The International Symposium on Spatial Temporal Data Mining & Geo-Computation at UCL, July 19-23, 2011

Visualising Space-Time Dynamics:

Plots and Clocks, Graphs and Maps

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http://www.ComplexCity.info/

Outline

- Macro-Stability & Micro-Volatility in City Systems
- City-Size Distributions: Scaling and the Rank-Size Rule
- Visual Mnemonics: Plots, Clocks, Graphs, Maps
- Classic Exemplars: US City Populations 1790-2000
- US Metro Area Populations
- Japanese Populations: Cities at Different Scales
- Adding Place to Rank Clocks:
- Animations: Rank Clocks and Rank Space
- Next Steps

Macro-Stability & Micro-Volatility in City Systems

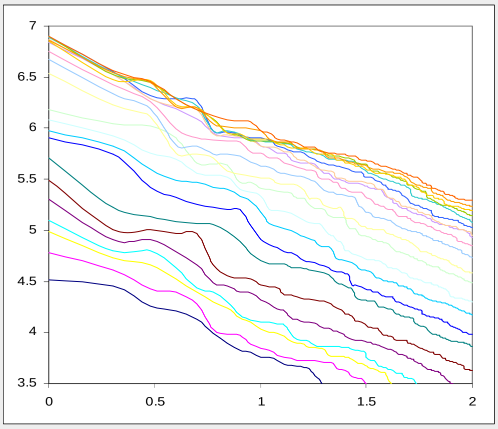
Cities have a remarkable degree of regularity and stability with respect to their size …

A Quote:

"The size distribution of cities in the United States is startlingly well described by a simple power law: the number of cities whose population exceeds P is proportional to 1/P. This simple regularity is puzzling; even more puzzling is the fact that it has apparently remained true for at least the past century."

Paul Krugman, 1996, Confronting the Mystery of Urban Hierarchy, **Journal of the Japanese and International Economies 10**, 399–418.

What does the actually mean, well we need to plot city size distributions to see



From George Kingsley Zipf (1949) ***Human Behavior and the Principle of Least Effort*** (Addison-Wesley, Cambridge, MA)

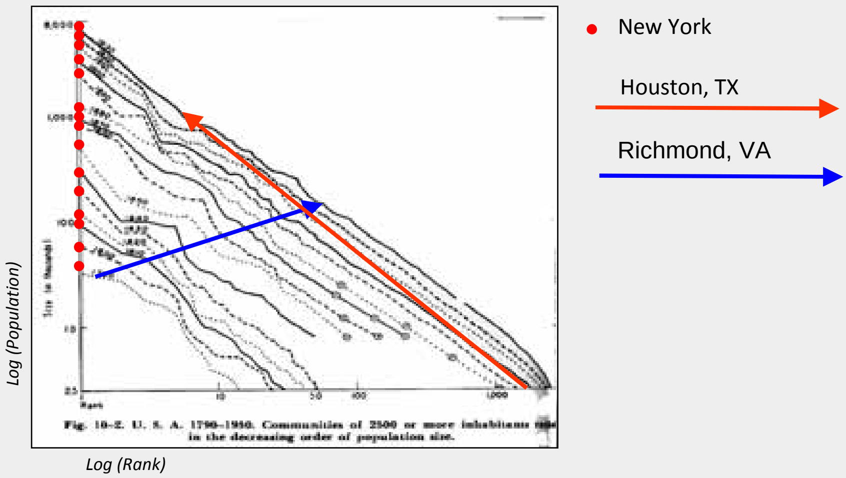
But cities also display remarkable volatility. To be a big city you must have been small once, but to be small you do not have to have been big. This is a strange asymmetry that pervades all our analysis.

Another Quote:

"I will [tell] the story as I go along of small cities no less than of great. Most of those which were great once are small today; and those which in my own lifetime have grown to greatness, were small enough in the old days"

From **Herodotus – The Histories** –
Quoted in the frontispiece by Jane Jacobs (1969) **The Economy of Cities**, Vintage Books, New York

What does this actually mean, well we see how the elements of the city size distribution change – back to Zipf



Key issues in this talk and research:

We first want to explore and understand the dynamics of such systems where the system appears stable at the macro level but volatile at the micro

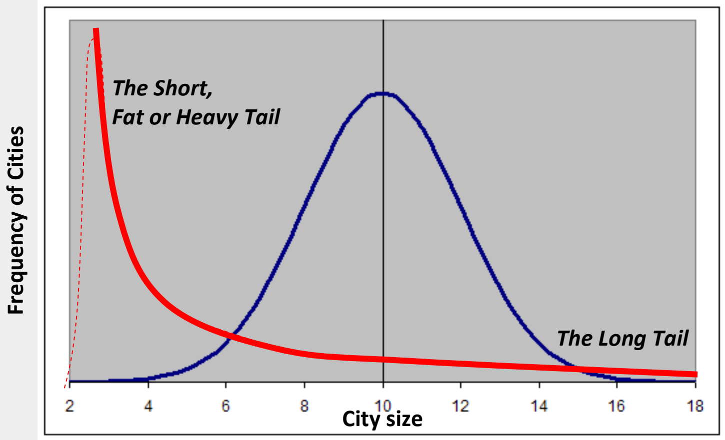
We want to model the dynamics but we will not do this here. Yet I need to at least tell you how we might as an addendum. Growth theory, trade theory, central place theory, and so on are all involved as are the economics of agglomeration …..Fujita, Venables, Krugman and all that – random proportionate growth model …

City-Size Distributions: Scaling and the Rank-Size Rule

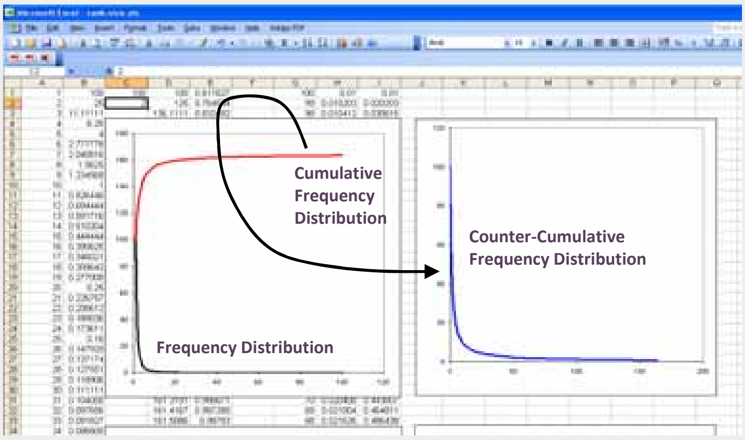
Ok, let me explain something about how we measure city size distributions. To cut a long story short, essential if we look at the frequency of city sizes, we find that they are heavily skewed to the right – positively skewed. They are not normal – if anything they are lognormal

Most distributions that are generated under competitive conditions – income, trips, cities, etc – are like this. As Bin said this morning *"This is the new normal"* or this is *"More normal than normal"*

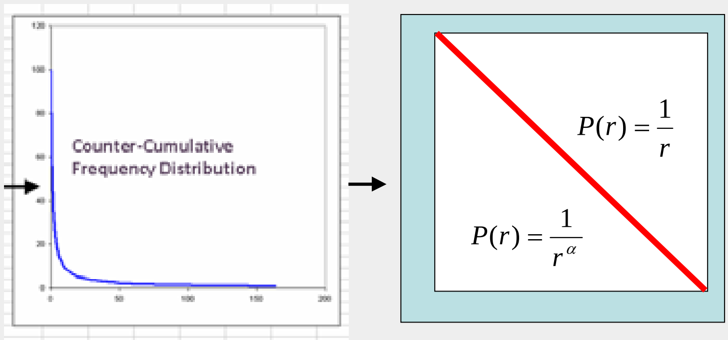
What we thus find for city sizes is the following – a distribution that is more like a power law or at least a lognormal



I am going to spare you the algebra although it is easy and this is how we get the rank size distribution from the frequency power



Now if we take logs – i.e. a simple transformation, this power law becomes a straight line in 2-d space and it is this form that we refer to as the rank-size rule



Let me revisit the key issue. Essentially we can illustrate the stability of city size population by showing how this rank size curve changes over time

It remains quite stable for the US from 1790 to 1930 and this is what Zipf, amongst others, discovered in the 1930s. And it prompted the Krugman quote.

It is all in Zipf's famous book. Moreover Paul Krugman in the late 1990s also said that Zipf's Law and Pareto's Law before, are the only real examples of iron laws in the social sciences. Let us see what he meant.

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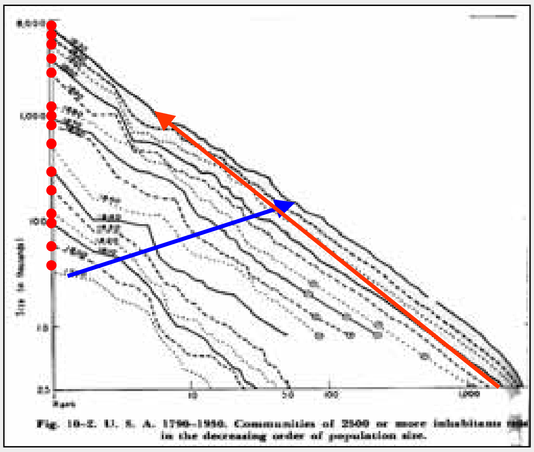
The Rank Clock and Other Visual Mnemonics

Log (Population)



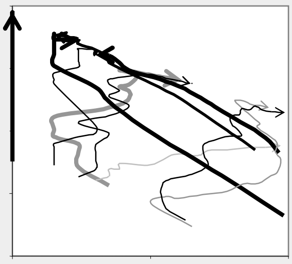
Log (Rank)

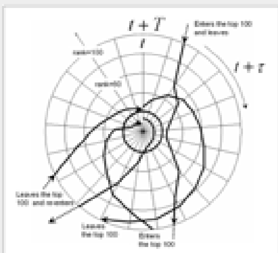
- New York
- Houston, TX
- Richmond, VA

From George Kingsley Zipf (1949) ***Human Behavior and the Principle of Least Effort*** (Addison-Wesley, Cambridge, MA)

Let us look at four different visualisations of this change

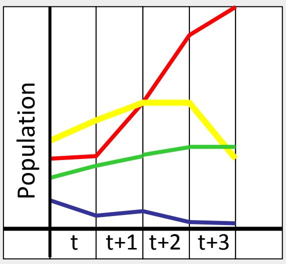
Rank Plots

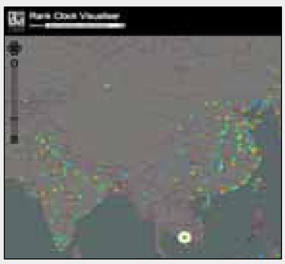




Rank Clocks

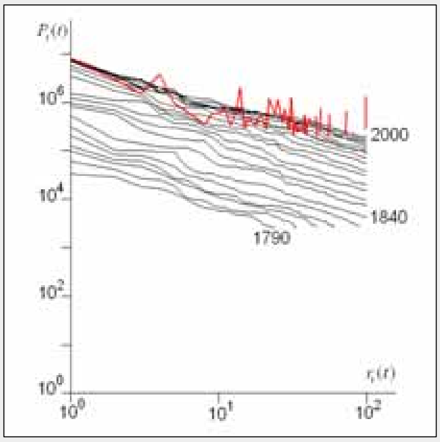
Pop Graphs, Slope Graphs

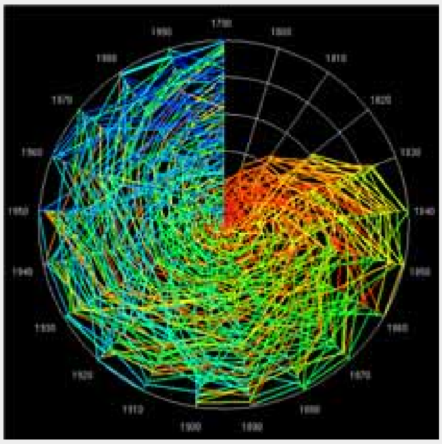




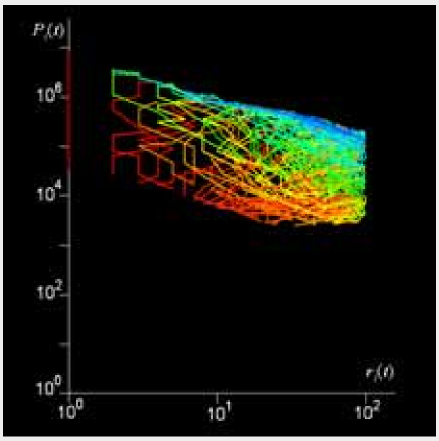
Pop Maps

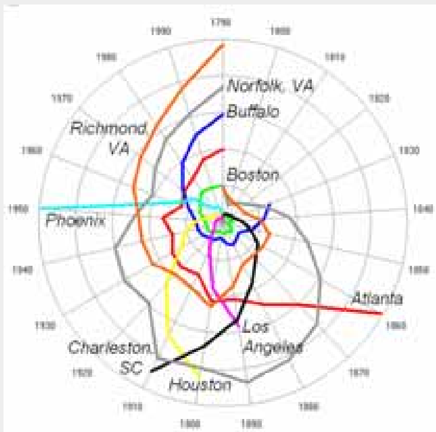
Classic Exemplars: US City Populations 1790-2000





The ‘morphology’ of the clock should tell us something – i.e. the increase in cities, the volatility of ranks and so on.

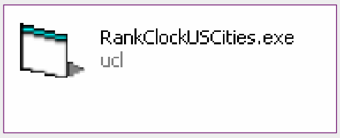




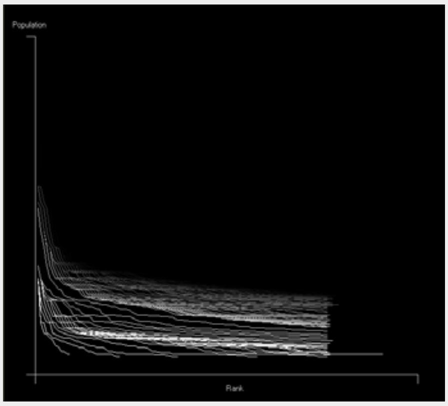
The rudimentary software for this in on our web site at http://www.casa.ucl.ac.uk/software/rank.asp

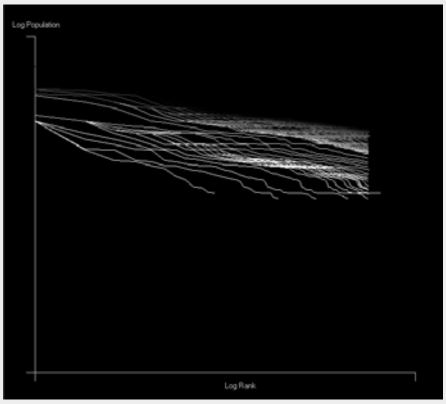
I will show you an animation of the clock but for a long while I simply plotted the clock and left it at that and measured various properties of the dynamics – but this time last year I decided to animate it and of course the work that Ollie and Martin are doing comes from the notion that the graphics need to be livened up.

Here is the US city ranks from my desktop software



Properties of the Dynamics – we have computed many functions – and have done little or no analysis of these as yet – for example we can compute half lives – on average how many years does it take a typical set of 100 cities from a particular year to decay to one half of that – to 50. Here are some graphs





Rank Size Relations for the Top 100 High Buildings in the New York City from 1909 until 2010

power form (left), log form (right)

& here is the clock RankClockNYCitySkyscrapers.... ucl

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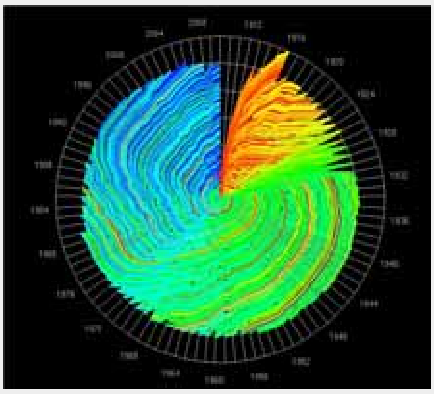
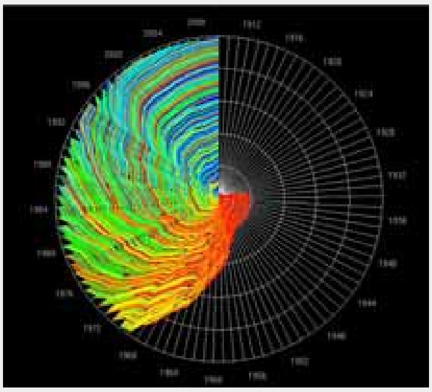

Rank Clocks of the Top 100 High Buildings in the New York City (a) and the World (b) from 1909 until 2010

There is much more work to do on all this and I am only giving you a taste of this, now back to shape and size

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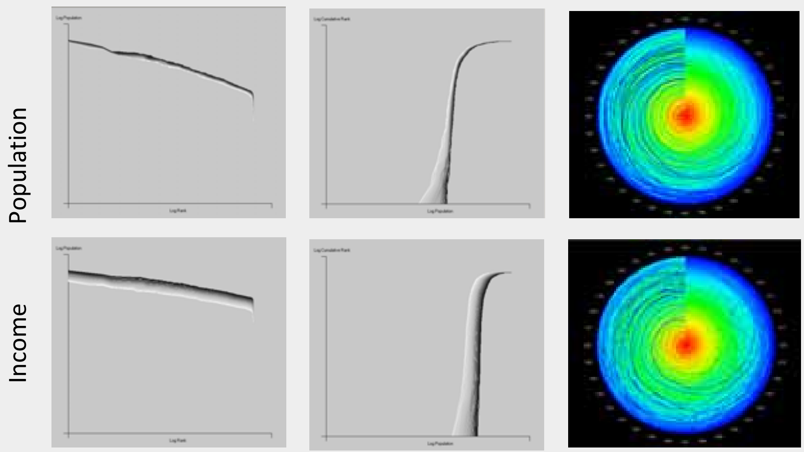
US Metro Area Populations

My last example – and we have many now – is from the US Bureau of Economic Analysis on metro areas –SMSAs from which I simply took their 366 regions for which population and income data are available for 37 years from 1969 to 2005.

One of the nice things here is that we can plot population ranks etc and income ranks – but we can also look at the ratio – population per capita which is much more volatile than each of the prime variables – let us see

We can easily plot the shifts, spaces, and clocks for these population and income data. These follow very regular scaling laws, at least in their fat tails. Here is a potpourri



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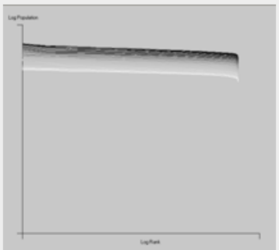
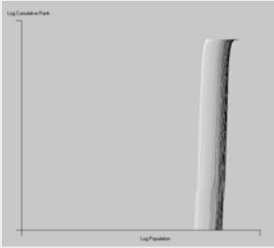
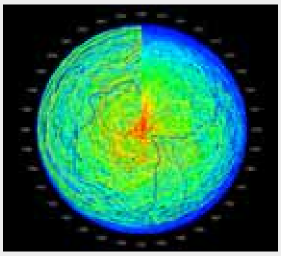
But the real interest is in per capita income/wages – i.e. *Incomes / Population*. How does this rank? And if there are big shifts in rank, this shows divergence of these two variables







As you might expect the rank clock provides a graphic animation of this relative disorder at the micro level

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Japanese Populations: Cities at Different Scales

We have a large population data set of 2137 'cities' in Japan that are mutually exclusive subdivisions of the Japanese space and these are not cities in the sense of the US cities we have used.

We also have an aggregation into 269 cities at a higher level

We also have other attributes of these cities – with data – such as area so we can compute densities

And we have these from 1920 to 2000 in five year periods

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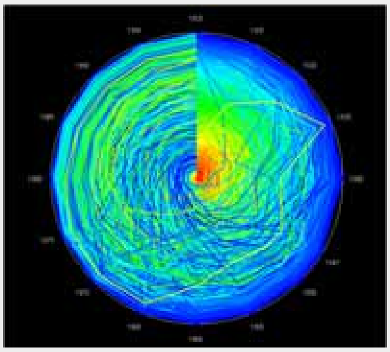
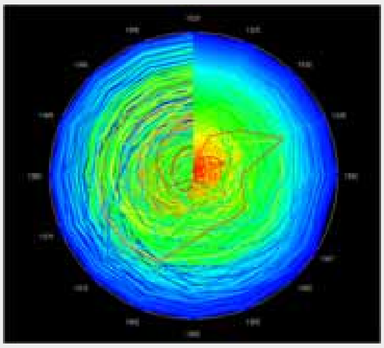
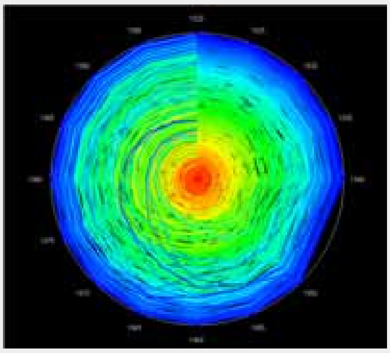
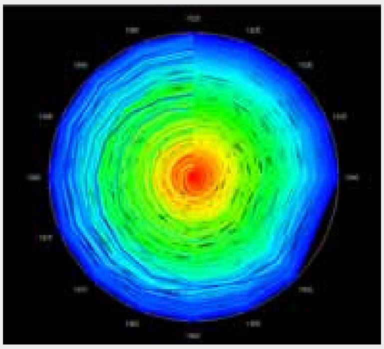
We will look first at the complete set of counts and then densities for 2137 and 269 and then look at Tokyo : first 2137 for counts and densities





then 269 for counts and densities





And let us look at the animation of the counts

RankClockJapaneseCities.exe
ucl

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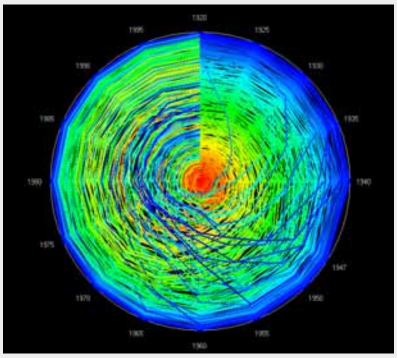
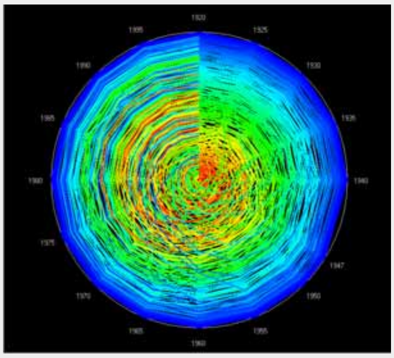
then Toyko, counts and densities,





Adding Place to Rank Clocks

Use OpenStreetMap as a base map

Use Google Earth browser plugin for 3D mapping

- Represent each point as an extruded pillar
- Create the pillar size and height based on the extent and average density of data

For simplicity, a uniform distribution of points across a square extent is assumed

Communicate with Google Earth by passing it KML

OpenLayers will readily convert any geometry to KML

Additional Options to Aid Visualisation

Inverting the rank clock

Limiting the size

Colour by:

- Initial interval
- Initial rank
- Final rank

Layering the lines (painter’s algorithm) by:

Initial or final highest or lowest ranked

http://splintmap.geog.ucl.ac.uk/~ollie/rankclocks/

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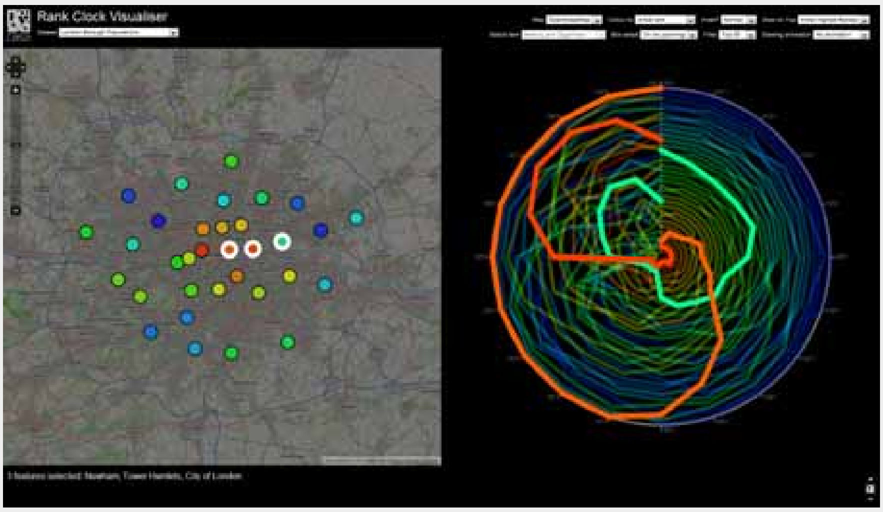
Demo – populations in 33 Greater London Boroughs from 1801



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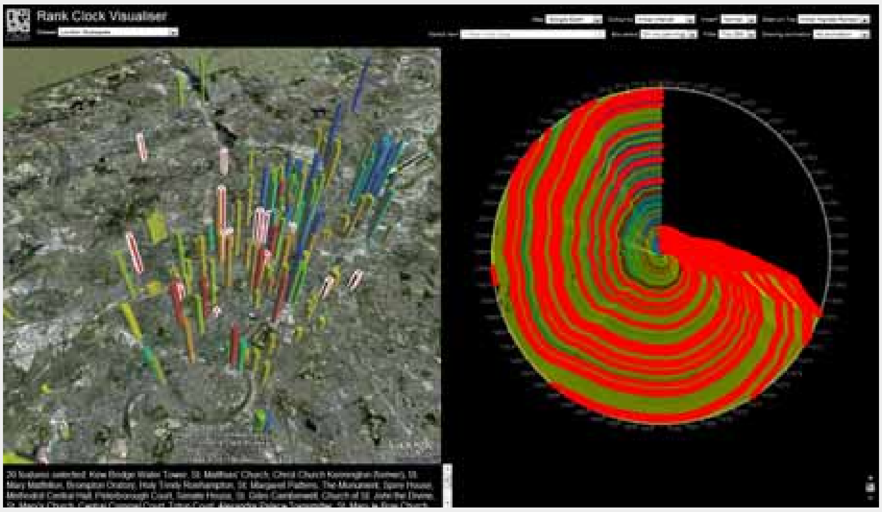
Demo – High buildings in London from 1950 to 2015



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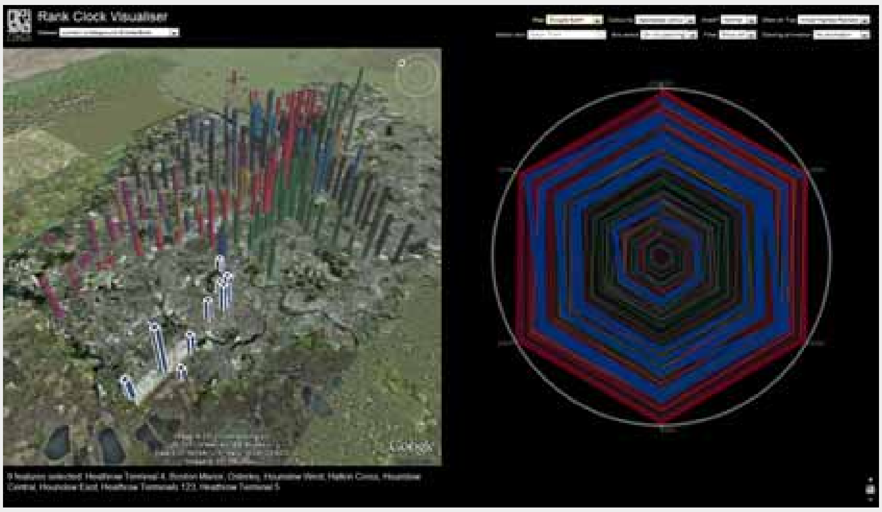
Demo – Tube Exit Volumes from 2003 to 2009



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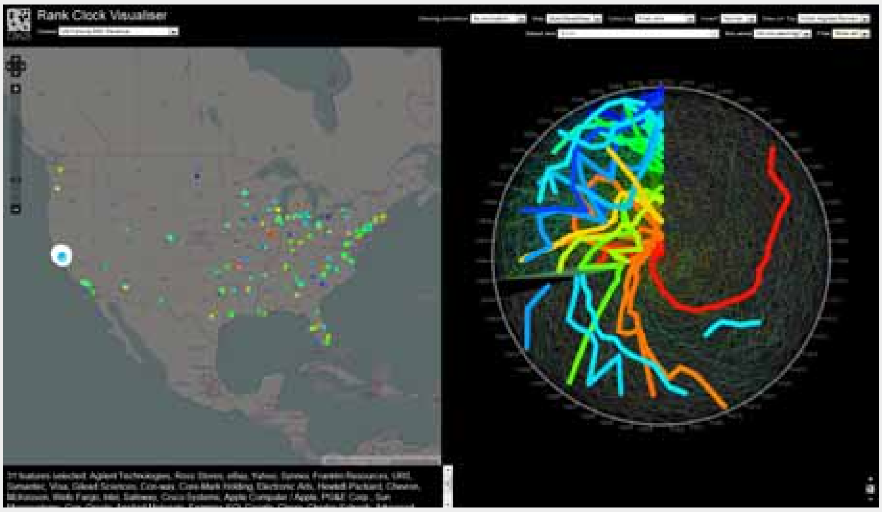
Demo – Fortune 500 from 1955 to 2010 for a sample of fast rising companies



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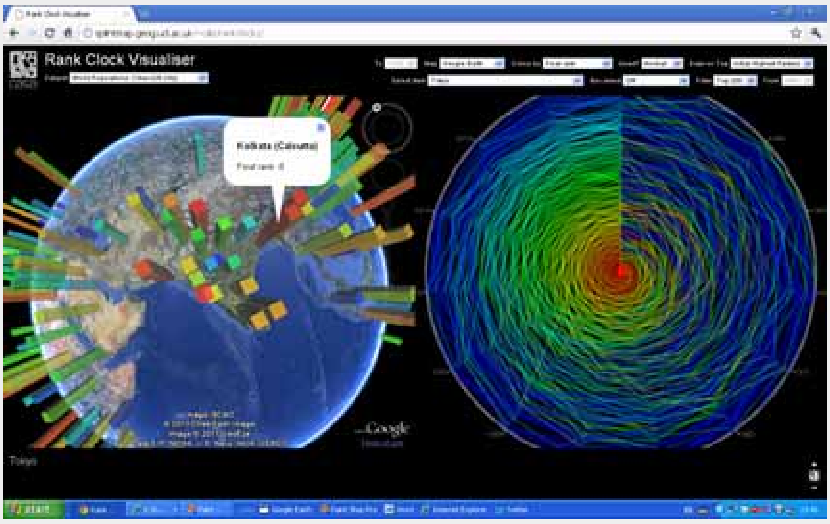
For United Nations World Cities Population (595 cities) from 1950 to 2025



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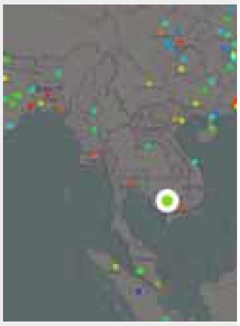

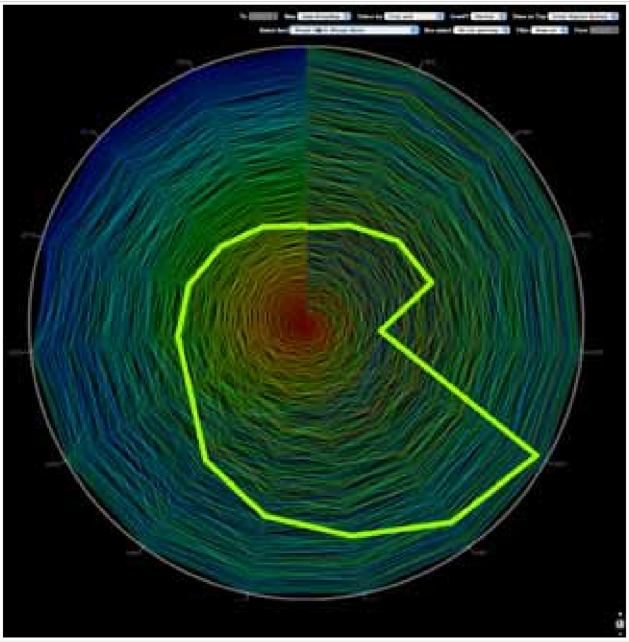

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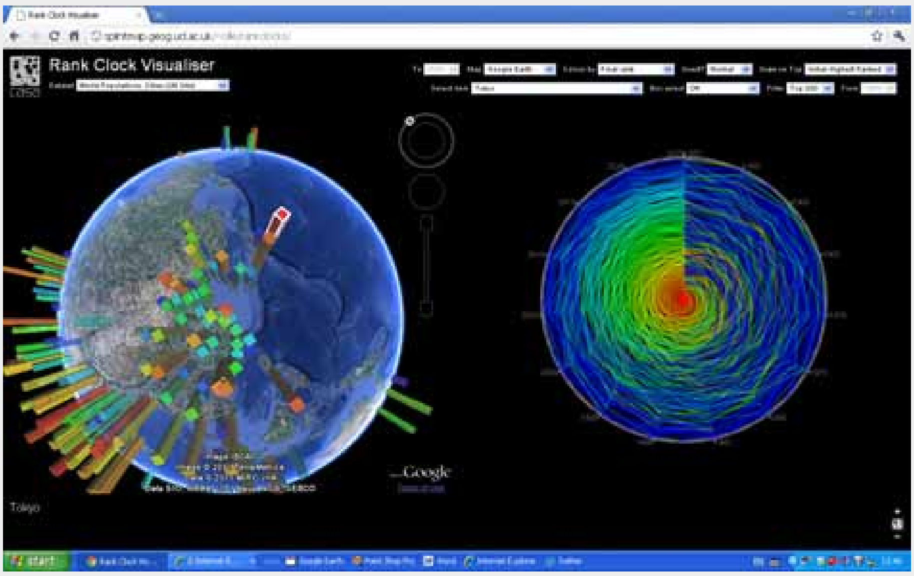

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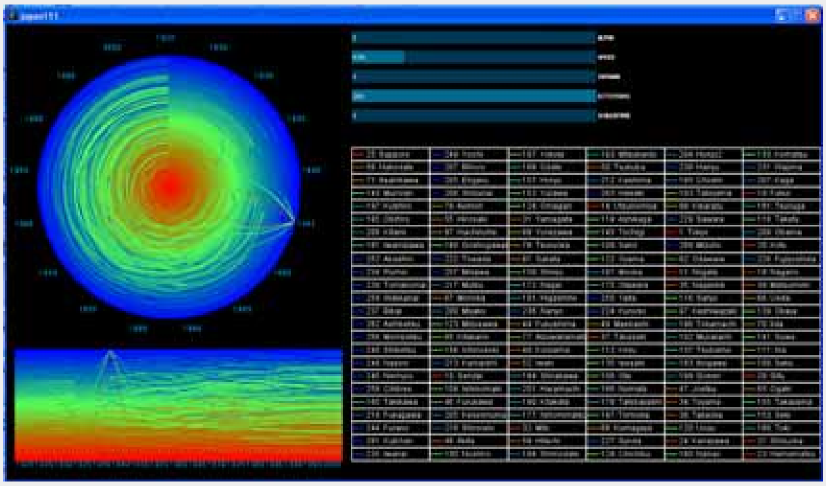
Animations: Rank Clocks and Rank Space

- Martin Austwick's has developed another set of programs which are superb at animation using *Processing*
- The essence of this is to continuously animate the clock and then we can see the deviations
- We can also plot individual trajectories and we can shorten the trajectories to show how each moves relative to one another
- We can do all of this also in rank space but I can't show you this

Here is the typical user interface and let me show it to you running ……………… *next page* ………………………………………▶



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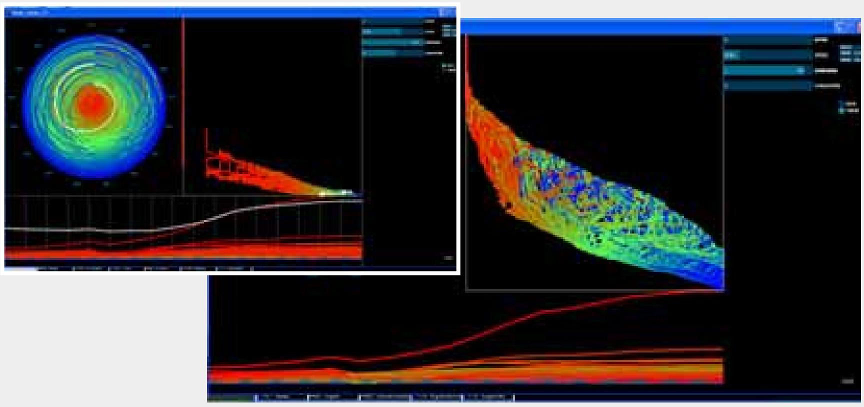
And here is the Tufte plot below– i.e. population against time which implicitly shows rank



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Next Steps

- ***Good measures of the volatility***: some of these I have explored but as yet we haven't done anything comprehensive – such as distances measures on the clock – measures of spread such as entropy and so on
- ***Extensions to network systems*** – trade and migration and traffic flows and their changes over time – in terms of nodal volumes and flows on links
- ***Examining different definitions of cities*** – and related systems: cities as exhaustive partitions of space versus cities as nodes or points

  Some papers ………

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nature

Vol 444 | 30 November 2006 | doi:10.1038/nature05302

LETTERS

Rank clocks

RANK CLOCKS AND PLANT COM

RESEARCH ARTICLE

Visualizing Space–Time Dynamics in Scaling Systems

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Questions?

http://www.ComplexCity.info/

http://new.oobrien.com/rankclocks/

http://jmichaelbatty.files.wordpress.com/2011/06/batty-complexity-2010.pdf

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