SECTION 3

Alternative Representations in GIS and Society Research

10

Human-scaled Visualizations and Society

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INTRODUCTION

> We must create a new language, consider a transitory state of new illusions and layers of validity and accept the possibility that there may be no language to describe ultimate reality, beyond the language of visions.
>
> (Denes, 1979: 3)

When you look out of the window you can see a great deal in an instant. The mind has an extremely powerful system for processing imagery, which can instantly analyze a pattern of colours, of light and shade and know (or at least think) that these are trees, houses or people out there. How long would it take to describe all that you can see in words? Yet we still have to argue that in the study of societies there are many things that cannot be eloquently described in words or succinctly captured by equations. We depend on vision, we think visually, we talk in visual idioms and we dream in pictures, but we cannot easily turn a picture in our mind into something other people can see. An artist will take days to paint a single portrait. Suddenly, just as the last generation now dead was given the camera, we have received the computer, which can turn a huge amount of data into pictures – snapshots of our society. Increasingly people are being able to speak visually.

Spatial information about the world and its people has always been at the forefront of visualization. As map-making developed into the art of cartography, rules were formalized and conventions defined (for early work see Peucker, 1972 Friis, 1974; Bertin, 1978; Howe, 1986). 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 (for an example see Figure 10.1, which is an equal area land map of the world that is also revisited and redrawn in the third section of this chapter).

Conventional maps are very good in 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

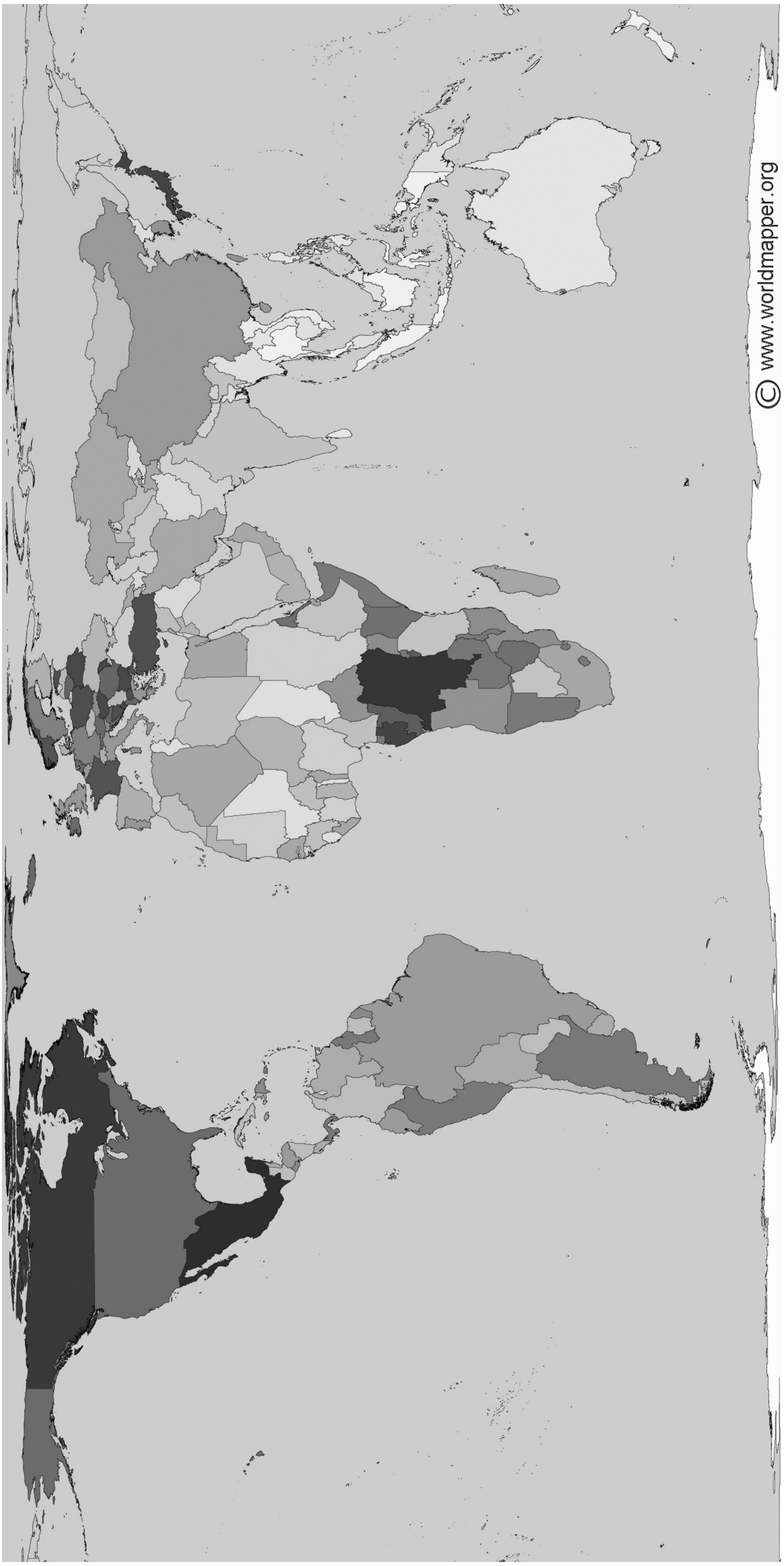

Figure 10.1 Land Area map (www.worldmapper.org)

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 to a degree of distortion as they transfer the area of the earth being mapped (or the whole globe) into a flat surface such as a piece of paper or a display unit such as 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 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. Most conventional maps, regardless of the projection method that was adopted to create them, are not designed to show the spatial distributions of humans, although the single spatial distribution of people upon the surface of the globe, at one instance in time, can be shown on them. They cannot illustrate the simplest human geography of population. People are points on the map, clustered into collections of points called homes, into groups of points known as villages or cities. Communities of people are not like fields of crops. The paths through space which they follow are not long wide rivers of water, and yet, to see anything on maps of people they must be shown as such.

As noted above, conventional maps cannot show how many people live in small areas, instead they show how little land supports so many people. They cannot show who the people are, what they do, where they go. They show no temporal distribution, they do not need to – how quickly do rivers move or mountains shrink on a human timescale? They will not show the distributions of people changing – international migration, moving house or just going to work. They cannot portray the distribution of the wealthy or the poor; on the map, at almost any scale, both groups can be found to live in much the same square inch of paper. Nor will they show where and when people had certain jobs, certain power, voted, were out of work, lived and died.

This chapter presents alternative ways of mapping human societies and demonstrates that they are more suitable for human-scaled 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. Such cartograms can be defined as maps in which at least one scalar aspect, such as distance or area, is deliberately distorted to be drawn in proportion to a socio-economic or demographic or any other 'human' variable of interest. Human cartograms are similar to conventional maps in that they also involve a degree of visual bias and distortion. However, this distortion is aimed to aid the examination and deeper understanding of issues, problems and research questions pertaining to human societies rather than environmental, geological or meteorological issues. It is also argued that visualization methods that have been developed in cartography and related disciplines provide enhanced capabilities when adapted for use in human-scaled visualizations. These methods can be used to make the huge volumes of data and figures that have been collected and recorded about human populations and their actions understandable without misrepresenting their meaning, and without reducing them to tables, graphs, crude maps or models.

The remainder of the chapter is organized as follows: first, the next section reviews the historical development of human cartograms in relation to conventional cartography. It also discusses the societal impacts of traditional maps and how these may differ from the impacts of non-conventional maps such as human cartograms. The following section then identifies the predominant current trends in visualizing human populations and discusses how they may tackle the problems associated with traditional approaches. In particular, this section introduces and discusses equal area cartogram methods (also known as density-equalizing maps), which typically re-size each area according to the variable being mapped. The next section shows how such methods can be used to create maps of the world, with each country re-sized and re-shaped according to a particular variable. Furthermore, it discusses the societal implications of decisions to adopt a particular mapping and visualizing method. The following two sections give similar examples with regards to visualizing the 'nation' and the 'city' respectively. The chapter concludes by illuminating issues and problems that are inherent in visualizing human populations and outlines possible new areas of research that could improve existing approaches and ways of thinking.

REVIEW OF THE STATE OF THE ART IN HUMAN GEOGRAPHY

> The world is complex, dynamic, multidimensional; the paper is static, flat. How are we to represent the rich visual world of experience and measurement on mere flatland? (Tufte, 1990: 9)

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 that basis.

Conventional cartography tends to focus on land, even if there are human aspects in the mapping of landownership or the navigability of the terrain for armies of men. Conventional cartograms 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) 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 and its continuing rapid development in the twenty-first century has been so multifaceted that no solid definition could emerge – and the multiple meanings of the word continue to mutate. During the first three-quarters of the twentieth century it is likely that most people who drew cartograms also believed that they were inventing them or at least inventing a new variant of them. This was because what we know now as cartograms did not arise from cartographic orthodoxy but were instead mainly produced by mavericks and consequently only tolerated in cartographic textbooks – often referred to as being on the margins of the subject: map-like rather than map.

The heterogeneous development of cartograms in the twentieth century is partly reflected in the many names that exist for cartograms. For instance, the area distorting kind alone have been termed: *anamorphosis* (Dorling , 2006); 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' (Dorling, 1996). 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 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 the end of the century (given in Gastner and Newman (2004) and discussed in the following section). These are, of course, just part of the start of the history of cartograms. Tobler's (2004) review is an excellent place to begin to go further – for work since then see Henriques et al. (2009), Keim et al. (2002, 2004, 2005), Dorling (2006) and Dorling et al. (2006, 2007a, 2007b).

The motivations for drawing cartograms have in most cases been related to the rapidly changing political geography of the twentieth century and the period shortly before that century began, which followed the upheavals of industrialisation and the concretisation of nation-states and the consequence visualization of 'state-istics'. The earliest known area cartogram was Levasseur's 1870 cartogram of Europe, which depicted countries in their 'correct' (in this case correct physical area) size. That cartogram is reproduced on page 29 of Tobler (2004) and is shown in Figure 10.2.

The very first cartogram is a good example to begin with to understand that these have never been neutral maps (of course no maps can be neutral). In studying Figure 10.2 it is hard to imagine that part of Levasseur's aim was not to imply that Russia was somehow balanced by, or a threat to, the combined land weight of Europe. Levasseur's cartogram, seen in the context of political mapping and visualization of its time added to the images of the apparent invulnerability of Russia and the threat of its land area in a way uncannily similar to its depiction using the Mercator projection on Cold War US television screens a century later.

By many, in the years leading up to the start of the twentieth century Russia was seen as the largest potential threat to new emerging political systems in Europe; and some images such as Figure 10.2 were drawn suggesting that it should have been taken more seriously than its traditional depiction on maps suggested. It is very important to stress the possible societal and political implications of choosing a particular cartographic method to draw a map. It has also often been argued that all forms of mapping are forms of social control in the sense that they are created to serve the purposes and designs of their creators rather than to inform the 'public' and that the organizations controlling most cartographic production choose what information they collect and how they show it in quite partisan ways (for example, see Harley, 1988; Pickles, 1995). Undoubtedly, the choice of a method has a potentially huge influence on the message that comes across. It should always be borne in mind that all mapping and cartographic approaches represent alternative views and at the same time propagate a particular doctrine by choosing to present (or hide!) information in a suitable way (Monmonier, 1991; Dorling, 1996).

Although both area and linear cartograms were drawn before the advent of the twentieth century, only a handful of examples of explicitly created cartograms have ever been referred to from those times. All these, to the best of our knowledge, dated from the last half of the nineteenth century. Many ancient maps do, of course, look like modern day

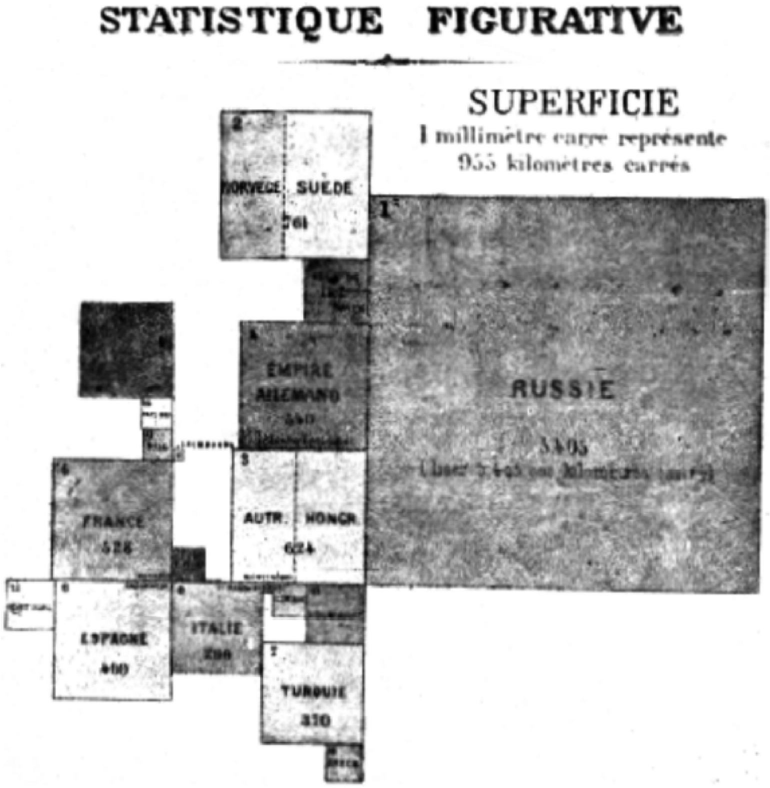

Figure 10.2 Levasseur's 1870 cartogram of Europe (Reproduced from Tobler (2004: 29))

cartograms, and land was often drawn in rough proportion to perceived social importance in *mappa mundi* for instance – but the modern day cartogram really is a product of very recent generations. The increasing availability of a wide range of new data sources in digital format, coupled with computer hardware and software advances including high quality computer graphics and presentation facilities were key. Orthodox cartographic methodology has been translated onto the computer screen (Bickmore, 1975; Hagen, 1982; Taylor, 1985; Jupe, 1987; Goodchild, 1988; Visvalingham, 1989; Muller, 1989). Swirling images were produced from the simplest formulae (Davis, 1974; Mandelbrot, 1983; Andrews et al., 1988). So, during the twentieth century methods of cartogram projection developed from manual drawing and the manipulation of hundreds of cardboard tiles (Hunter and Young, 1968); through to the use of thousands of ball bearings and hinged metal joints (Skoda and Robertson, 1972); to early computer modelling (Dougenik et al., 1985), to a plethora of algorithms becoming available towards and shortly after the end of the century that were developed to cope with the shifting of millions of vertices (House and Kocmound, 1998; Kocmound, 1997; Gusein-Zade and Tikunov, 1993). At the same time, map makers such were still using paper and pen to draw several social atlases worth of cartograms, albeit with a little aid from computers, to achieve effects that computer algorithms alone could not (Dorling, 1995).

The twentieth century also saw the description of cartograms in theory that have yet to exist in practice (Angel and Hymen 1972). These included cartograms where travel time is shown as distance not just from a single point but between all points on the map (approximated by Ahmed and Miller, 2007; Ewing, 1974; Muller, 1978; Spiekermann and Wegener, 1994). Such a linear cartogram would be possible (it has been proved mathematically if not visually) were the map to be drawn as a two-dimensional surface (manifold) undulating within, wrapped up in and occasionally torn within three-dimensional space – no longer the flat map of tradition. Linear and area cartograms could be combined in this way and together merged into quantity as volume cartograms where, for instance, each life that had existed were given an equal amount of volume in a deliberately distorted block of space-time. Such possibilities have been described and a few developed (Dorling, 1996), but it often takes several decades between the proof of what is possible and its realisation. Thus part of the history of cartograms in the twentieth century has been in imagining new possibilities that have yet to be realized. Many may never be realized.

The actual construction of what are now seen as traditional cartograms remains problematic for most of those who wish to draw cartograms and was near impossible for most people living in most places in the twentieth century. Many months, even years could be spent creating a cartogram by hand, of – for instance – the parliamentary constituencies of Britain in 1964, only for their boundaries to be redrawn by 1970 and the cartogram then abandoned.

Instrumental in all this work and in the development of automated methods of cartogram production and the theories behind them was Dr Waldo Tobler (1930–) whose work inspired all those who worked in this area in the last third of the century. His seminal publication (Tobler, 1973) was related to the need for cartograms that arises periodically in America with the political redistricting following each decadal population census. Thirty-seven years later, as we say above, his review of the development of computer cartograms remains one of the most useful summaries of the field (Tobler, 2004).

Due to the recent availability of new algorithms, more cartograms were drawn in the first few years of twenty-first century than were produced throughout the whole of the twentieth (see Dorling et al., 2008). Software to produce linear cartograms (and sophisticated flow maps) has lagged that used in creating area cartograms and so there are fewer examples to discuss of linear cartograms in which distance (or the width of lines) is rescaled to be proportional to a variable of interest (see Figure 10.3 below for an example). Figure 10.3 is a traditional travel time map of Switzerland. Such time-scaled maps are created by transforming the physical locations into new ones that satisfy travel-time linear constraints (see Axhausen et al., 2006, 2008, for more details).

The significant developments in cartographic methodologies aided by increasing computational power and sophisticated graphical capabilities has led to many 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 use no 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'. Figure 10.4 gives a

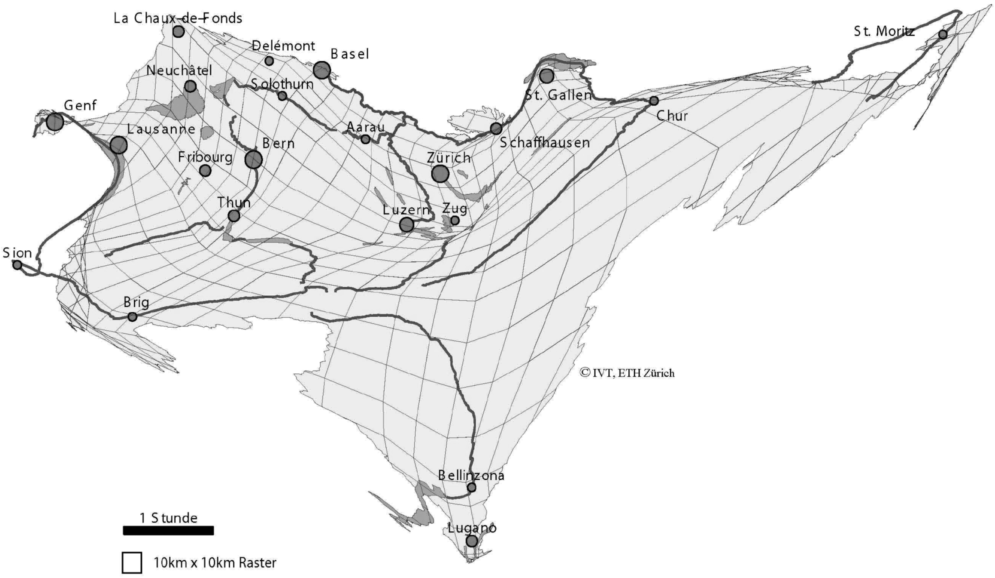

Figure 10.3 1950 time-scaled map (Axhausen et al. (2008: 402))

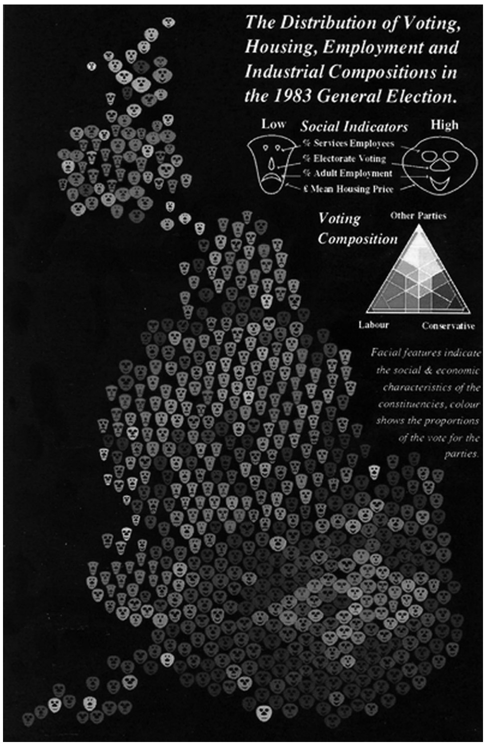

Figure 10.4 Using Chernoff faces in a human cartogram of voting, housing, employment and industrial composition (Dorling, 1991)

good example of how human cartograms should be used to depict the spatial distribution of a variable that has been systematically mapped using conventional maps: voting. In particular, it shows the spatial distribution of voting in Britain and how Chernoff (1973) faces combined with the appropriate use of colour can be used in a human cartogram of the distribution of voting, housing, employment and industrial compositions in the 1983 general election in Britain. The 633 parliamentary constituencies are each represented by a face whose features express the various variables, and which is coloured by the mix of voting – drawn on the equal population cartogram (for more details see Dorling, 1991).

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 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 location of boundaries (dasymetric mapping) 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 is much easier for the human eye-brain system to assess when compared to trying to translate shades of colour into rates and then to imagine what they imply. Rescaling area to 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 is rescaled in proportion to even out number of nerve endings[1] (also see Dorling, 2007a, 2007b).

In addition, using human population cartograms instead of traditional maps has very important societal implications. An early example of using human cartograms to promote a particular viewpoint or support an argument is the publication of a map in *The Washington Post* on Sunday 3 November 1929 with state areas equal to population and taxation, accompanied by a proposal to the Congress to modify the allocation of tariffs (Tobler, 2004). A more recent example is the work of Kidron and Segal (initially in 1981 and 1984; and in recent years updated by various authors and published by Earthscan) who drew an alternative State of the World Atlases, in which they used area cartograms to show how inequitably the world's health, weapons and food were distributed. These cartograms were designed by hand to keep the shape of the world familiar while still showing clearly how unfair the distribution of resources and power was at the time (it is now more unfair). The cartograms and maps used in these atlases were perhaps some of the best remembered by the school children that were taught in the 1980s with such books and therefore may have had very important social effects upon this generation.

Other examples of using human cartography in advocacy include the work of Seager and Olson (1986) who described the geography of women's rights in the world, Gilbert's (1982) *Atlas of the Holocaust* and Bunge's (1988) *Nuclear War Atlas* illustrating what would be the devastating impact of a possible nuclear war. A more recent example is shown in Figure 10.5. This is a map produced by Social Watch.[2] This map treats population sizes in the same way that a conventional method such as Peter's projection treats land area. In this map countries are represented by rectangles of varying size, which is determined by how many people live there and not by how many hectares the country occupies. The rectangles are then coloured according to their rank in the Basic Capabilities Index, which a way of identifying poverty situations not based on income. By not using income this index is consistent with the definitions of poverty based on capabilities (promoted by Sen, 1982; Nussbaum and Sen, 1993) and lack of human rights (Social Watch, 2007). Countries in blue on the map are those that provide their inhabitants with a minimum level of social services, whereas countries in red face critical situations of deprivations. In addition, the colour scale of the circles shows degrees of progress towards gender equity.

The map shown in Figure 10.5 depicts very different societal impacts on the views of its readers compared with traditional mapping approaches. This becomes clear by comparing the size of countries, for instance the Russian Federation, Australia and Canada in the , and their respective sizes in a land area map (see Figure 10.1). Figure 10.5 has a very different impact upon the public's perception regarding the progress in achieving a set of

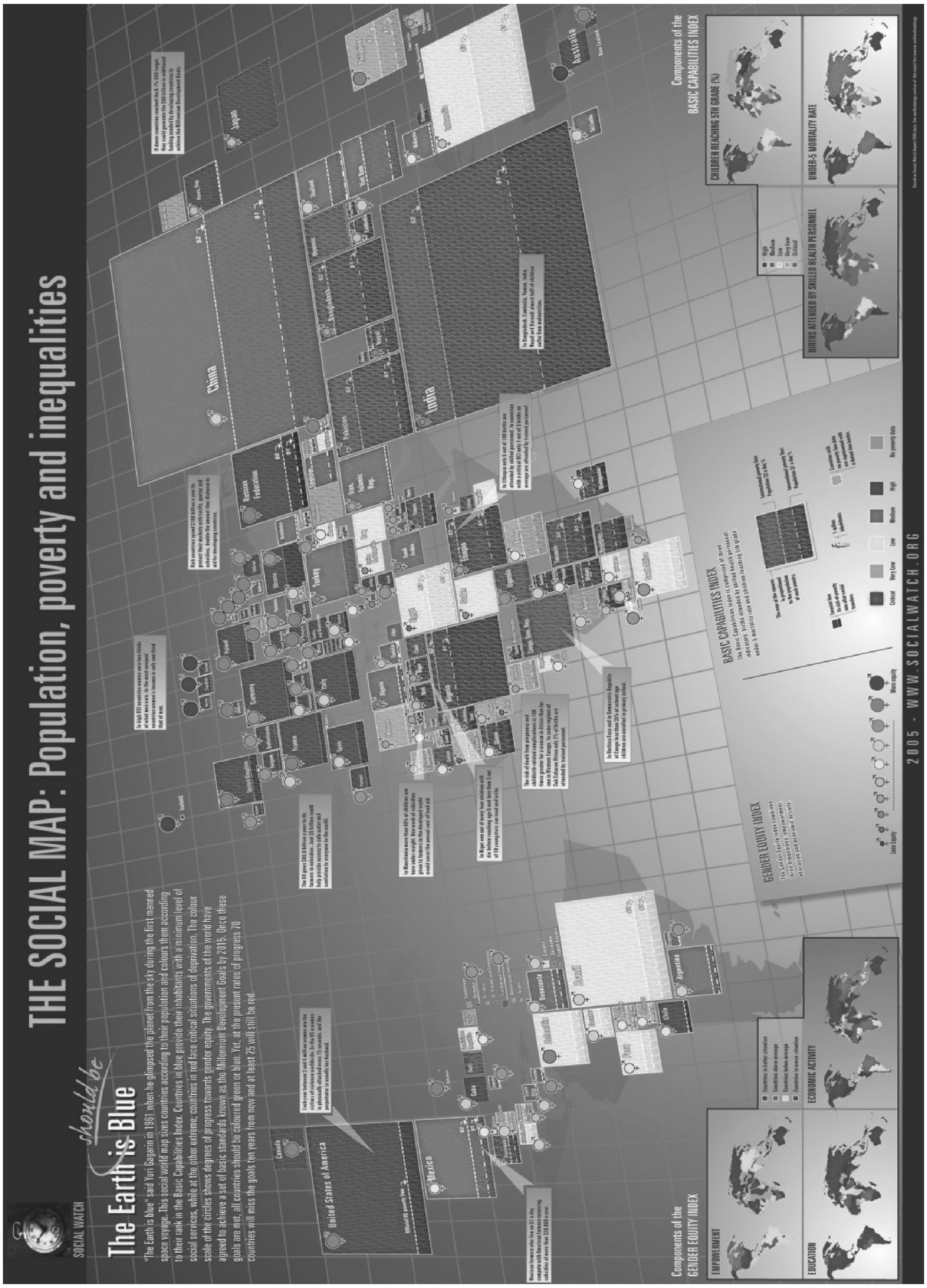

Figure 10.5 The Social Map (http://www.socialwatch.org)

basic standards known as the Millennium Development Goals for the majority of the planet's population (if all these standards are met then all countries in the map will be coloured blue or green).

It is increasingly and convincingly argued that conventional maps should not be used to map human data and that cartograms such as that shown in Figure 10.5 should be used instead. However, it is also argued that it would be useful if population cartograms approximate the shapes of the regions and countries as much as possible, while at the same time preserving orientation and contiguity, so that areas on them can be easily recognizable and familiar to the map reader (Dent, 1996). The following section discusses new approaches that have been adopted and implemented in order to produce cartograms that distort the least on the surface of the sphere while still scaling areas correctly.

MAPS AND SOCIETY: THE SOCIETAL IMPACTS OF TRADITIONAL/CONVENTIONAL MAPS VS. HUMAN CARTOGRAMS

> What use are Mercator's North Poles and Equators,
>
> Tropics, Zones and Meridian Lines?
> So the Bellman would cry: and the crew would reply,
> They are merely conventional signs!
>
> (Hunting of the Snark by Lewis Carroll, quoted in Truss, 2003: 200–1)

Cartograms such as that shown in Figure 10.5 represent good examples of how social scientists should be using maps for human-scaled visualization. However, a disadvantage of this cartogram is that it distorts the original regions' real shapes and this affects the degree to which it is familiar and recognizable by a map-reader. As suggested by the brief review in the previous section, there have been numerous methodological developments aimed at creating cartograms on the basis of automated computer algorithms. These methods attempted 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 projection uniquely.
- Minimize computational speed.
- Make the end result independent of the initial projection being used.
- Make the end result look aesthetically acceptable.
- Have no overlapping regions

As noted in the previous section the work of Tobler (1963, 1973) was instrumental in facing these challenges. In particular, Tobler constructed the first computer algorithm that created an equal density approximation by compressing or expanding lines of latitude and longitude until a least root mean square error solution is obtained. The method generates pseudo-continuous cartograms according to partial differential equations in order to fix a planimetrically correct base map to an underlying continuous surface. This was then projected onto a distorted plane, which represented the variable transformation (Tobler, 1963; Dougenik et al., 1983). The original Tobler algorithm is regarded as imaginative but highly inaccurate as the resulting cartograms may contain extensive area errors, slow due to the number of iterations required by the algorithm and guilty of producing an over generalized end product. There have been several attempts to build upon Tobler's original work, including the work of Nicholas Chrisman, which uses a different distorted plane approach. In this scheme, each region or polygon has an amount of 'force' applied to it based on the variable's value being mapped (Dougenik et al., 1983). More recently, a Cellular Automaton approach has been developed (Dorling, 1996; Henriques et al., 2009) to create cartograms. This approach involves superimposing a grid on a map. The individual cells are then swapped on this grid until every geographic region has a number of cells corresponding to its desired area. This method is very effective at achieving the correct area, but regions tend to lose their unique contours and acquire a shape reflecting the grid. An example is given in Figure 10.6 reproduced from the more recent work of Henriques and collaborators (see Henriques et al., 2009).

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 can be adapted to 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, which used the linear diffusion method from elementary physics to model this process. The computer algorithm has been altered so that it re-projects the boundaries of territories on the surface of the sphere – rather than on the plane. It can also be described as 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, 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 remainder of this chapter shows how this projection

Figure 10.6 USA county population cartogram. (Henriques et al., 2009: 508)

method can be used to visualize countries around the world, regions within countries and areas within cities.

VISUALIZING THE WORLD

The pioneering diffusion method of Gastner and Newman described above was first applied by them in order to depict the results of the 2000 US presidential election, as well as to investigate the distribution of lung cancer cases among the male population in the state of New York and to also study the geographical distribution of news stories in the USA. Following on from this work, there have been a number of extensive applications of the technique to generate world cartograms. The first such cartogram was presented by Richard Webb (2006) in *Nature* showed how Mark Newman had overlaid a grid of 4096 by 2048 squares on a rectangular world map based on a cylindrical equal-distance projection and then computed a starting population-density function by dividing the population of each country equally between the squares covering its territory. In this way population was allowed to diffuse away from higher to lower density areas with national boundaries moving such that the net population flow through them was zero at all times. The 'Gastner and Newman' diffusion technique has also been used extensive to generate a series of world cartograms in the context of Worldmapper,[3] 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 600 world maps where territories are re-sized on each map on the basis of a number of subjects, ranging from health, life and death to income, poverty and wealth (Dorling, 2006; Barford and Dorling, 2007a, 2007b; Dorling et al., 2008). Figure 10.7 shows a Worldmapper cartogram of the world population distribution across territories, similar to the first such cartogram by Richard Webb (2006) briefly discussed above.

It is noteworthy that, unlike conventional choropleth maps of population data (as well as the Mercator-projection maps briefly reviewed above), the Worldmapper cartogram shown in Figure 10.7 reveals more of the real pattern of population distribution by showing where the highest population concentrations are and therefore how human population can be more revealingly mapped by social scientists. China and India which account for about a 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 also think about the societal effects of such a cartogram on collective imaginations. As we also shown above, 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 (United Nations, 2008). A useful indicator pertaining to this target is the prevalence of underweight children under five years of age, which is also discussed in this context in latest recent report by the United Nations Children's Fund (UNICEF) on the state of the World's children (UNICEF, 2007). According to data collected and calculations made by the Worldmapper project, between 1995 and 2002 almost a quarter of all children aged under 15 years old were estimated to be underweight.[5] Figure 10.8 shows a world map of all underweight children in the world.

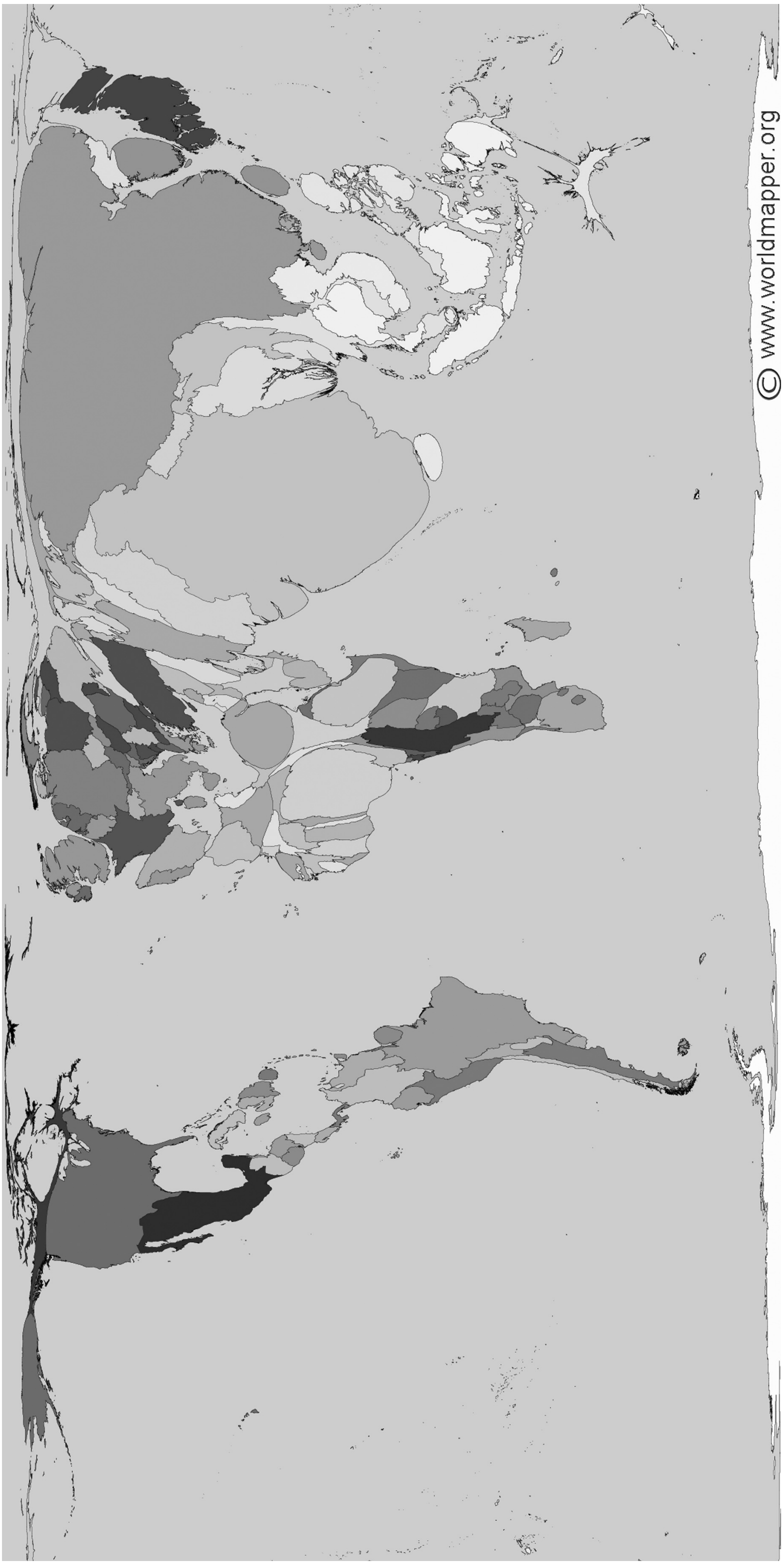

Figure 10.7 Total Population (Worldmapper map 002). The size of each territory shows the relative proportion of the world's population living there. (United Nations Development Programme, 2004, Human Development Report)

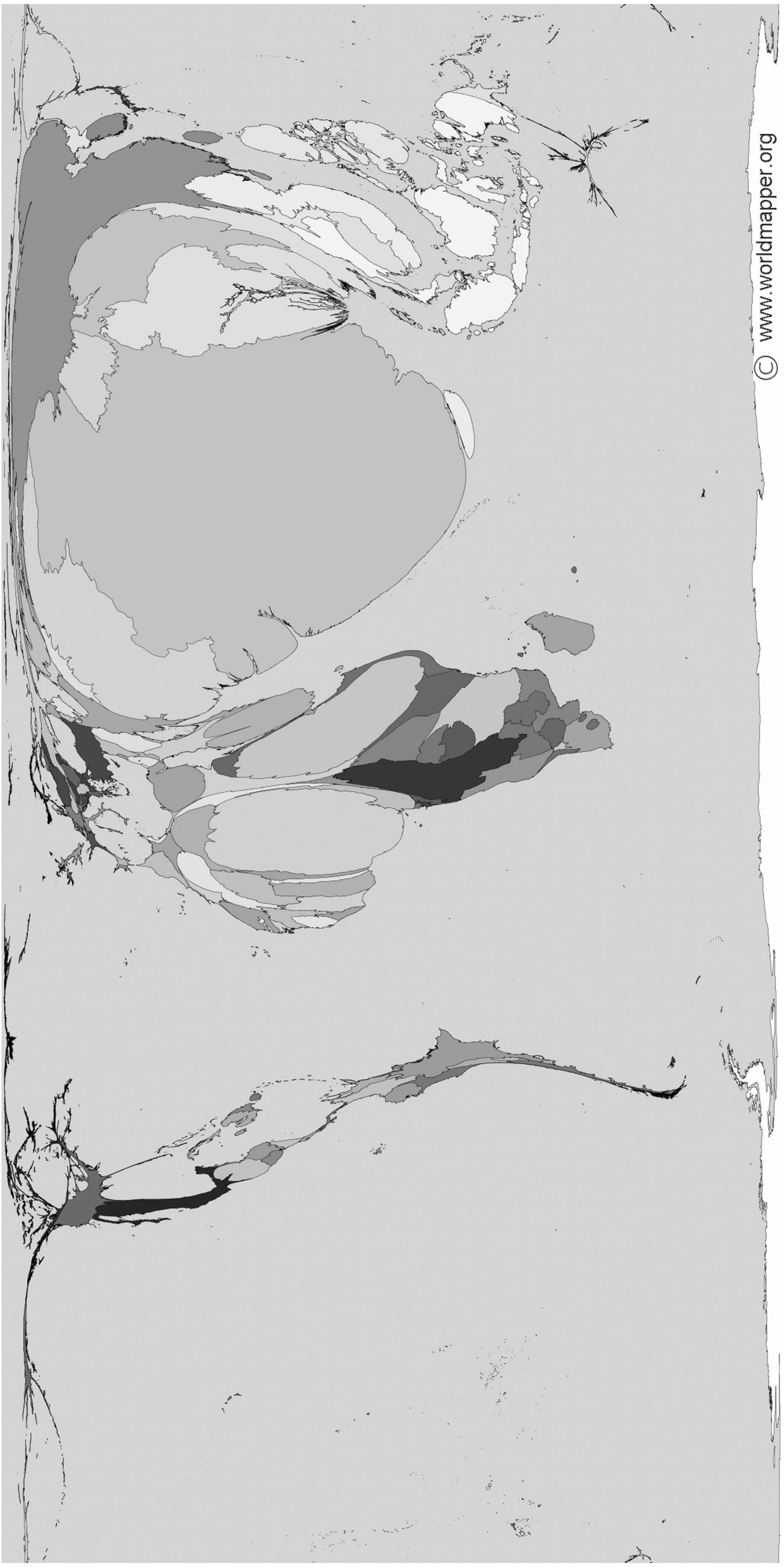

Figure 10.8 Total Population (Worldmapper map 182). Territory size shows the proportion of all underweight children in the world that live there. (United Nations Development Programme, 2004, Human Development Report)

It is interesting to consider at this stage the impact that Figure 10.8 may have on the public's perception of progress regarding the achievement of Millennium Goals, when compared to conventional maps. Figure 10.8 is a much better representation of the spatial inequality and in particular it highlights that half of all underweight children under the age of five 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 Ethiopia, Indonesia, Nigeria and China. In contrast, it is very difficult to distinguish the shapes of most countries in Europe and the Americas because they are hardly visible. When compared with conventional maps a human-scaled visualization such as that presented in Figure 10.8 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. Or, as one of us has argued elsewhere with regards to the social and spatial inequalities that underpin inequalities in health: 'You can say it, you can prove it, you can tabulate it, but it is only when you show it that it hits home' (Dorling, 2007a: 13). Cartograms have been around for many years and thus it is perhaps surprising that human cartograms have not been used more by organizations such as UNICEF as well as a number of non-governmental organizations to increase awareness and improve the quality of information that the public have about global issues.

Figure 10.8 is just one example of how new innovative cartogram creation methodologies can be used to draw alternative human-scaled visualizations by keeping the shape of the world 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: there are over 600 such maps created so far by the Worldmapper project alone. In principle, any variable pertaining to human population could be mapped in this way at the world scale in order to address research questions and policy issues pertaining to human societies.

VISUALIZING THE NATION STATE

The cartogram methods discussed above in a world mapping context, can also be very powerful tools in depicting socioeconomic information for smaller geographical levels, within nation states. Among the first applications of the Gastner and Newman method was to provide an alternative visualization of the results of the 2000 US presidential election and subsequently it was also used to depict the 2004 presidential and the 2006 congressional election results.[6] One of the key arguments against using conventional maps to depict election results is that they may give the superficial impression that electoral regions that have a large topographic area but relatively small populations dominate the political landscape. For instance, in the case of the US 2000 and 2004 presidential elections conventional maps were dominated by the red colour (the republican candidate) whereas the blue colour (democratic candidate) was much less visible, despite the fact that the 'blue' states had very large numbers of voters. Gastner et al. (2004) show how such biases can be corrected by resizing each state according to its population and they also conduct the same analysis at the county level. In 2008, Barack Obama did not appear to win on the conventional map.

In this section we further demonstrate the power of cartogram technologies for human-scaled visualizations by mapping regions within a country, resizing the areas of the regions on the basis of a variable that 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 drawn from a representative sample of over 5,000 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, 1995; Diener and Diener, 1995). For instance, it has often been suggested that Americans have a tendency 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 10.9 is based on data from the BHPS and represents the 'mirror image' of happiness and unhappiness in Britain. In particular, the cartogram on the left-hand side was created using the Gastner and Newman's diffusion method to rescale the sizes of all areas according to the number of the 'unhappy'

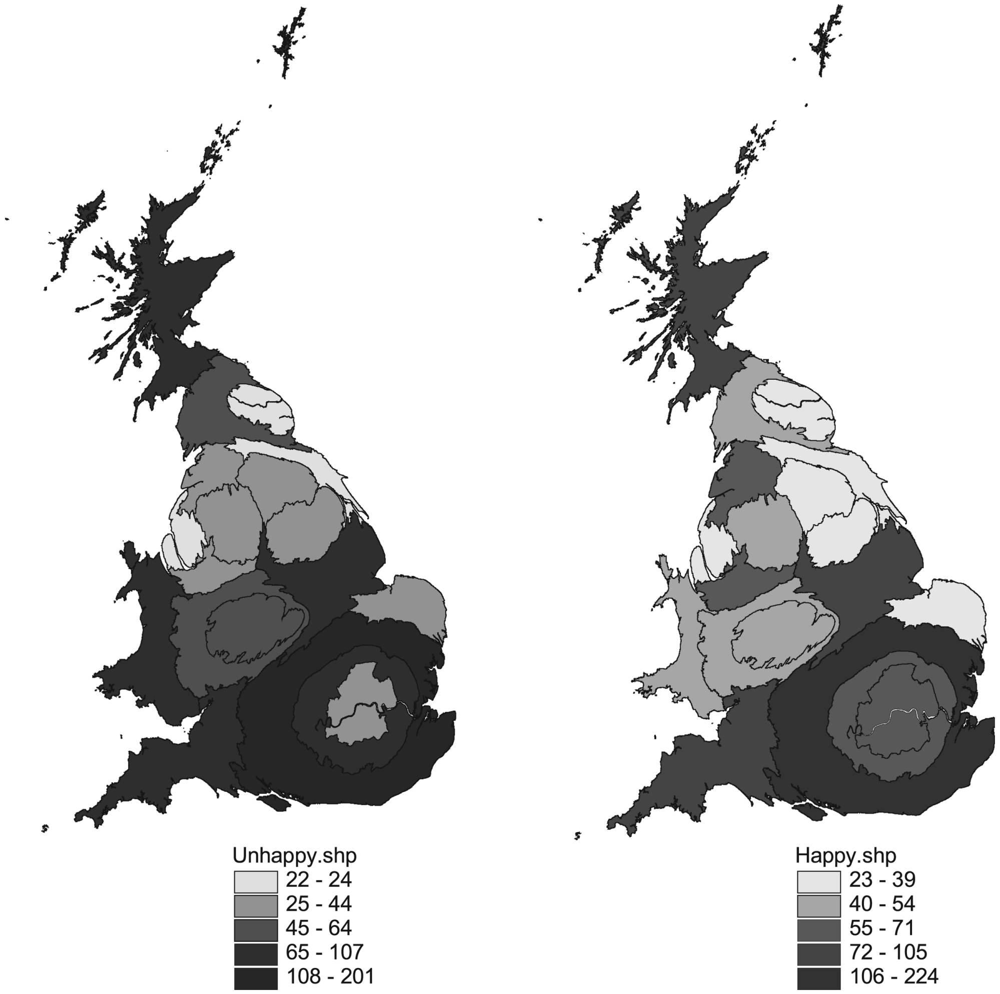

Figure 10.9 Mirror image of happiness/unhappiness in Britain

respondents in the survey. Likewise, the same method was used to create the cartogram on the right-hand side of Figure 10.9, in which the sizes of all areas are rescaled on the basis of the number of 'happy' respondents. As can be seen these human cartograms are very different from conventional maps of Britain, as 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', coloured in red in both cartograms, has very similar numbers of both 'happy' and 'unhappy' people. Nevertheless, there are also some notable differences. In particular, the sizes of Scotlandand Wales is slightly larger in the cartogram of 'unhappy' people. The shades of the region vary because the different shades show populations happy and unhappy, whereas the areas show the absolute numbers. 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 10.9 see Ballas et al., 2007).

A key societal implication of using cartograms such as those shown in Figure 10.9 in order to depict areas within nation states is that, if widely reproduced, it may influence considerably the public's mental map of the nation, which is typically constructed by mainstream media representations.

VISUALIZING THE CITY

In this section we show how the Gastner and Newman diffusion cartogram method can be employed to visualize human variables 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.

As noted above, one of the key advantages of the diffusion cartogram method is that it minimizes the distortion of the shape of the geographical areas being mapped, while at the same time it maintains the topological features. This advantage is perhaps more important when mapping countries or regions within countries that have shapes with which most people likely to read the cartograms are familiar. However, it can be argued that people are perhaps much less familiar with administrative, census or postal geographical units that are typically used when mapping socio-economic and demographic variables at the sub-regional or intra-city level. In this section we have chosen the parliamentary constituency as the unit of analysis for intra-city, human-scaled visualisation. UK parliamentary constituencies are a very useful unit of analysis of socio-economic and demographic data as they each contain roughly the same number of people. In addition, it can be argued that they are an intra-region and intra-city unit of analysis with which the public is familiar, given that election results are mapped at this level and such maps are extensively used by the media, especially at the time of parliamentary elections.

The Greater London metropolitan area, which is used as an example here, comprise 74 in 2009 parliamentary constituencies which are shown in Figure 10.10.

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 UK case of parliamentary constituencies, a population cartogram would result in all areas having roughly the same size (see Dorling, 2005; Dorling and Thomas, 2006). However, cartogram methods can also be used to distort the size of each constituency on the basis of a socioeconomic 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

Figure 10.10 Map of Greater London parliamentary constituencies

degrees of spatial polarisation increasing within Britain at regional and local levels (Dorling et al., 2007; Dorling and Ballas, 2008). 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 10.11 and 10.12 show an alternative human-scaled visualisation of the geography of poverty and wealth in London. In particular, they show how the London parliamentary constituencies can be distorted on the basis of the number of households living in them classified as 'core poor' and 'exclusive wealthy', respectively.

As can be seen in Figure 10.11, the 'core poor' map of the locations of the poorest of the poor in London is dominated by inner city areas and areas in the South East. 'Core poor' are defined as people who are simultaneously income poor, materially deprived and subjectively poor and who have very little money coming in, very few possessions and resources and they also consistently perceive themselves as poor (Dorling et al., 2007). The parliamentary constituencies with the largest numbers of this group of households, those which dominate the map (and also dark shaded) 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 10.12 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

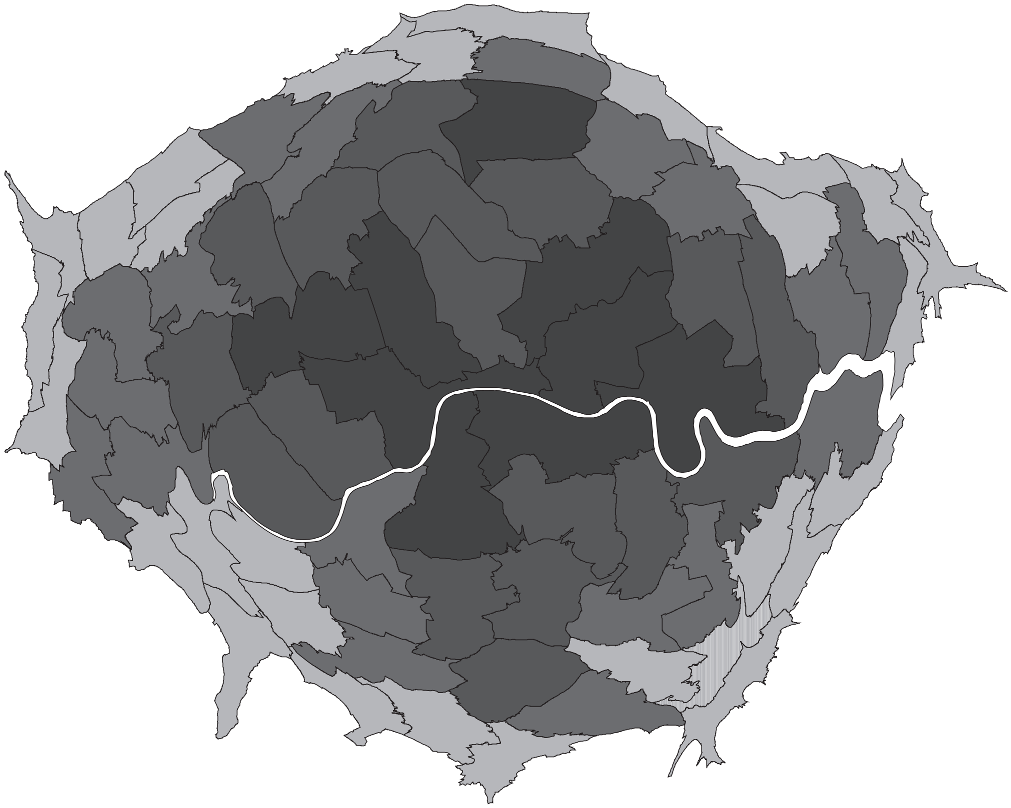

Figure 10.11 'Core Poor' cartogram of Greater London parliamentary constituencies (darker areas show higher concentrations of 'core poor')

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). On the other hand, most of the areas in the shrinking (in Figure 10.12) East End of London have very few households that could exclude themselves by dint of wealth from the norms of society if they wished to do so. Many households there are excluded by their poverty.

Maps such as those shown in Figure 10.11 and 10.12 may have a very different impact on the public perception about the state of societal inequality when compared to conventional maps. They can also be used to raise awareness about social disparities and their geographical manifestations within cities and regions and to monitor progress (or lack of progress!) with regards to stated government social, regional and urban policy goals.

CONCLUSION

In this chapter we provide an overview of the state of the art in human area population

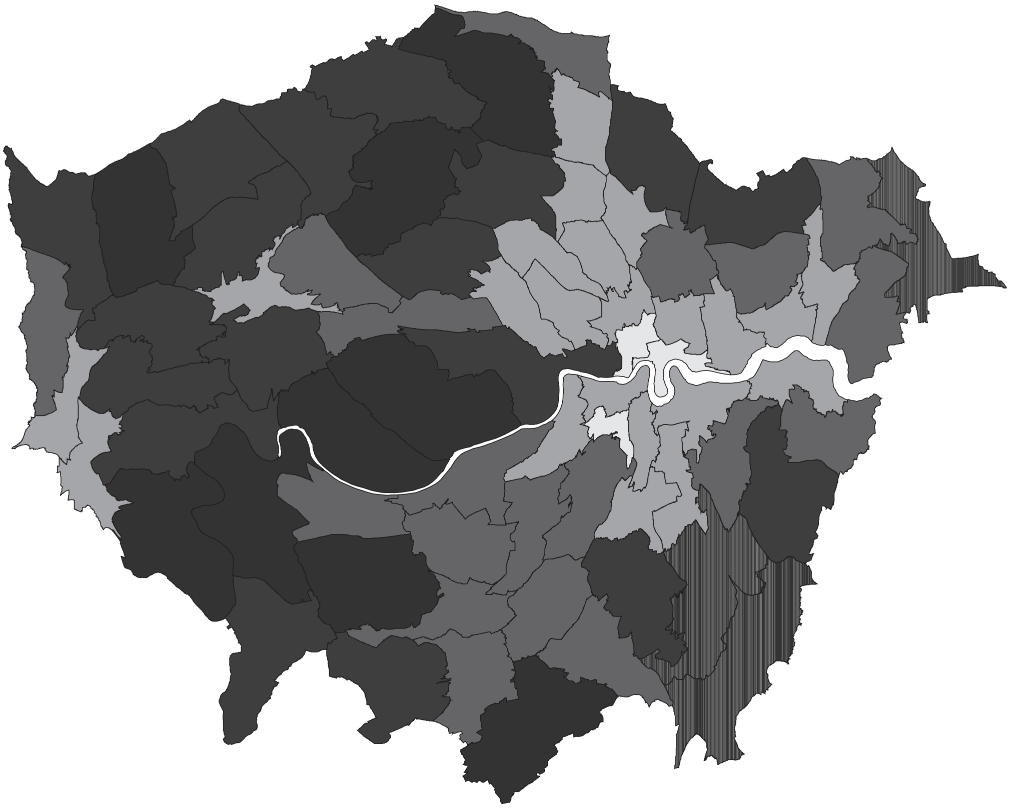

Figure 10.12 ***Exclusive Wealthy*** **cartogram of Greater London parliamentary constituencies (darker areas show higher concentrations of 'exclusive wealthy')**

cartograms and also give a number of examples at different geographical scales in order to illuminate issues and problems that are inherent in visualizing human populations. We have argued strongly that conventional maps that show how cities, regions and countries appear from space are not depicted in an appropriate way to show the spatial distributions of humans and their characteristics. Human cartography provides the appropriate methods and tools for the depiction of the spatial distribution of variables pertaining to human societies rather than environmental, geological or meteorological problems.

As we argued throughout this chapter, the visual impact of human cartograms may have a considerable influence upon the public's perception about very important issues at different geographical scales: from achieving World Millennium Goals planet wide to ameliorating income and wealth inequalities within cities or regions.

Undoubtedly there has been progress in human cartography over the past 20 years. It can be argued that the new developments in human cartogram technologies, some of which were reviewed here, provide the tools and the enabling environment for social scientists across disciplines to map their data using methods that are appropriate for human-scaled visualizations. The new methods are relatively easy to understand and use and the resulting cartograms can be extremely powerful images to support the arguments of social science researchers. They are also much more successful than previous attempts in retaining recognizable aspects of the physical geographical zones that they seek to represent. It should be noted however, that the ability to deliver this 'recognisability' is always subject to the nature of the geography concerned and therefore automatic cartograms are not a panacea. The products of cartogram algorithms such as those discussed in this chapter should always be subject to scrutiny by the cartogram creator as well as the viewer (ideally through computer-user interaction through appropriate interfaces) and it should be acknowledged that non-automatic manual cartograms may be sometimes more appropriate. Also, it could be argued that the effectiveness of human cartograms of smaller sub-regional or intra-urban areas the physical shapes of which are less recognizable by viewers could be enhanced with the use of interactive tools ('mouseover', links to bar charts and alternative visualisation and conventional maps) so that the cognitive effort in order to make comparisons between areas is minimised. More simply, some place name labels could just be added!

Finally, it can be argued that one of the ways in which human cartography can be improved is the enhancement of visual impact of human cartograms through the use of computer animation (Herzog, 2003) 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 human cartography to other new mapping technologies such as Google Earth™ in order to allow the viewers to spin around the sphere and allow viewers to zoom in and out of the globe and query where they were looking–to find out more about each place, to learn more, more quickly and even to see one image morph into another. This is one of the immediate priorities of projects such as the Worldmapper, which was discussed in above and it is possible that by the time you read this chapter, the Worldmapper Web site may well have enhanced 3D human cartograms (it already has some basic animations of map transformations).

ACKNOWLEDGEMENTS

The authors would like to thank John Pritchard for his help with the illustrations presented in Figure 10.9. They would also like to thank the editors and three anonymous reviewers for their very useful comments and suggestions on an earlier draft. The British Household Panel Survey data which were used to create this figure were made available through the UK Data Archive. The data were originally collected by the ESRC Research Centre on Micro-social Change at the University of Essex, now incorporated within the Institute for Social and Economic Research. Dimitris Ballas and Danny Dorling were funded by the UK Economic and Social Research Council (research fellowship grant number RES-163–27–1013) and the British Academy and Leverhulme Trust (British Academy Research Leave Fellowship and Leverhulme Trust grant) respectively, while writing this chapter.

NOTES

1 Also see: http://en.wikipedia.org/wiki/Homunculus

2 http://www.socialwatch.org/

2 http://www.socialwatch.org/

3 http://www.worldmapper.org/

4 The Worldmapper maps and data files cover 200 territories, mainly United Nation Member States plus a few others to include at least 99.95% of the world's population.

5 http://www.worldmapper.org/display.php?selected=182#

6 http://www-personal.umich.edu/~mejn/election/

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