product of urban form and function?
Mapping space-form-function

Pixelmapper* binning spatial and urban data

For the second filter we define latent variables that capture the relationship between spatial structure and form-function parameters

Does street accessibility come first in the process of urban development?

*Modelling dependency networks*
In Manhattan, there was a clear pattern of dependencies, where street accessibility in 1920 was found to relate well to commercial land uses and land values. Land values were found to mediate the relationship between accessibility 1920 on the one hand and high-rise development, block density, and area of commercial activity in 2010. High-rise development in 1914 was also found to correspond to land values 2010, which in turn rendered high correlations with block density.
This research is part of Kinda Al_sayed PhD thesis (2007 -2014) supervised by Alasdair Turner, Sean Hanna, and Alan Penn

Al-Sayed, K; (2014) Urban morphogenesis; how form-function complexity coupled temporal changes on street configurations in Manhattan and Barcelona over the past centuries. Doctoral thesis, UCL (University College London).