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TEN

Innovative Ways of Mapping Data About Places

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Introduction

Spatial information about the world and its people has always been at the forefront of visualization. Most people are used to conventional maps of their regions, countries and the world. Such conventional maps appear on television every evening in the weather reports, showing geographical regions and countries as they appear from space. Conventional maps are very good for showing where oceans lie and rivers run. Their projections are calculated to aid navigation by compass or depict the quantity of land under crops. These maps are typically based on area projections such as that of Gerardus Mercator, developed in 1569, which was and is suitable as an aid for ships to sail across the oceans because it maintains all compass directions as straight lines.

All projections inevitably result in a degree of distortion as they transfer the area of the earth being mapped (or the whole globe) onto a flat surface such as a piece of paper or a display unit; most usually today a computer screen. For instance, the Mercator projection stretches the earth's surface to the most extreme of extents and hence introduces considerable visual bias. Areas are drawn in ever expanding proportions to how near territory is to the poles and this results in areas such as India appearing much smaller than Greenland (when in reality India has an area more than seven times the size of Greenland). The degree to which such a distortion may be acceptable depends on the intended use of the map. There are a number of alternative projections that correspond to the actual land area size and these are much more suitable for the visualization and mapping of environmental variables and for pinpointing the location of physical geographical features of interest than Mercator's map ever was.

However, looking at a city, region or country from space is not the best way to see their human geography. For instance, mapping the distribution of a human population on a conventional map means that urban areas with large populations but small area size are virtually invisible to the viewer. Conversely, the large rural areas with small populations dominate the map. When mapping data about people, it is therefore sensible to use a different spatial metaphor, one that reflects population size.

This chapter presents alternative ways of mapping human societies and demonstrates that these alternatives are more suitable for human scale visualization than conventional maps. In particular, the chapter argues that it is 'human cartograms' that should be used conventionally to visualize societies instead of conventional thematic mapping. We begin by providing a brief history of environmental and human mapping, arguing when it is good to employ conventional mapping techniques to visualize places and why human cartographical approaches are more appropriate in a social science context. We then give illustrative examples of how the innovative methods of mapping data can be used to create maps of the areas within a city (taking London's parliamentary constituencies as an example) with each spatial unit re-sized and re-shaped according to a particular variable. Similarly, it shows how the method can be applied for larger areas such as regions and countries to create new knowledge about the extent of geographical divides at different levels. We conclude by offering some concluding comments and outline possible new areas of research that could extend existing approaches and ways of thinking.

Visualizing data about people and places

The term 'Human cartography' is credited to Swedish cartographer Janos Szegö (1984, 1987, 1994) who criticized the use of conventional mapping to depict people. Human cartography pertains to mapping where the focus is on people, where they live, where they go and what they do. Human cartograms were based on the development of ideas that underpin traditional cartograms, focusing on human variables. In this section we provide a brief history of conventional cartograms and show how human cartograms have been developed on the basis that we should focus on people, not on land and sea, when we are studying the geography of people.

Conventional cartograms tend to focus on people and can be thought of as maps in which at least one scalar aspect, such as distance or area, is deliberately distorted to be drawn in proportion to a variable of interest. Many conventional maps are cartograms, but few cartograms appear like conventional maps. An equal area conventional map is a type of area cartogram, as is the Mercator projection briefly described in the introduction. The Mercator projection is just one of many that draws land areas in proportion (albeit non-linear and descending) to their distance from the poles. This definition of cartograms sees them as a particular group of map projections.

The map projection definition is just one of a plethora of definitions that have been offered for cartograms. The cartography of cartograms during the twentieth century has been so multifaceted that no solid definition could emerge – and the multiple meanings of the word continue to evolve. The heterogeneous development of cartograms into the 21st century is partly reflected in the many names that exist for cartograms. For instance, the area distorting kind alone have been termed: *anamorphosis*; diagrammatic maps; map-like diagrams; *varivalent* projections; density equivalized maps; isodensity maps; value-by-area maps; and even mass distributing (*pycnomirastic*) map projections. The sub-category of those where area is drawn in proportion to population have gone under many names also, including: political map; demographic map; population scale map; and many very specific titles such as 'a map for health officers'.

There are non-continuous (Olson, 1976) as well as contiguous (Tobler, 1973) varieties, and – as an infinite number of correct continuous area cartograms can be produced (Sen, 1975) for any given variable – very many different cartograms have been drawn scaled to the same quantity, usually population. However, by the end of the 20th century, it became clear that only one area cartogram will approximate the best, least distorting solution (Tobler, 2004) and a practical means to achieving that solution became available shortly after (given in Gastner and Newman [2004] and discussed below). These examples are, of course, just part of the story of cartograms. Tobler's (2004) review is an excellent place to start for a fuller story – for work since then see Henriques (2005), Keim et al. (2002, 2004, 2005) or Dorling (2006; Dorling et al., 2006, 2007a, 2007b) and for a more detailed discussion of relevant literature see Ballas and Dorling (2010).

Recently there have been significant developments in cartographic methodologies aided by increasing computational power and sophisticated graphics capabilities leading to alternative maps and visualizations of societies that were not based on physical geography. These cartogram-based visualizations differ considerably from traditional thematic maps. The latter drastically distort the reality they purport to contain, at worse reversing the patterns that exist. People who study people, who are interested in societies, politics, history, economics and increasingly even human geography, usually do not use these maps. They usually do not use any maps at all. A topographic map base allows, at most, the depiction of human land use. People have created maps based on human geography in the past, but only with the advent of sophisticated image and graphics software has it become possible to do this on an easily replicable basis.

Human cartography concentrates on the human experience of space and portrays the human encounters with 'reality', rejecting the view that behaviour (and, therefore, features such as population distribution and the location of industrial activity) is governed totally by the framework of the earth and the 'tyranny of distance'. During the 19th century, as interest in population statistics grew and as people who had been peasants became consumers, the relative value of land to human life fell, and human rather than physical geography began to matter more. The emergence of detailed census cartography after the Second World War grew out of these shifting priorities. However, most of the thematic maps of census variables were still governed by the logic of physical geography. For instance, choropleth maps of population data typically shade regions with boundaries defined on the basis of their area size in proportion to the measurement of a variable of interest. It can be argued however, that such maps, apart from often being bad examples of physical geography's cartography, are bad social science. They make concentrations appear where they are not, and dissolve existing patterns.

Human cartography can address these issues by redrawing the locations of boundaries and size of territories on the basis of a population variable of interest. In this way the relative values of objects on a map are reflected by the size of the area and this much easier for the human eye-brain system to assess when compared to trying to translate the shades of colour into rates and then to imagine what they imply. Rescaling area to show the variation in particular variables is very effective in terms of visual communication and a good example of this is the traditional homunculus used in medical science to portray the human body in terms of the degree of sensitivity: the skin and the whole human body is rescaled in proportion to the number of nerve endings in all areas[1] (also see Dorling, 2007a, 2007b).

There are several types and methodological approaches to human cartography, but it can be argued that all approaches generally attempt to address a number of key challenges:

- Develop a method which is as simple and easy to understand and implement as possible.
- Generate 'readable' maps by minimizing the distortion of the shape of the geographical areas being mapped, while at the same time preserving accuracy and maintaining topological features.
- Determine the cartogram or other distorting projection to be unambiguous.
- Minimize computational speed for the construction of new visualizations.
- Make the end result independent of the initial projection being used.
- Make the end result look aesthetically acceptable.
- Have no overlapping regions or other more complex portrayal.

The problems of distortion and projection-dependence have been successfully addressed by Gastner and Newman (2004) who developed computer software that creates unique cartograms that minimize distortion on the surface of the sphere while still scaling areas correctly. The process is essentially one of allowing population to flow out from high-density to lower-density areas. They used the linear diffusion method from elementary physics to model this process. The computer algorithm re-projects the boundaries of territories on the surface of the sphere – rather than on the plane using a diffusion equation from the physics of heat transfer and molecular mixing (for a detailed formal discussion see Gastner and Newman [2004]). The resulting maps remain recognizable and incorporate the striking re-sizing used previously in 'rectangular maps'. Furthermore, unlike its predecessor projections, Gastner and Newman's method does not reflect the arbitrary choice of initial projection (for instance, Newman has adopted it for the Worldmapper project so that it joins East–West unlike any other equal population projection) and produces an image that approximates a unique least distorting solution. This means that the cartogram reader has only one new projection to learn should they wish to map upon population rather than land. The next section of this chapter shows how this projection method can be used to map cities, regions, nations and the world.

Human mapping of the city, region, nation and world

In this section we show how the Gastner and Newman diffusion cartogram method can be employed to visualize human variables at different geographical levels. First we show how the method can be applied at sub-regional and sub-city level, drawing on recent research on poverty, wealth and place in Britain (Dorling et al., 2007) and focusing on the city of London.

The Greater London metropolitan area, which is used as an example here, comprised, up until 2009, 74 parliamentary constituencies which are shown in Figure 10.1.

Figure 10.1 Map of Greater London parliamentary constituencies, 2009

As can be seen the shapes and the size of each area vary considerably and this variation introduces undesirable visual bias, given that all areas have roughly the same population. As it was the case with regions and countries, such bias can be corrected by using cartogram methods. In the case of UK parliamentary constituencies a population cartogram would result in all areas having roughly the same size (Dorling and Thomas, 2004). However, cartogram methods can also be used to distort the size of each constituency on the basis of a socio-economic variable that pertains to the political agenda of national and local government authorities. A policy-relevant theme in this context is the spatial distribution of poverty and wealth, which according to recent research has been characterised by high degrees of spatial polarization at regional and local levels (Dorling and Ballas, 2008; Dorling et al., 2007). In particular, the highest wealth and lowest poverty rates in Britain tend to be clustered in the South East of England, with the exception of some areas in inner London (Dorling et al., 2007). The geographical patterns of social and spatial inequalities can be explored further with the use of human cartograms. For instance, Figures 10.2 and 10.3 show an alternative human scale visualization of the geography of poverty and wealth in London. In particular, they show how the London parliamentary constituencies can be distorted on the

Figure 10.2 'Core poor' cartogram of Greater London parliamentary constituencies

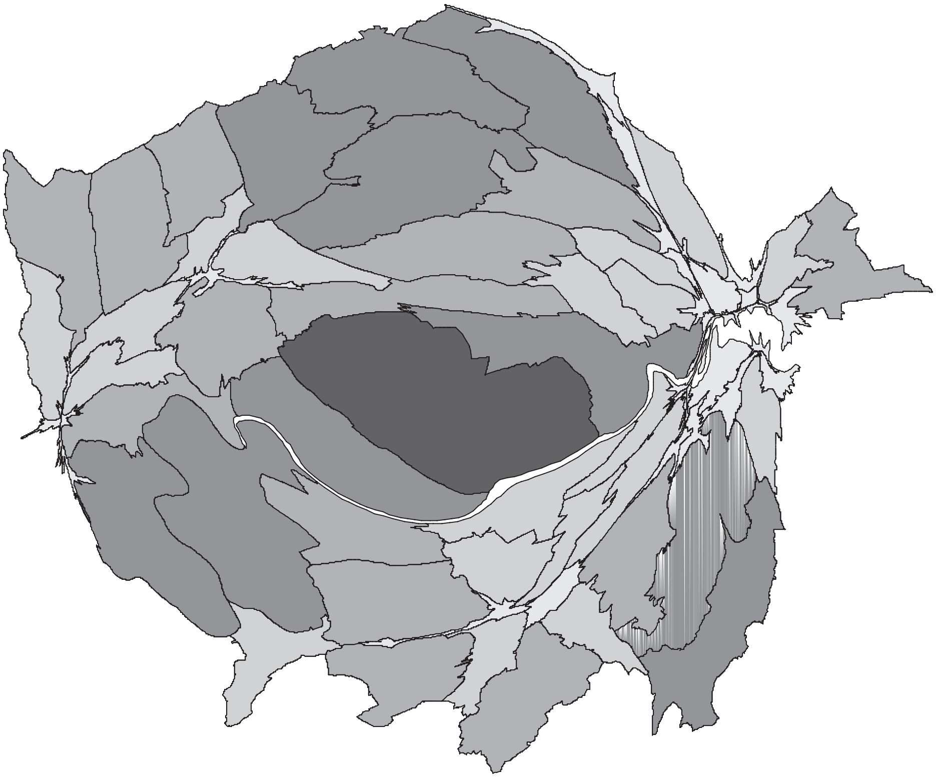

Figure 10.3 'Exclusive wealthy' cartogram of Greater London parliamentary constituencies

basis of the number of households living in them which are classified as 'core poor' and 'exclusive wealthy' respectively. In both maps darker shades are also used to colour larger areas (areas with more poor and rich people) so help emphasize the distortions.

As can be seen in Figure 10.2, the 'core poor' map is dominated by inner city areas and areas in the South East of London. 'Core poor' are defined as people who are simultaneously income poor, materially deprived and subjectively poor and who thus have very little money coming in, very few possessions and resources and they also perceive themselves as poor (Dorling et al., 2007). The parliamentary constituencies with the largest numbers of this group of households that dominate the map (and also shaded in dark red) are Poplar and Canning Town, Vauxall, Hackney South and Shoreditch, North Southward and Bermondsey and Bethnal Green, all located in the East End of London.

In contrast, Figure 10.3 shows a very different picture of London, as it distorts the size of all parliamentary constituencies on the basis of the number of households classified as 'exclusively wealthy'. These are households that have sufficient wealth to exclude themselves from the norms of society, if they so wish (Dorling et al., 2007). As can be seen, the west end of London dominates the map, but also some of the wealthy suburbs in the outskirts of the city, whereas the size of most of the areas in the east end of London has shrunk. Kensington and Chelsea (the largest dark shaded area in the middle of the cartogram) is the parliamentary constituency with the highest number of exclusive wealthy households, which is nearly double that of Richmond Park which comes second, followed by Finchley and Golders Green and Twickenham (all areas in the west end of London). Conversely, most of the areas in the shrinking (in Figure 10.3) East End of London have very few households that could exclude themselves from the norms of society if they wished to do so.

The power of cartogram technologies for human scale visualizations can be further demonstrated by mapping regions within a country, resizing the areas of the regions on the basis of a variable which is increasingly used in the social sciences: subjective happiness. In particular, we use data from the British Household Panel Survey (BHPS) which is one of the most comprehensive social surveys in Britain draw from a representative sample of over 5000 households and which includes a number of questions pertaining to subjective happiness and well-being, such as: 'Have you recently been feeling reasonably happy, all things considered?'

It has often been argued that responses to such questions may not be readily comparable between countries due to various kinds of cultural bias (Diener et al., 1995). For instance, it has been suggested that Americans tend to claim that they are very happy because the term 'happiness' is positively valued in their society whereas in other countries such as Japan and France, there is the exact opposite tendency (Frey and Stutzer, 2002). It can be argued therefore that the subjective happiness variable is more suitable for analysis and visualization at the national and sub-national level, when such data is available. Figure 10.4 is based on data from the BHPS and represents the 'mirror image' of happiness and unhappiness in Britain. The cartogram on the left hand side was created using the Gastner and Newman diffusion method to rescale the sizes of all areas according to the number of the 'unhappy' respondents in the survey. Likewise, the same method was used to create the cartogram on the right hand side of Figure 10.4, in which the sizes of all areas are rescaled on the basis of the number of 'happy' respondents.

These human cartograms are very different from conventional maps of Britain. They give more prominence to regions with large concentrations of a human variable of interest, which in this case is the number of 'happy' and 'unhappy' people. Taking a closer look at these cartograms, we observe similarities in terms of the shape and size of most regions. For instance, the region 'Rest of South East', shaded in black in both cartograms, has very similar numbers of both 'happy' and 'unhappy' people. Nevertheless, there are also

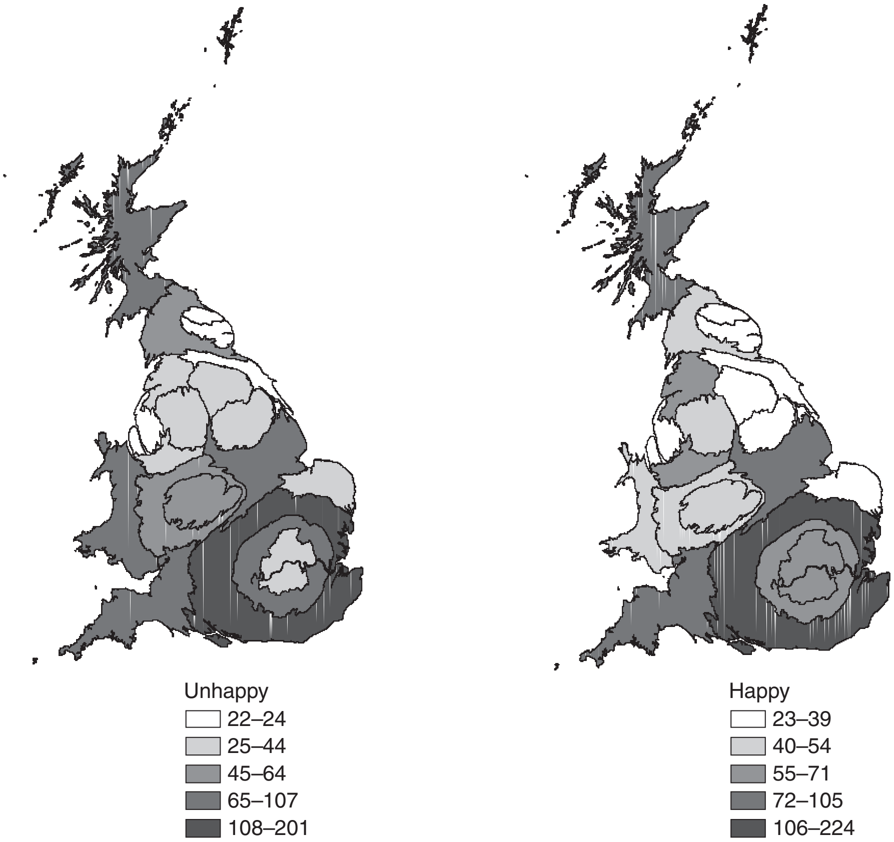

Figure 10.4 Mirror image of happiness/unhappiness in Britain. Both figures are scaled by the numbers of people saying they are less or more happy. The figures look very similar as geographical variations are not huge, but look closely, or at the shading, and they become evident.

some notable differences. In particular, the sizes of Scotland and Wales are slightly larger in the cartogram of 'unhappy' people. In contrast, the regions of Inner and Outer London have considerably larger sizes in the cartogram of 'happy people' (for a more detailed discussion of the happiness data used to create Figure 10.4 see Ballas et al. [2007]).

The 'Gastner and Newman' diffusion technique has also been used extensivly to generate a series of world cartograms in the context of Wolrdmapper,[2] which is a collaborative project between researchers at the Social and Spatial Inequalities Research Group of the University of Sheffield, UK, and Mark Newman, from the Center for the Study of Complex Systems at the University of Michigan in the USA. The project has so far produced nearly 700 world maps where territories[3] are re-sized on each map on the basis of a number of subjects, ranging from health, life and death to income, poverty

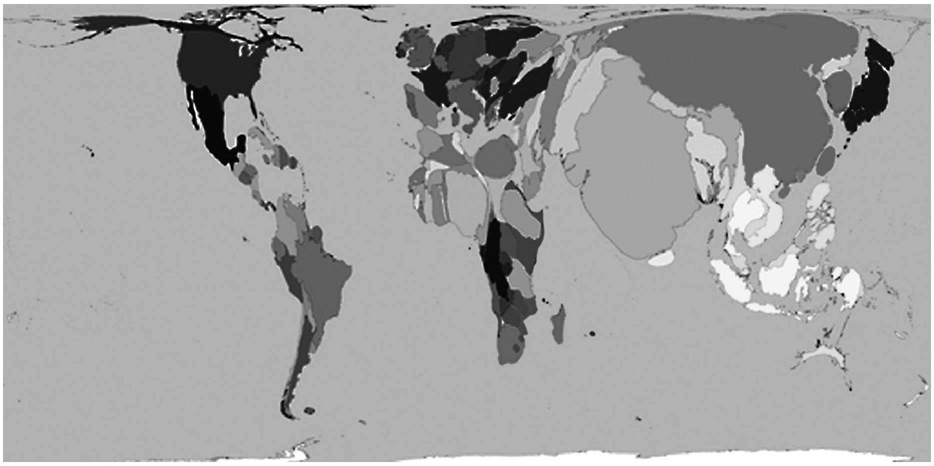

Figure 10.5 Total population (Worldmapper map 002), the size of each territory shows the relative proportion of the world's population living there
Source: United Nations Development Programme, 2004, Human Development Report.

and wealth (Barford and Dorling, 2007a, 2007b; Dorling, 2006). Figure 10.5 shows a Worldmapper cartogram of the world population distribution across territories.

It is noteworthy that, unlike conventional choropleth maps of population data, the Worldmapper cartogram shown in Figure 10.5 reveals more of the real pattern of population distribution by showing where the highest population concentrations are and therefore how human population can more revealingly be mapped by social scientists. China and India, which account for about one-third of the world population, are the largest territories on the map. In contrast, the size of territories of countries with large land sizes but low population densities such as Russia, Canada and Australia are diminished when compared with conventional land-based choropleth maps.

It is also interesting to see how the sizes of the territories change in relation to the population cartogram when mapping other socio-economic variables and to think about the societal impacts of such a cartogram on collective imaginations. Using a cartogram instead of a conventional map has a very different impact upon the public's perception regarding the World's progress in achieving the United Nations Millennium Development Goals. One of these goals is the eradication of extreme poverty and hunger and a more specific target in relation to this goal is to halve between 1990 and 2015 the number of people who suffer from hunger (UNICEF, 2007). A useful indicator pertaining to this target is the prevalence of underweight children under five years of age (UNICEF, 2007). According to data collected and calculations made by the Worldmapper project, between 1995 and 2002 almost one-quarter of all children aged under 15 years old were estimated to be underweight,

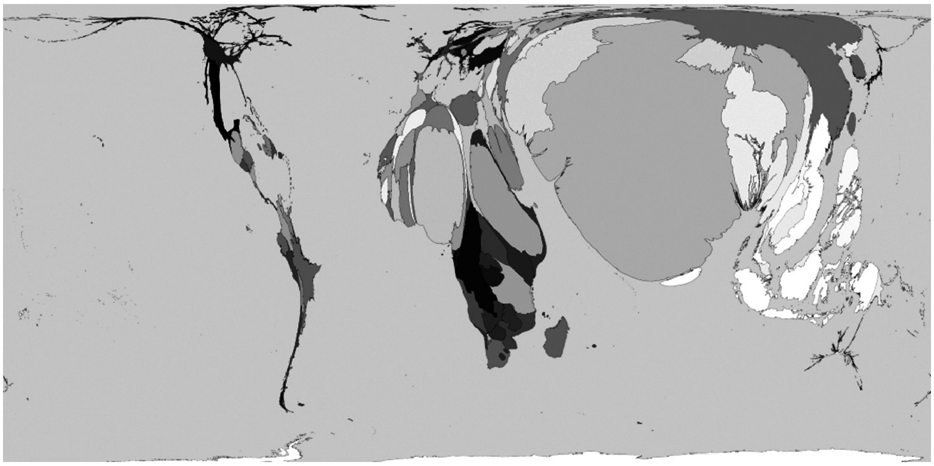

Figure 10.6 Total population (Worldmapper map 182), territory size shows the proportion of all underweight children in the world that live there
Source: United Nations Development Programme, 2004, Human Development Report

which was then approximately equivalent to a total number of about 439 million.[4] Figure 10.6 shows a world map where area is drawn in proportion to this number.

It is interesting to consider at this stage the impact that Figure 10.6 may have on the public's perception of progress regarding the achievement of Millennium Goals, when compared to conventional maps. Figure 10.6 is a much better representation of the spatial inequality and in particular it highlights that half of all underweight children under the age of 5 years live in Southern Asia, whereas Southeastern Africa, Asia Pacific, Northern Africa and Eastern Asia also have very large numbers of underweight children, and especially in Ethiopia, Indonesia, Nigeria and China. In contrast, it is very difficult to distinguish the shapes of most countries in Europe and the Americas. When compared with conventional maps a human scale visualization such as this presented in Figure 10.6 is possibly presenting a much more accurate, appropriate and powerful depiction of the magnitude of issues such as child poverty as well as the associated social and spatial inequalities. Apart from the statistical human population data that this map communicates, it can be argued that it also has a very effective and emotionally powerful visual impact. Cartograms have been around for many years and thus it is perhaps surprising that human cartograms have not been used so far by organizations such as UNICEF and other non-governmental organizations to increase awareness and improve the quality of information that the public have about global issues. In very recent years the number of children going hungry in the world has been rising as food prices rose due to financial speculators.

The cartograms presented in this chapter are just a few examples of how new innovative cartogram methodologies can be used to draw alternative human scale visualizations by keeping the shape of intra-city areas, regions and nation-states familiar, while at the same time showing clearly striking patterns of inequalities. There are of course numerous other examples of variables that can be and have been mapped in a similar way. The methods presented here are very relevant not only to human geographers and cartographers but to any social scientist with an interest in the spatial dimension of human variables. For instance, the examples that were briefly discussed in this chapter may be of interest to people working in a number of social science disciplines ranging from sociology, economics and social policy to psychology. Perhaps the best example of the diversity of social science fields to which the cartogram methods are relevant is the list of variables that were mapped in the Worldmapper project (currently 696 variables pertaining to a different social science fields).[5]

Due to the recent availability of new algorithms it is increasingly easy to create such cartograms. For instance, freely available web-based software such as the online 'Cartogram Generator' developed by Frank Hardisty at the University of South Carolina are very simple and easy to use by any social scientist who has a minimal knowledge of geographical information systems.[6] All that is required to run this free online software is a file containing the digital boundaries of a conventional polygon map (for example, in the digital boundaries of the parliamentary constituencies of London as shown in Figure 10.1) together with a metric statistical variable (for example, the number of 'core poor' households) for each area. The data needs to be in ESRI shapefile format, one of the most common formats for geographical data used in the social sciences.[7] This data can then be uploaded by the software with the use of any Internet browser that is supported by the Java Virtual Machine (version 1.4 or later, also freely available from: http://java.com). The software then asks for the variable of interest that should be used to rescale the polygons of the conventional map and proceeds to convert the map into a cartogram on the basis of this variable by applying the Gastner and Newman diffusion algorithm that was discussed above. A more recent software development that allows the creation of cartograms is 'Scapetoad'[8] (Andrieu et al., 2008), which is also freely available, but does not run online. As with the 'Cartogram Generator'. 'Scapetoad' just needs a digital polygon boundary file with a statistical variable of interest in shapefile format and applies the Gastner and Newman diffusion technique. It also enables the user to set their own 'cartogram quality' settings (for more details see Andrieu et al., 2008).

In principle, such software can be used to create human cartograms of any variable pertaining to human populations. It is also user-friendly and simple enough to be used by any social scientist with an interest in the spatial distribution of socio-economic data.

Conclusion

This chapter provides an overview of the state of the art in human area population cartogram creation and also gave a number of examples at different geographical levels in order to illuminate issues and problems that are inherent in visualizing human populations. We have argued that conventional maps that show how cities, regions and countries appear from space, are not an appropriate way to show the spatial distributions of humans and their characteristics, other than simple location. A more human cartography begins to provide a more appropriate set of methods and tools for the depiction of the spatial distribution of variables pertaining to human societies rather than projections designed to illuminate environmental, geological or meteorological problems.

Undoubtedly there has been much progress in human cartography over the past 20 years. The new developments in human cartogram technologies reviewed here provide just a small glimpse of the tools and the enabling environment for social scientists across disciplines to map their data using methods that are appropriate for human scale visualizations. The new methods are relatively easy to understand and use and the resulting cartograms can be extremely powerful tools to support the arguments of social science researchers.

Nevertheless, it should be noted that one of the potential drawbacks of the methods presented here is the difficulty in recognizing the regions that are being mapped. This is perhaps less of a problem when creating cartograms of nation states, as generally people are more likely to be familiar with their physical shapes as opposed to smaller sub-regional or intra-urban areas. In addition, caution is needed when comparing trends through time, given that the shapes and sizes of geographical units being mapped change through time and therefore the temporal analysis that can be conducted is very different (and more powerful than) from conventional maps.

One of the ways in which human cartography can be improved is the enhancement of the visual impact of human cartograms through the use of computer animation showing the changing shape and size of neighbourhoods, cities, regions and countries on the basis of different variables. It would also be useful to link the new, more human, cartography to other new mapping technologies such as 'Google Earth' in order to allow viewers to spin around the sphere, to zoom in and out of the globe, to find out more about each place more quickly, and even to see one image morph into another. This is one of the immediate priorities of projects such as the Worldmapper, and by the time you read this chapter, the Worldmapper or other web sites may well have enhanced three-dimensional human cartograms, showing not just human geography but also our history when people are put at the visual centre. Animations are already there.

Acknowledgements

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Notes

1. Also see: http://en.wikipedia.org/wiki/Homunculus
2. See http://www.worldmapper.org/
3. The Worldmapper maps and data files cover 200 territories, mainly United Nation Member States plus a few others to include at least 99.95 per cent of the world's population.
4. See: http://www.worldmapper.org/display.php?selected=182#
5. See http://www.worldmapper.org/textindex/text_index.html
6. See http://people.cas.sc.edu/hardistf/cartograms/
7. See http://en.wikipedia.org/wiki/Shapefile
8. See http://scapetoad.choros.ch/

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