CoMPLEX Annual Conference

CENTRE FOR MATHEMATICS AND PHYSICS IN THE LIFE SCIENCES AND EXPERIMENATAL BIOLOGY

Networks: From Genes to Cities

Friday 10th December 2010 Welcome Collection Euston Road London

Networks and Cities

Michael Batty
Bartlett Professor of Planning

http://www.casa.ucl.ac.uk/

Outline

- What are Networks in Cities: A Little Bit of History
- A Question of Spatial Scale: Planarity v Topology
- Down At Street Level: Space Syntax
- Urban Transport Infrastructures
- Throwing Out the Planarity
- Growing Networks
- Flows on Networks: Scale Again – Local to Global
- The Mathematics and Beyond
- An Indulgent and Interesting Example to Finish

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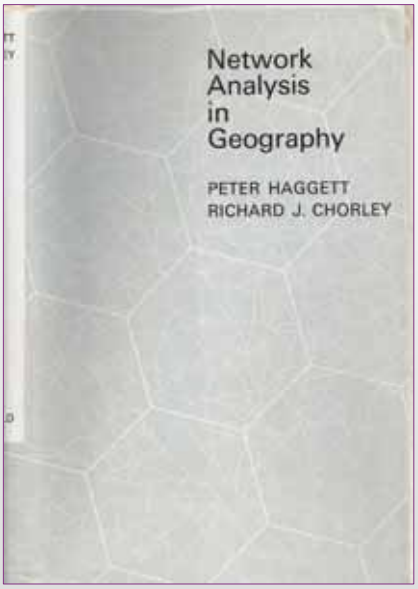

What are Networks in Cities: A Little Bit of History

Haggett and Chorley's famous book Network Analysis in Geography 1969 about rivers, transport networks, and flow systems of all kinds that permeated geographical Euclidean space but it was linked very strongly to location as well as interaction.

Networks in this sense dealt with flows and their infrastructure as arcs and nodes. Graph theory essentially was discovered in these fields

But these two worlds of flows and graphs were separate. Let me show you these contrasts by way of introduction

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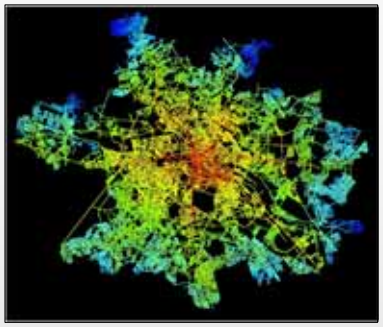

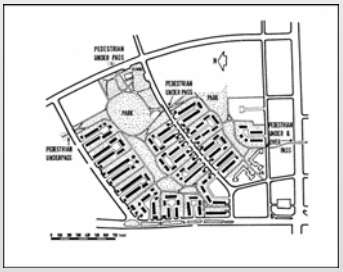

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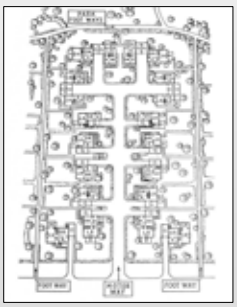
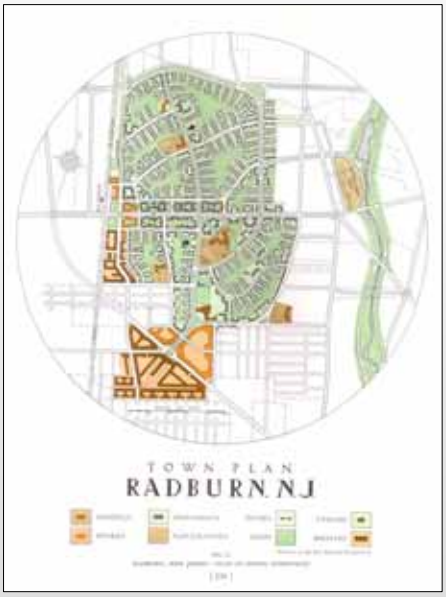




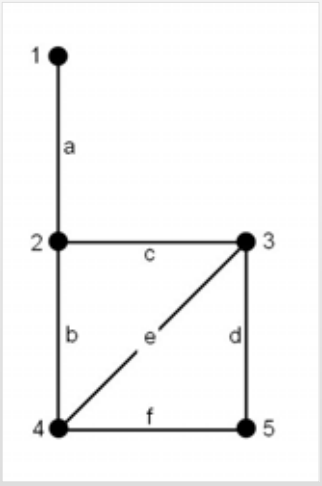
A Question of Spatial Scale: Planarity v Topology

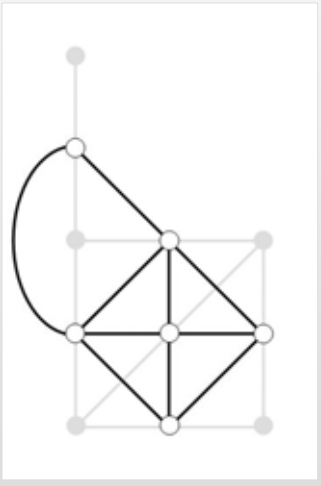
Essentially at the fine scale, in cities we deal with Euclidean space but as we aggregate in terms of spatial scale, we abstract and space although rooted in the 2 or 3 dimensional world becomes a world of points and lines.

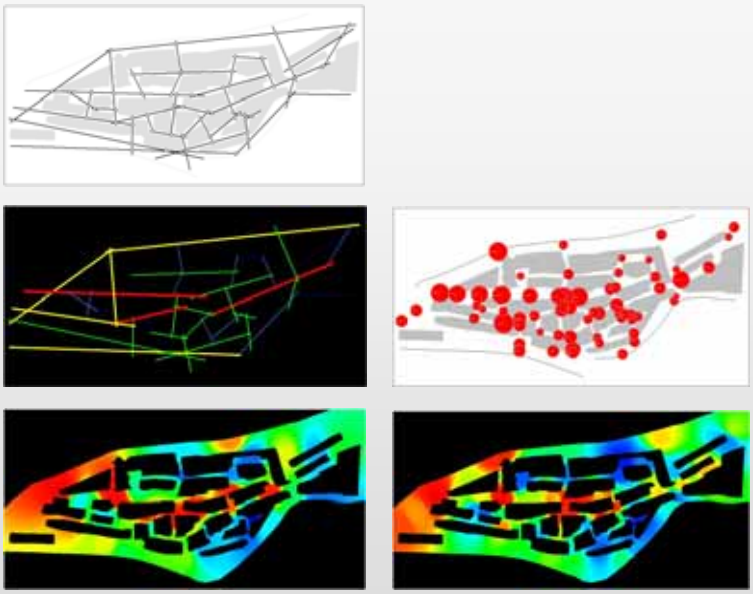
In short we move from planar graphs such as street networks to graphs of flows between cities, which can be treated topologically

Network science which developed well after this early forays into graph theory in the 1960s such as those by Haggett and Chorley, has largely eschewed planarity but it is coming.

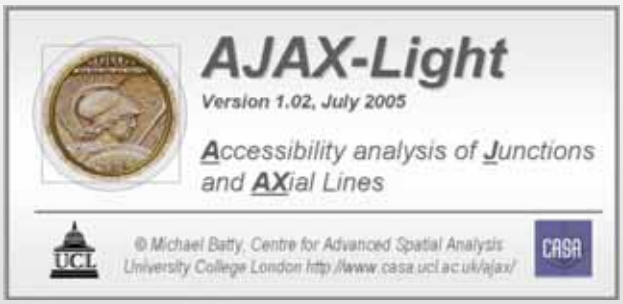
Down At Street Level: Space Syntax





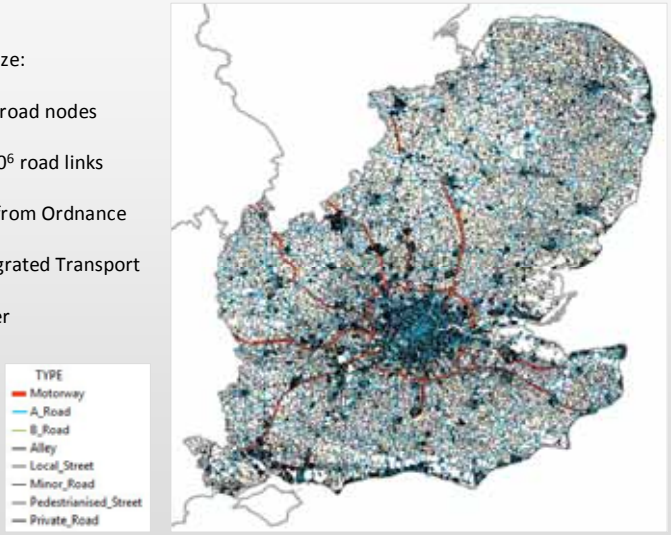


Let me have a go at demonstrating this kind of analysis



Urban Transport Infrastructures

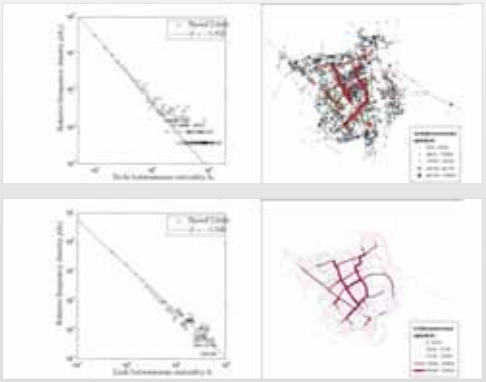
- Network size:
  - ~10^6 road nodes
  - ~$2x10^6$ road links
- Extracted from Ordnance Survey's Integrated Transport Network Layer

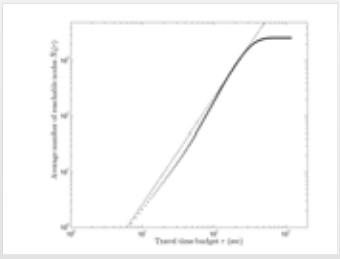


- Road network for Milton Keynes
- Network size:
  - ~$3x10^3$ road nodes
  - ~$7x10^3$ road links

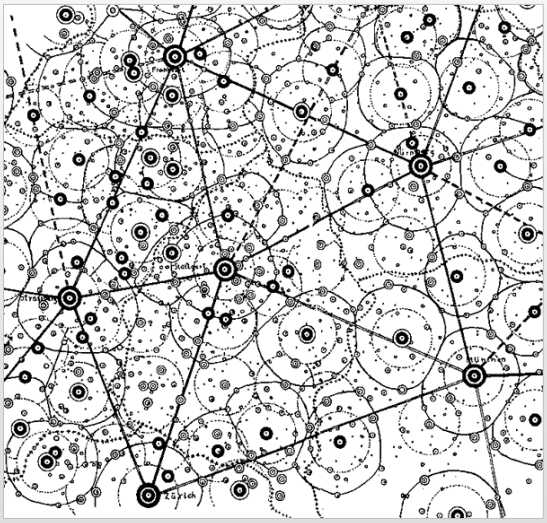
Power laws in road networks topology

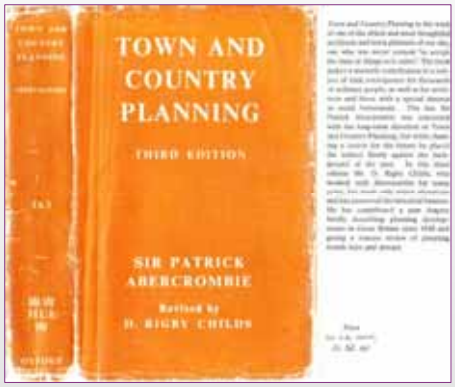
- ❑ Effective dimension
- ❑ Node betweenness centrality
- ❑ Link betweenness centrality





Throwing Out the Planarity





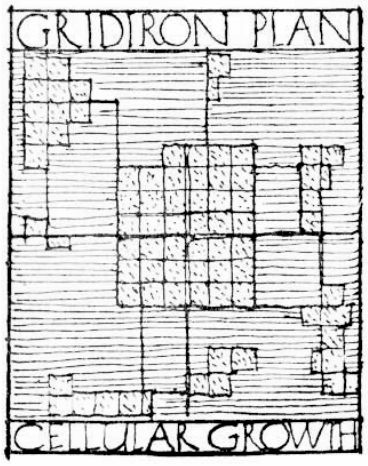


FIG. 1.

Historical Examples – from Abercrombie's book **Town and Country Planning** (1935)

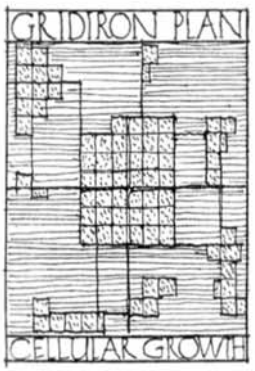


FIG. 1.

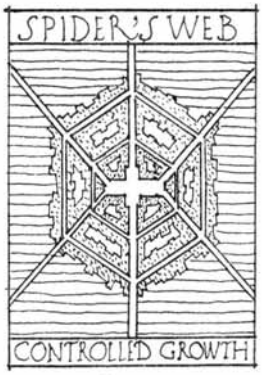


FIG. 3.

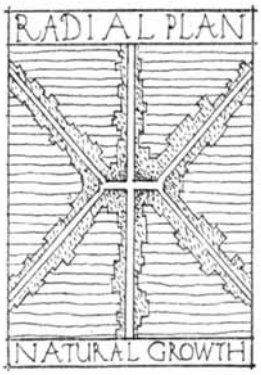
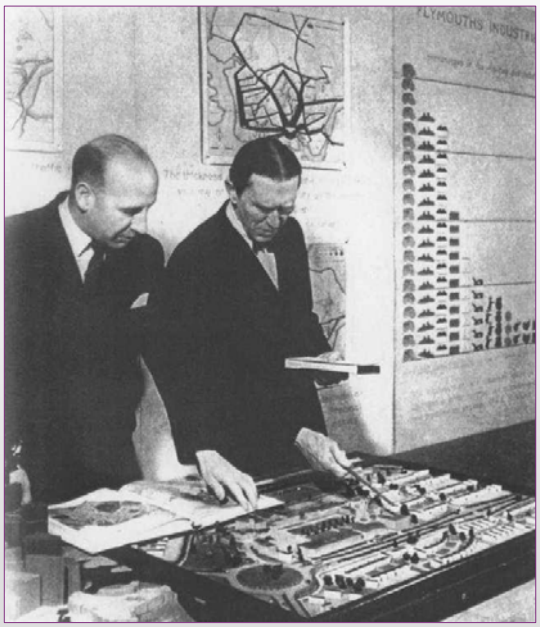
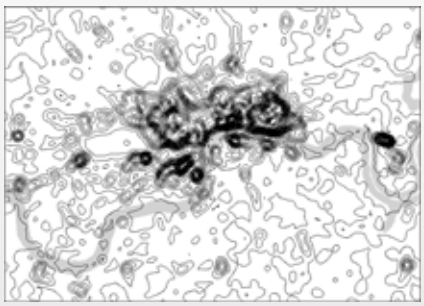


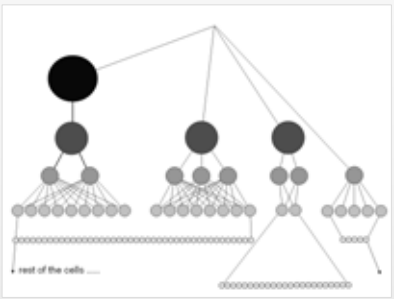
FIG. 2.

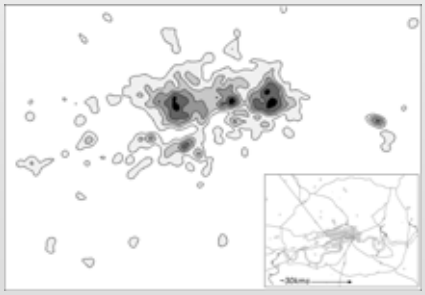


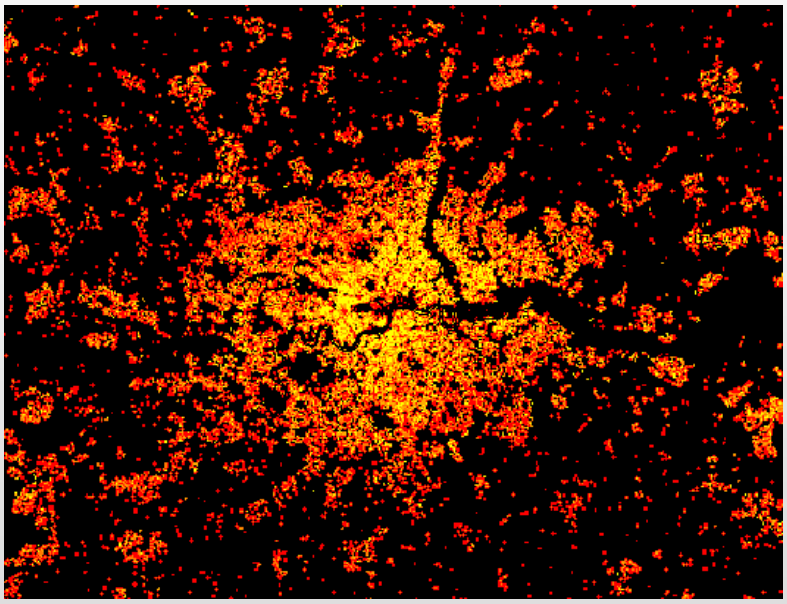
Note the flow of traffic and the pictogram – or histogram of employment.

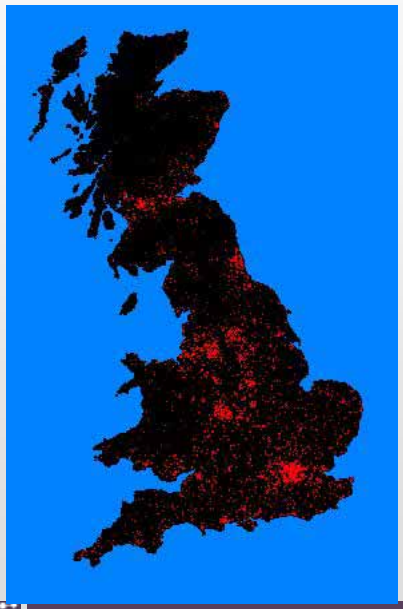
Essential science supporting the physical plan



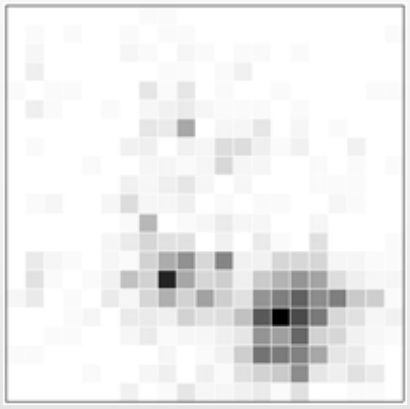


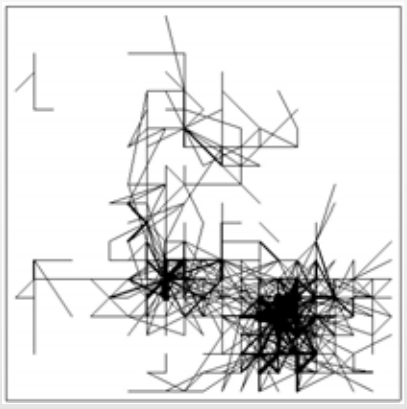


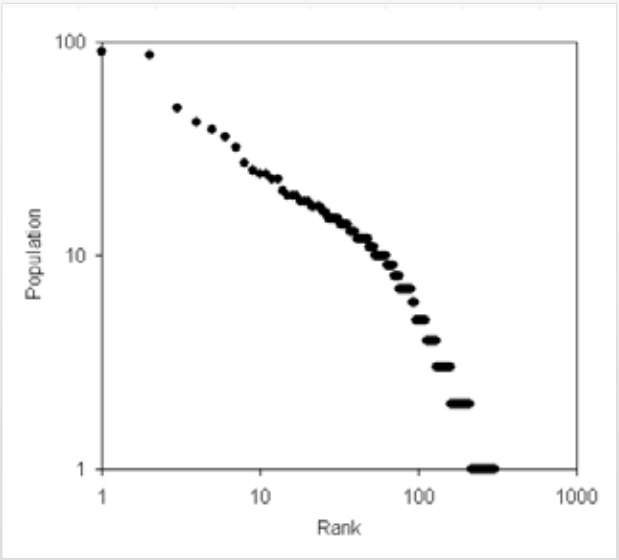




These clusters scale geometrically and their organization is ‘fractal’. This is fractal geometry where objects of the same shape exist at all scales





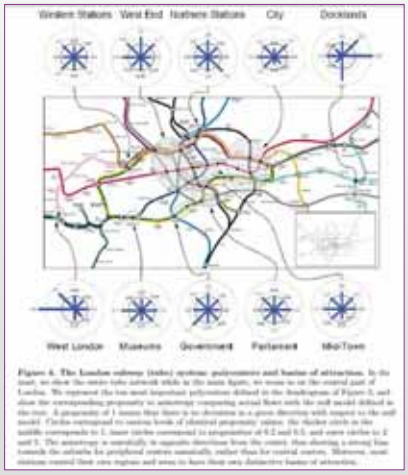

100
10
1
Population
1
10
100
1000
Rank

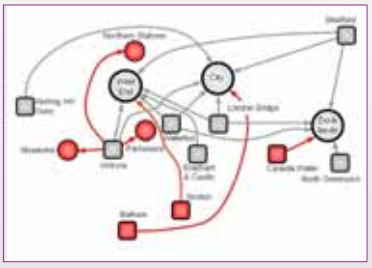
Network Data in the COSMIC project

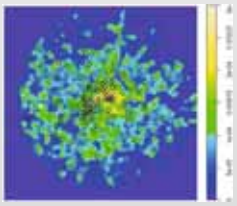
CASA Telecoms – see article in PLoS ONE Wednesday this week

CASA Subway Data – London Tube, and London data generally

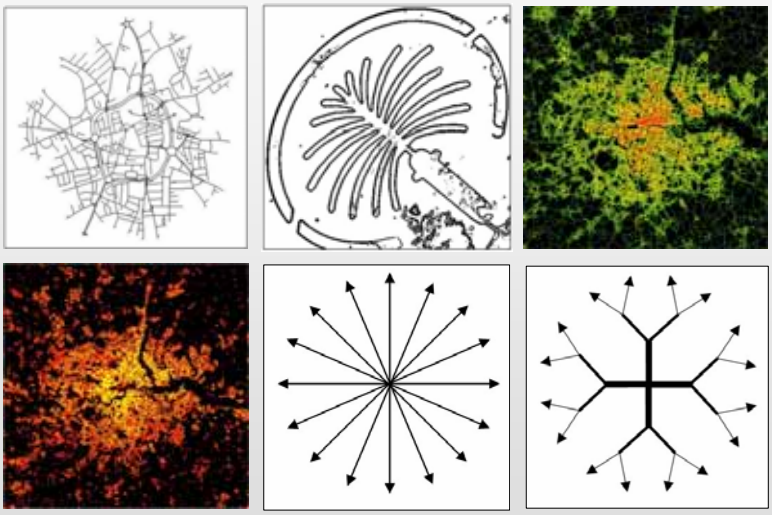
See forthcoming paper in PLoS ONE

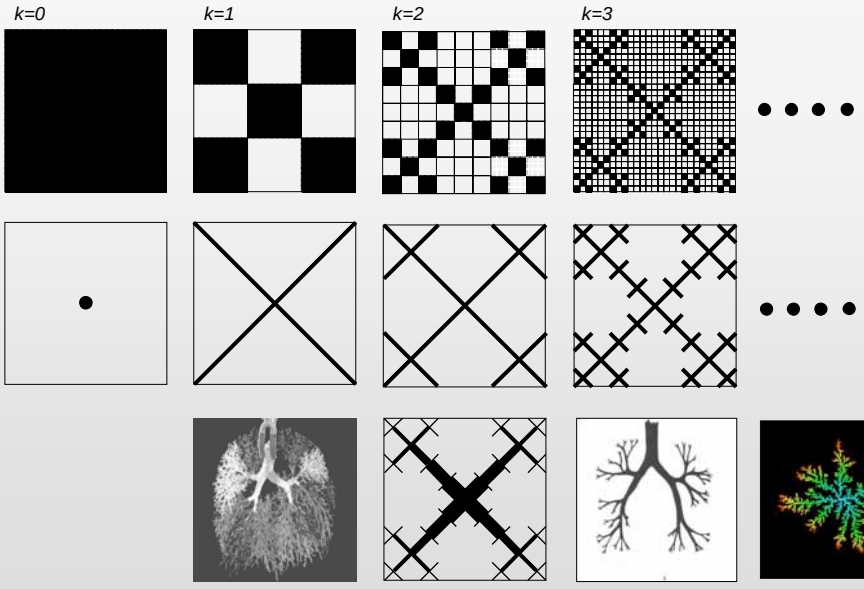




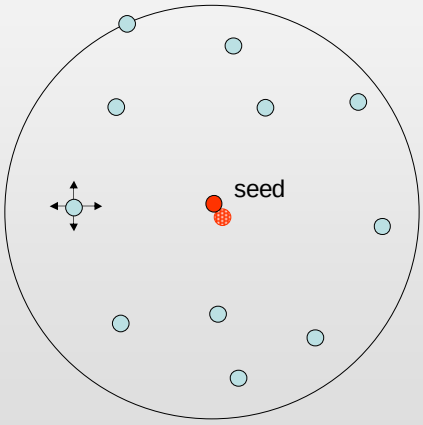


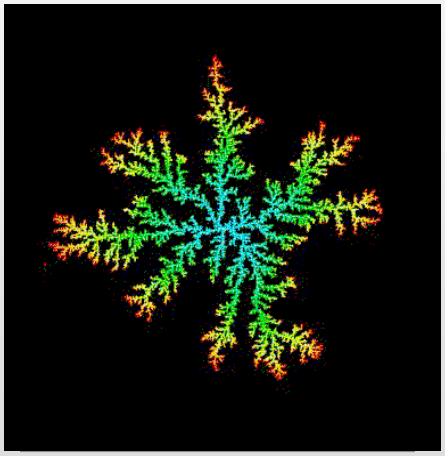
Growing Networks

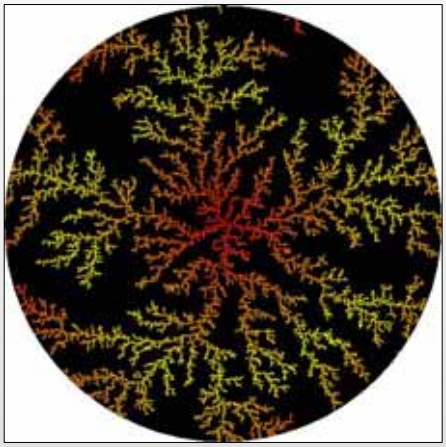


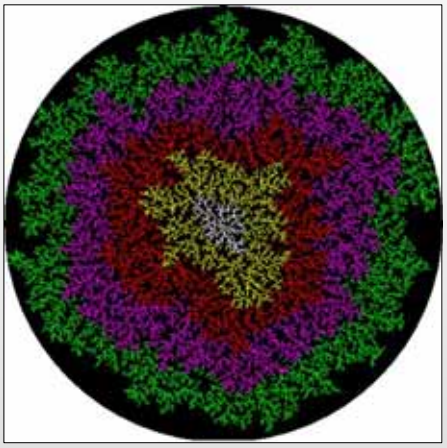


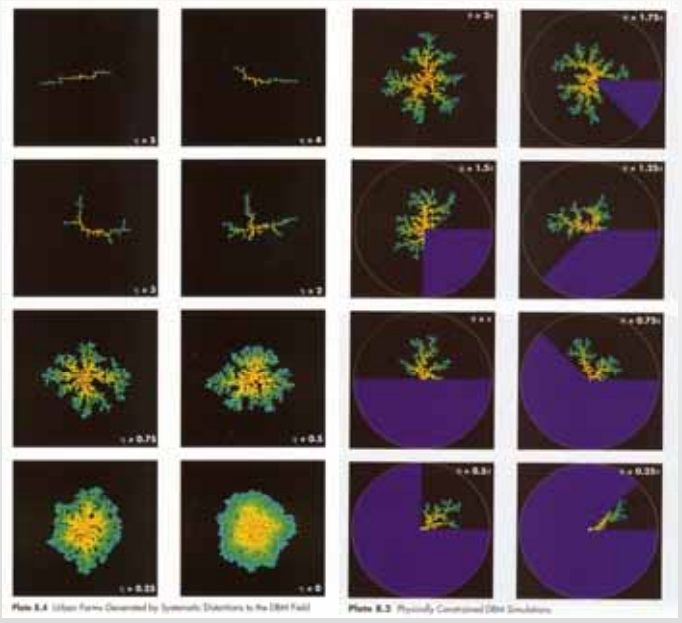
In essence, this is random walk in space which is can be likened to the diffusion of particles ○ around a source ● but limited to remain within the influence of the source – the city











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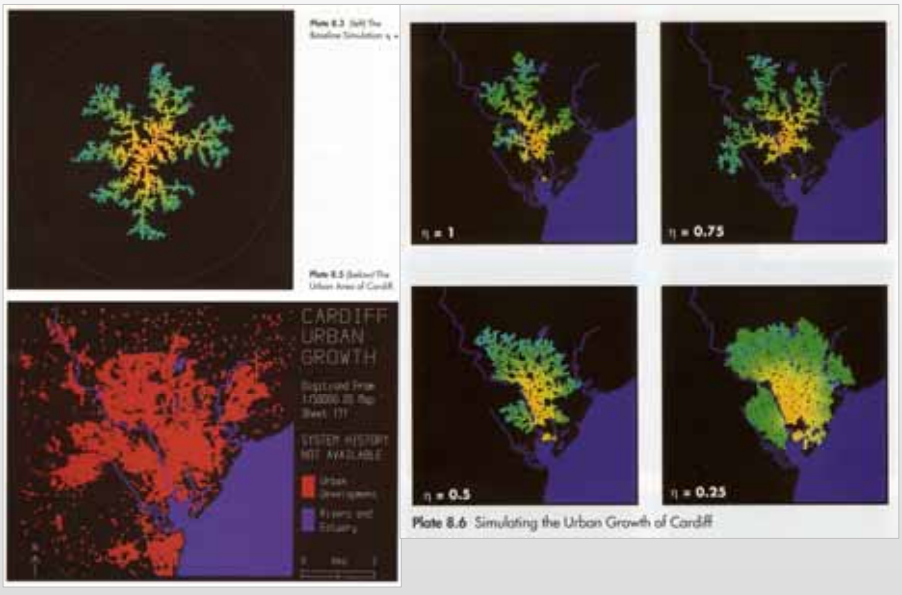

Plate 8.6 Simulating the Urban Growth of Cardiff

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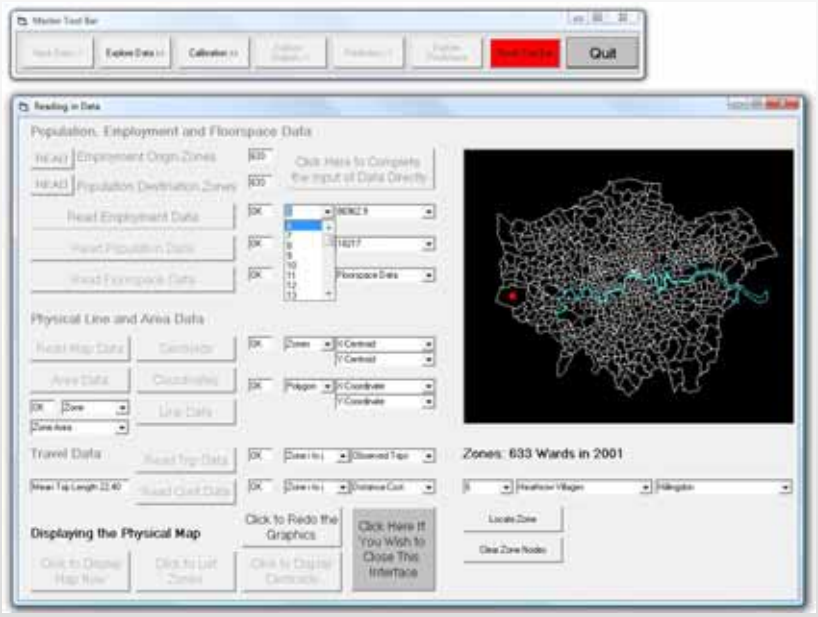
Flows on Networks: Scale Again – Local to Global

There is an enormous amount of work on spatial interactio, largely separated from the underlying networks but conceived in terms of gravitational models – which lie at the origins of social physics

Many of these models are being developed in our group and I simply illustrate some snaps from our London land use transport model that we have built for the Tyndall Centre Climate Change Cities project

These models predict flows on fixed networks – which we have seen earlier for London



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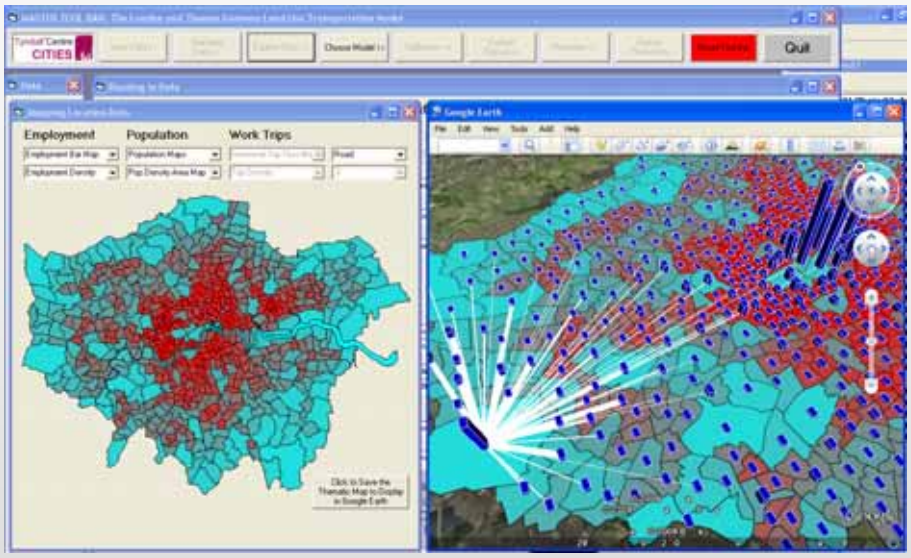
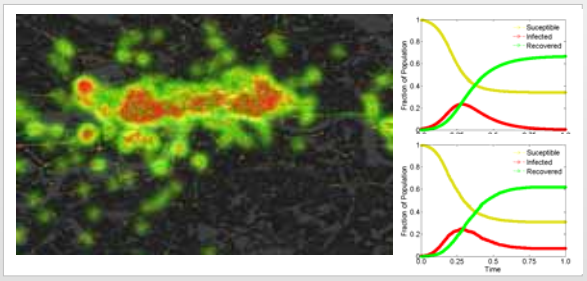
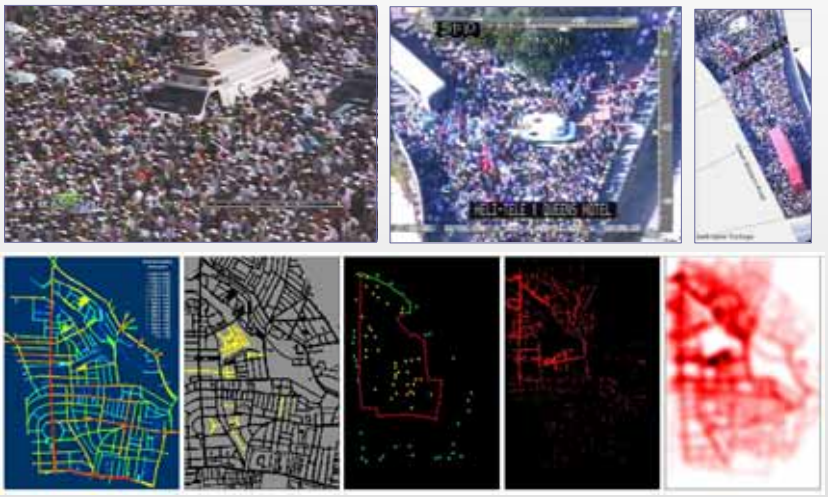


The Mathematics and Beyond

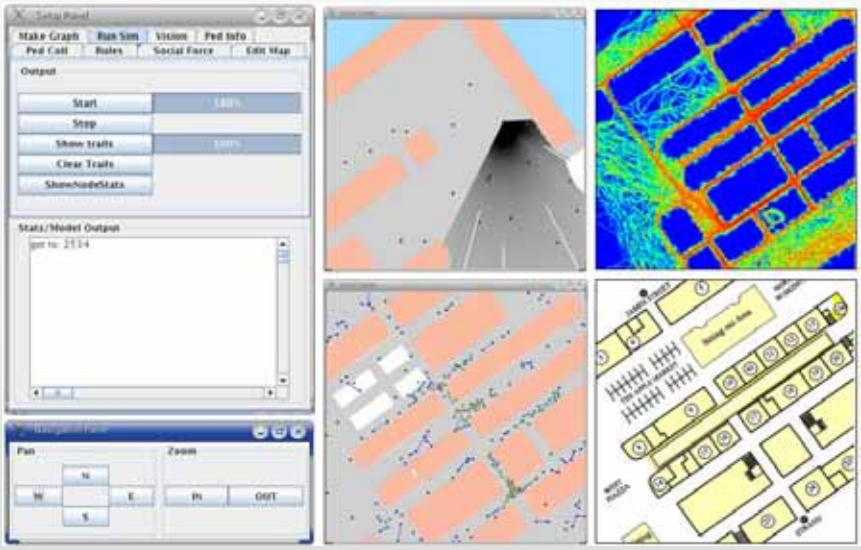
Basically we are building various models of processes on such networks – we want to develop some diffusion models of disease on networks, like the spread of the common cold in enclosed transportation spaces – like the tube.



http://www.ajohansson.com/london_epidemics.avi



Above: Crowd Scenes and Emergency Vehicles at Hajj and in Notting Hill: Below: Our ABM of the Notting Hill Carnival



John Ward's ABM of Tourists & Shoppers in Covent Garden

My Indulgent and Final Example

London Bikes Project

Scraping Data: The London Bikes Experiment

Locally called Boris's Bikes

4200 bikes, 340 stations, access via online registration or by paying on a credit card at the local bike station – so all online data

City	Official Name	Installed	System	# of Bikes
London	Barclays Cycle Hire	July 2010	Bixi	4,300
Barcelona	Bicing	March 2007	Bikemi	4,200
Milan	Bikemi	December 2008	Bicing	1,100
Saragossa	Bizi	May 2008	Bicing	800
Girona	Girocleta	September 2009	TNT	100
Washington DC and Arlington	Capital Bikeshare	September 2010	Bixi	650
Montreal	Bixi	May 2009	Bixi	4,200
Minneapolis	Nice Ride	June 2010	Bixi	600
Denver	B-cycle	April 2010	B-cycle	350
Melbourne	Bike Share	June 2010	Bixi	400

Let's Visualise Them!

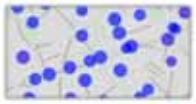
- Obtain the data from the operators' websites
  - Some provide XML/JSON/KML
  - Lots of Regex parsing
  - Velib-based systems require two stages
- Store it for analysis
- Stick it on a map
  - OpenLayers has some nice vector styling for points
  - OpenStreetMap-based background
  - Charts of historical trends via the Google Chart API

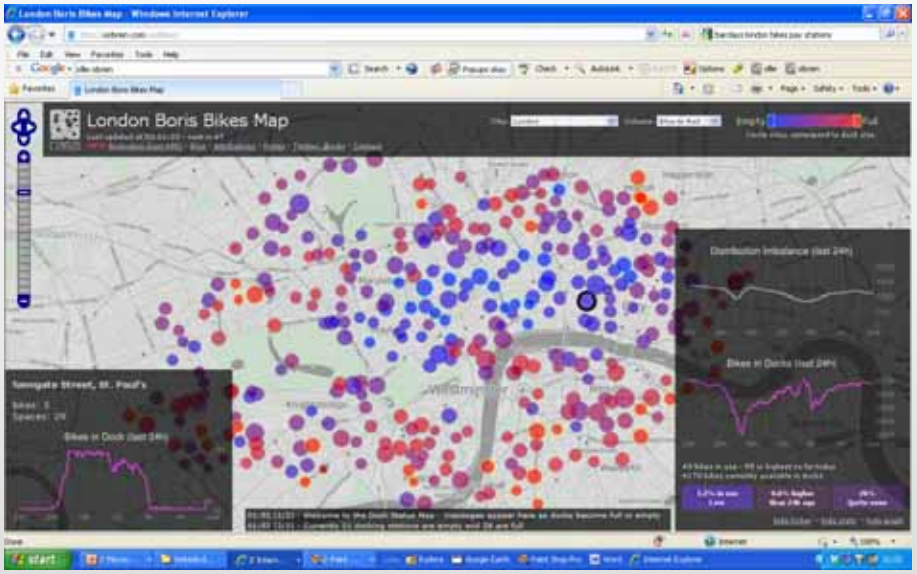
Bike-o-Meter
casa.ucl.ac.uk/bom

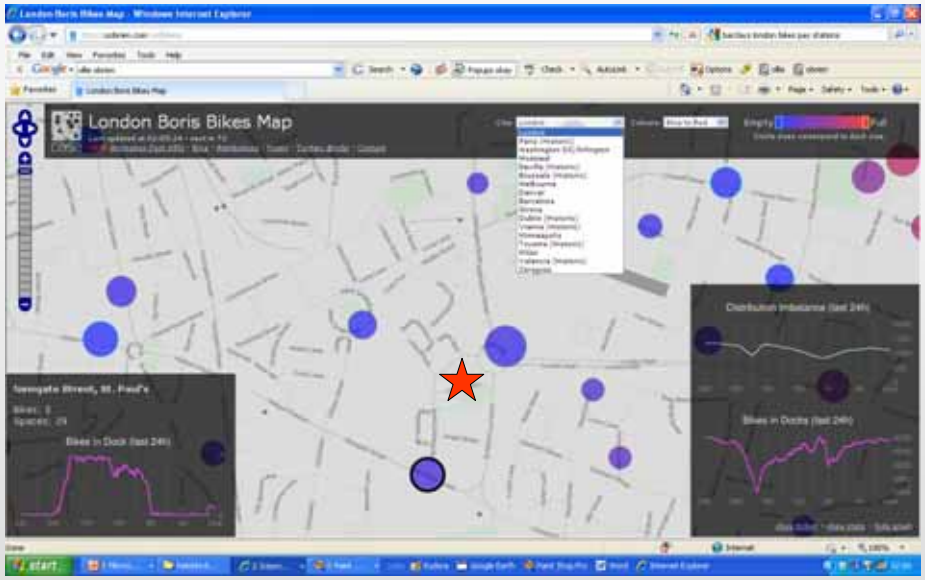
- Tweet-o-Meter for bikes
  - Steven Gray (@frogo)
  - Using Google Gauges
- See the real life Tweet-o-Meters at the new British Library "Growing Knowledge" exhibition
  - Should be easy to hack to show the Bike-o-Meters instead ☺

Bike/Dock Ratio

- No of bikes per 100 docks
  - Based on max availability at around 5am ("no" usage)
  - Averaged over a few weeks



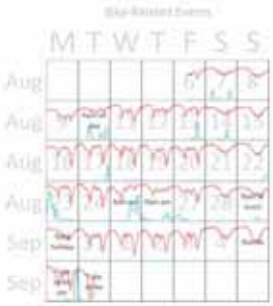




As yet no records of demand from people logging on, so no management capabilities, but could happen probably from an App based software but maybe from the server

Weekday Use – 1. Europe ex-Spain

More Analysis



- **London**
- Graph shows number of bikes available to hire
- Effect of rain
  - Using the CASA weather station
- Effect of the tube strikes

Redistribution Effectiveness

Bike-o-Meter

casa.ucl.ac.uk/bom

- Tweet-o-Meter for bikes
  - Steven Gray (@frogo)
  - Using Google Gauges
- See the real life Tweet-o-Meters at the new British Library "Growing Knowledge" exhibition
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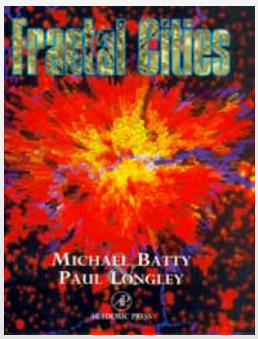
http://oobrien.com/vis/bikes/

If there is time,

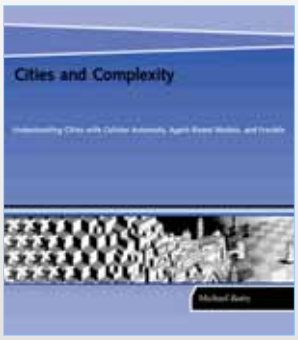
Questions

www.casa.ucl.ac.uk

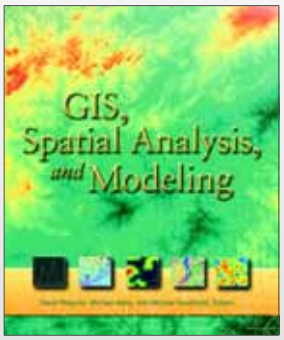
Some references which are accessible



Academic Press, 2009



MIT Press, 2005



ESRI Press, 2005