Patterns, Maps, and Fractals: The Case of United Kingdom Historical Data Sets

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INTRODUCTION

The historical data sets we work with cover a range of UK towns and cities from 1801 to 2001. To make consistent comparisons from one time to another, this study includes only those place names for which data appears in all decade sampling years. There are 458 such place names, each with a decade sampling value representing total population. When these sets are put into a spreadsheet and sorted by year, the ranking that occurs is naturally valid only for the year chosen for the ordering. Figure 1a shows a sample of the data set. In it, the ordering of the decade sets as a whole follows the 2001 data set. Thus, in 2001, Birmingham is the largest single-urban entity with a total population of 969828. In previous decades, Birmingham often has a larger population than it does in 2001; however, that population figure does not necessarily place it in first rank. In 1951, for example, Birmingham had a population of 1140382 whereas Glasgow had a greater population at 1178052. Indeed, prior to 1951 (including Glasgow's population was consistently larger than that of Birmingham. By 1961 and later, the reverse is true. Evidently, detailed, consistent, and fully accurate comparisons as to ranking are not possible between successive or separated decade values. Earlier, we had mapped the datasets (Arlinghaus and Batty, 2004). First, for 1951 for the whole set of locations for that year (Figure 1b) and then for London only across all decades (Figure 1c). A quick summary of those maps is displayed in Figures 1b and 1c in embedded .kmz files with some user control. Run your mouse over the image, navigation tools appear on the right side. Zoom in; move around; tilt the image, using the scroll wheel; to see the three dimensional bar charts reflecting total population at each location. Readers wishing the full experience should follow the link to the original article in the references (Arlinghaus and Batty, 2004), download the full .kmz files, and launch them in Google Earth in order to control layer appearance. Evidently it is possible to get a good picture of pattern based on these data sets and then to see where pattern might lead as a guide to further analysis—either numerical or historical. In this paper we extend the mapping analysis done earlier to cover broader issues, such as size changes and space-filling, using the full set of data.

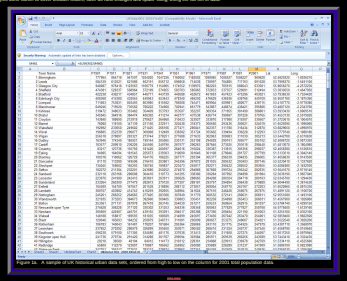

Figure 1a. A sample of UK historical urban data sets, ordered from high to low on the column for 2001 total population data.

Figure 1b. 1801 data portrayed in Google Earth.

Figure 1c. London data, 1801 to 2001, portrayed in Google Earth.

MAPPING THE ENTIRE DATA SET

Mapping the data sets, using latitude and longitude values calculated from a GIS database, reveals a variety of ranking issues. The size and number of the categories (ranges) that arise alters the outcome of associated mapped pattern. In Figure 2, the 458 values in each of 10 decades fall into 10 ranges of equal size: each range contains 45 or 46 entries per year. The same "large" circular symbol, for example, serves to represent the 45 largest cities of 1901. Similarly, that same-size circle represents the 45 largest cities of 1911 (not necessarily the same ones as in 1901), and so forth. The graduated circular symbols reflect variation in data set size. The color alternates between red and white, by decade. Thus as time progresses, concentric circles of alternating color reflect accumulated decrease in population. Glasgow City reflects this characteristic. What gets hidden is red circles from a later decade in relation to red circles from a much earlier decade (for example). The mapped pattern of Glasgow in Figure 2, however, adds an extra dimension to the data set in the table of Figure 1a. Animation of the maps lets us pinpoint some locations that change range from one decade value to the next.

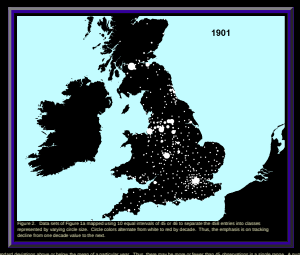

Figure 2. Data sent to Figure 1a mapped in GIS using the method of 45 or 46 to separate the data values into classes represented by varying circle size. Circle colors alternate from white to red by decade. Thus, the emphasis is on tracking decline from one decade value to the next.

Further GIS work may offer different or additional insight into mapping the data. For example, altering the method of ranging the data causes new pattern to appear. Figure 3 shows the results of mapping the same data using standard deviations to separate the data sets rather than using equal intervals. Data are assigned large or small circles according to whether they are one, two, or more standard deviations above or below the mean of a particular year. Thus, there may be more or fewer than 45 observations in a single range. A number of interesting patterns in Figures 2 and 3 offer promising directions for further investigation. As in some of our previous efforts involving three data sets, as suggested in Figures 3b and 3c, viewing the whole and a part, are an attractive alternative.

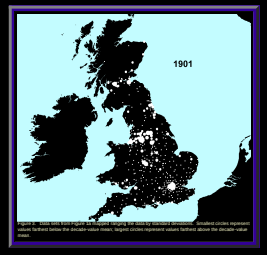

Figure 3. Data sent to Figure 1a mapped in GIS using the method of standard deviations. Broadest circles represent values far above the decade value mean; largest circles represent values farthest above the decade value mean.

MAPPING THE DATA AS REGIONAL SETS IN TIME AND SPACE

Glasgow, Scotland

Glasgow, Scotland, stands out in both Figures 2 and 3 as a place of considerable population change over time. Figure 4 shows the 1961 data mapped with the 1971 data superimposed and also with the 1991 data superimposed. What one also sees clearly from the mapped data sets, that is not evident in looking at only the numbers, is the general context in which such change is happening. As the ranking of Glasgow changes, what is happening to its neighbors? Indeed, is the observed shrinkage of the central city simply an expression of loss, or is it an indication of boundary change? Careful observation of mapped evidence can help to guide research. In this case, there is in fact an issue of boundary change, in addition to other factors, associated with the mapped pattern (Wikipedia).

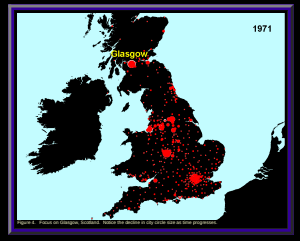

Figure 4. Focus on Glasgow, Scotland. Note the decline in city circle size as time progresses.

Greater London Area, England

In Figures 2 and 3 it is difficult to see the pattern in the London area, however, there are hints of color show-through from one decade to the next. In Figure 5, we see the results of taking a closer look at changes in the greater London area, with maps based on the equal interval ranging method. Figure 5a shows London of 1931 with London of 1941 superimposed where one sees a decline in central area population from 1931 to 1941. Reversing the overlay of these two layers within the GIS shows additionally, in Figure 5b, the growth of some surrounding towns in 1941. Apparently the population shifted outward. This same pattern continues in looking at the pair 1951, 1961 (again flip-flopping the layers) in Figures 6a and 6b. Continuing the process until the most recent data from 2001 continues the pattern: Figures 7a and 7b, 1961x1981; Figures 8a and 8b, 1981x1971; Figures 9a and 9b, 1971x1981; Figures 10a and 10b, 1981x1991; and Figures 11a and 11b, 1991x2001. In the later years, note that there is a hint of stabilization, and possible trend toward repopulation, of the center. Modern technology permits the easy presentation of a wealth of mapped evidence at no additional publication cost. Spread of London outward from its center is clearly evident in the mapped data of the late 20th century.

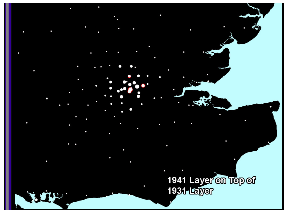

Figure 5a. Some central cities within the conurbation are larger in 1931 (red) than in 1941 (white). Does decline at the center result from movement of population outward (or elsewhere) or from larger than usual number of deaths (due to war)?

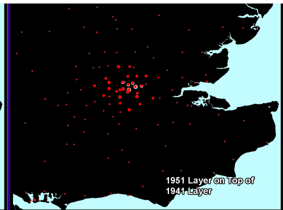

Figure 6a. As in Figure 5a, decline at the center. Some values from 1941 (white) are larger than corresponding ones from 1951 (red).

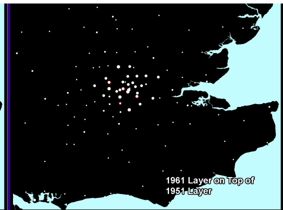

Figure 7a. Shrinkage of towns near the center. Some 1951 (red) towns are larger than their corresponding 1961 (white) counterparts.

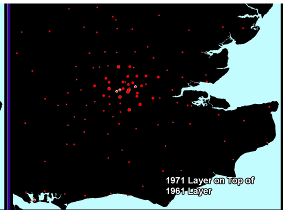

Figure 8a. Shrinkage of towns near the center. Some 1961 (white) towns are larger than their corresponding 1971 (red) counterparts.

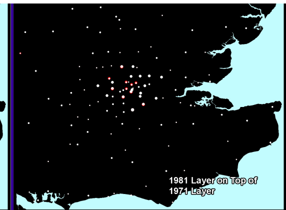

Figure 9a. Shrinkage of towns near the center. Some 1971 (red) towns are larger than their corresponding 1981 (white) counterparts.

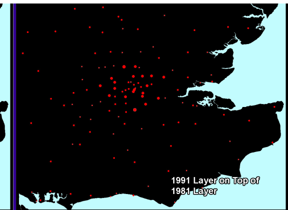

Figure 10a. Shrinkage at the center is no longer evident. All 1991 (red) towns appear to be at least as large as their corresponding 1981 (white) counterparts.

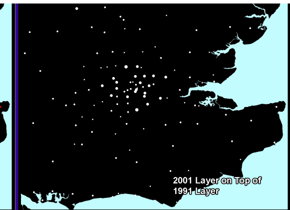

Figure 11a. Shrinkage at the center is no longer evident. All 2001 (white) towns appear to be at least as large as their corresponding 1991 (red) counterparts.

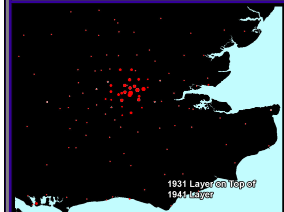

Figure 5b. Some edge-cities within the conurbation are larger in 1941 than in 1931. Coupled with Figure 5a, this pattern might represent the beginning of sprawl.

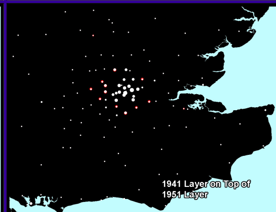

Figure 6b. As in Figure 5b, growth of towns away from the center. Some 1951 towns (red) are larger than 1941 (white) towns. More evidence of outward movement.

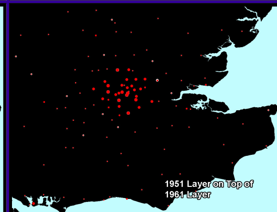

Figure 7b. More enlargement of towns near the periphery. Some 1961 towns (white) are larger than their corresponding 1951 (red) counterparts.

Figure 8b. More enlargement of towns near the periphery. Some 1971 towns (red) are larger than their corresponding 1961 (white) counterparts.

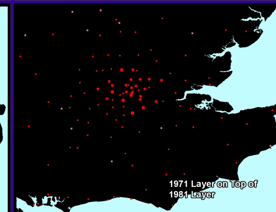

Figure 9b. More enlargement of towns near the periphery. Some 1981 towns (white) are larger than their corresponding 1971 (red) counterparts.

Figure 10b. More enlargement of towns near the periphery. Some 1991 towns (red) are larger than their corresponding 1981 (white) counterparts.

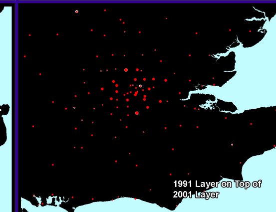

Figure 11b. More enlargement of towns near the periphery. Some 2001 towns (white) are larger than their corresponding 1991 (red) counterparts. Notice one town near the center that is growing in 2001. Does this observation, coupled with Figures 10a, and 11a, suggest a reversal of trend? Are people moving back to the central areas?

The sequence of maps in Figures 5a to 11b offers clear visual evidence of sprawl and it does so in a spatial context that permits seeing expansion of pattern to fill space. To capture, numerically, the space filling character of the sprawl, it is useful to apply concepts from fractal geometry to the distribution of dots. The software, Fractalyse, is applied to black and white .tif images of the distribution of dots. Space-filling is measured by counting numbers of black pixels in a sampling window whose scale is varied (to simulate fractal iteration sequences). The box method was used with a non-linear estimating curve of the form y=x^d+c. Figures 12a shows the set of maps to which the software was applied. These maps show the dot distribution with ranging according to the standard deviation strategy; the ranging method chosen alters the outcome of the dimension measure because the number of black pixels varies with the ranging method. Figure 12b shows the results of applying the software and the adjusted correlation coefficient indicating goodness of fit of the experimental curve derived in the box method with an estimating curve derived from the selected equation. Figure 12c graphs the results.

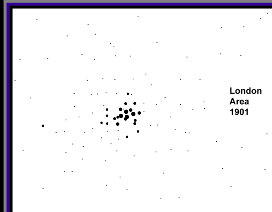

Figure 12a. London area towns; mapped ranges based on standard deviation partitions. Maps are prepared in true black and white .tif format suitable for use in the free Fractalyse software.

Date	Dimension	Adjusted Correlation Coefficient
1901	1.588	0.996908
1911	1.567	0.996903
1921	1.577	0.997150
1931	1.575	0.997202
1941	1.582	0.997518
1951	1.556	0.997143
1961	1.550	0.997337
1971	1.617	0.998897
1981	1.623	0.998954
1991	1.631	0.999059
2001	1.636	0.999096

Figure 12b. Fractal dimensions of the frames of the animated image in Figure 12a, derived using the "box counting method."

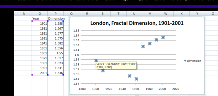

Figure 12c. Graph of data in Figure 12b. Once again, from yet another vantage point, the decade between 1961 and 1971 is one of great change. Observe, as well, the low values in the World War II decades following earlier stability. The animation is similar in nature to one in an earlier article [Arlinghaus, Batty, and Nystuen, 2003].

CONCLUSION

From tables of data, to animated color map sequences, to regional maps with shifted layers, to mapped views of sprawl, and back to numerical tables based on fractal dimensions capturing mapped sprawl, all paint the same picture of greater London. Before World War II, things are fairly steady. After the war, there is much change. By 1971, the center is clearly depopulating, people are moving out farther from the center as time progresses, and sprawl is fully entrenched and possibly reversing itself by the 2000s. Some methods show spatial context and are helpful for visualizing what else is happening nearby. Others show the picture numerically and make further arithmetical analysis easy. The fractal approach, using this software, appears a promising one. No strategy is complete; however, they work well together to offer various slants on a complex data set!

References and Software:

- Adobe, PhotoShop and ImageReady.
- Arlinghaus, Sandra L. and Batty, Michael. 2006. Visualizing Rank and Size of Cities and Towns. Part I: England, Scotland, and Wales, 1901-2001. Part II: Greater London, 1901-2001. *Solstice: An Electronic Journal of Geography and Mathematics*. Volume XVII, Number 2. Ann Arbor, Institute of Mathematical Geography.
- **Arlinghaus, Sandra L.; Batty, Michael; and, Nystuen, John D. with input from Naru Shiode. 2003. Animated Time Lines: Coordination of Spatial and Temporal Information.** *Solstice: An Electronic Journal of Geography and Mathematics*. Volume XIV, Number 1. Ann Arbor, Institute of Mathematical Geography. Direct link
- ESRI, GIS software. ArcView 3.2; ArcMap9.1.
- Fractalyse http://www.fractalyse.org/en-home.html
- Microsoft Excel, 2007.
- Wikipedia, Glasgow. http://en.wikipedia.org/wiki/Glasgow

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The primary author wishes to thank Professor Daniel A. Griffith, Ashbel Smith Professor of Geospatial Information Sciences; University of Texas at Dallas; School of Economic, Political and Policy Sciences; 800 W. Campbell Road; Richardson, TX 75080-3021; dagriffith@utdallas.edu, for pointing her to the Fractalyse software site.

Solstice: An Electronic Journal of Geography and Mathematics,
Volume XXI, Number 2
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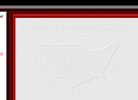

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Congratulations to all *Solstice* contributors.

Remembering those who are gone now but who contributed in various ways to *Solstice* or to IMaGe projects, directly or indirectly, during the first 25 years of IMaGe:

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