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City size: Spatial dynamics as temporal flows

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For simple systems characterised by two or more dimensions, visual understanding is essential if the number of objects is more than handful. George Miller (1956) argued that this handful was the magical number 7 ± 2 and Herbert Simon (1974) proposed that it was smaller still, being close to what he called a 'chunk', the number 5. This visualisation is concerned with modest numbers of objects, much bigger than a chunk but far, far less than the gigabyte–terabyte magnitudes of big data now being generated. Here, we visualise changes in city size measured by population whose frequency distributions when graphed in counter-cumulative form generate rank-size distributions that approximate a 'power law'. When arranged by size and rank on a two-dimensional graph whose axes are logarithmic, the distribution usually forms a set of points that are close to a straight line. What is hard to represent are changes in size and rank on the same graph, and usually size is dropped. One of us (Batty, 2006) has suggested that we portray rank over time on a clock where time is wrapped around a circle, thus enabling us to say something interesting about different systems and their dynamics (Batty, 2015).

Graphs that represent size in term of the thickness of their lines go back to the middle of the 19th century. A recent method due to Rosvall et al.(2010) is being applied to network evolution (http://www.mapequation.org/), while an older set of ideas called Sankey diagrams are used in mapping energy flows (http://www.sankey-diagrams.com/). Here, we use a similar pictorial representation to plot changes in city size through time on a graph where the vertical axis is ordered by rank but measured by size and the horizontal axis ordered by time. We define each city i at time t as $P_i(t)$, its rank as $r_i(t)$ and then order these at the first time period $t = 0$, from largest to smallest so that $P_0(0) > P_2(0) > P_3(0) > \cdots > P_N(0)$. The trajectories that mark out how each city changes in size are coloured across a spectrum from RGB = 255,0,0 for $P_1(0)$ to RGB = 0,0,255 for $P_N(0)$, from red through yellow to green and thence blue. These initial colours are preserved so that as the size of any city changes, the original colour shows how its rank changes. The line defining each trajectory is then plotted at a thickness that is proportional to the city size. If the cities do not change in rank or size, there are no overlapping trajectories and the graph is simply a horizontal stack, a default picture of the dynamics.

Sixty-three primary urban areas (PUAs) in England, Scotland, and Wales (http://www.centreforcities.org/puas/) are used to aggregate population data from 458 standardised local authority areas from the 1901 to 2011 population census data.

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We show the rank-size plots for these 63 cities in Figure 1, where the largest cities change the least in rank (but the most in absolute size) and the smallest the most with respect to rank. PUAs in the south of the country change the most – typically Reading, Southend, Milton Keynes, Bournemouth, Crawley – while those that decline the fastest are in the industrial north such as Blackburn, Burnley, Bolton, Wigan, Newport in South Wales, and Dundee. In Figure 1, these cities are easy to pick out but big cities like Liverpool and Manchester

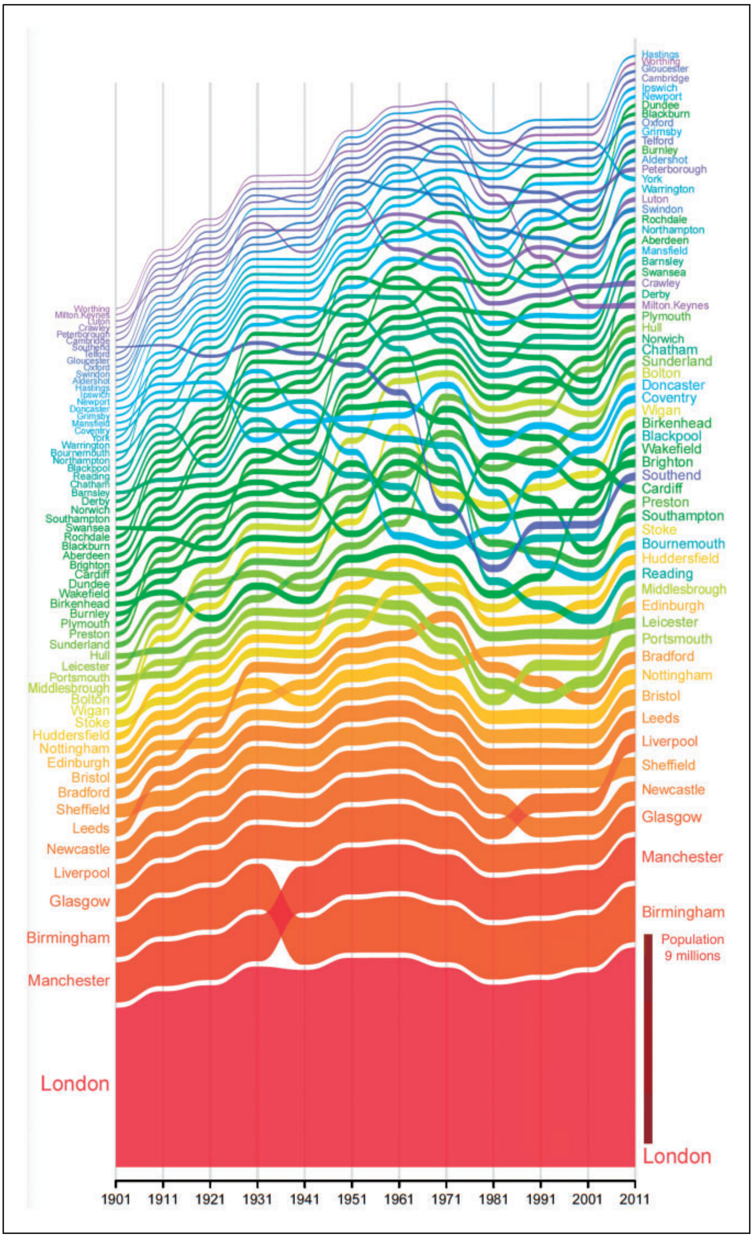

Figure 1. A century of urban dynamics based on the primary urban areas of Britain.

decline too. Alternative graphics based on the Rank Clock Visualiser developed by O'Brien at http://casa.oobrien.com/rankclocks/ provide another view of these dynamics, while other variants are shown at http://www.spatialcomplexity.info/city-rank-and-size-dynamics.

References

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