1

Envisioning information

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, p. 3)

1.1 Visual thinking

Envisioning means bringing into the condition of vision for the purposes of contemplation, making visible, to enable visualization. It is what this book practises. For at least a century we have known that envisioning is about giving information to people in a form that is better suited to all our minds.

This work does not concentrate on the mechanics of getting information into and out of the machine, but instead with how you get it out to people (Figures 1.1 and 1.2). To communicate spatial structure is hard without involving the sense of sight.[1] Language, along with music, the most sophisticated use of hearing, is an excellent means of conveying ideas and thoughts, but cannot present a large amount of information in a structured form at speed.[2] Neither can touch or our other senses.

[1] 'Visual displays of information encourage a diversity of individual viewer styles and rates of editing, personalizing, reasoning, and understanding. Unlike speech, visual displays are simultaneously a wideband and a perceiver-controllable channel' (Tufte, 1990, p. 31).

[2] 'Human visual perception is performed by the most complex structure of the known universe, the visual cortex, that contains at least 10^{10} neurons, where each neuron on average contains 10^4 synapses (gates)' (Papathomas and Julesz, 1988, p. 355).

The Visualization of Spatial Social Structure, First Edition. Daniel Dorling.

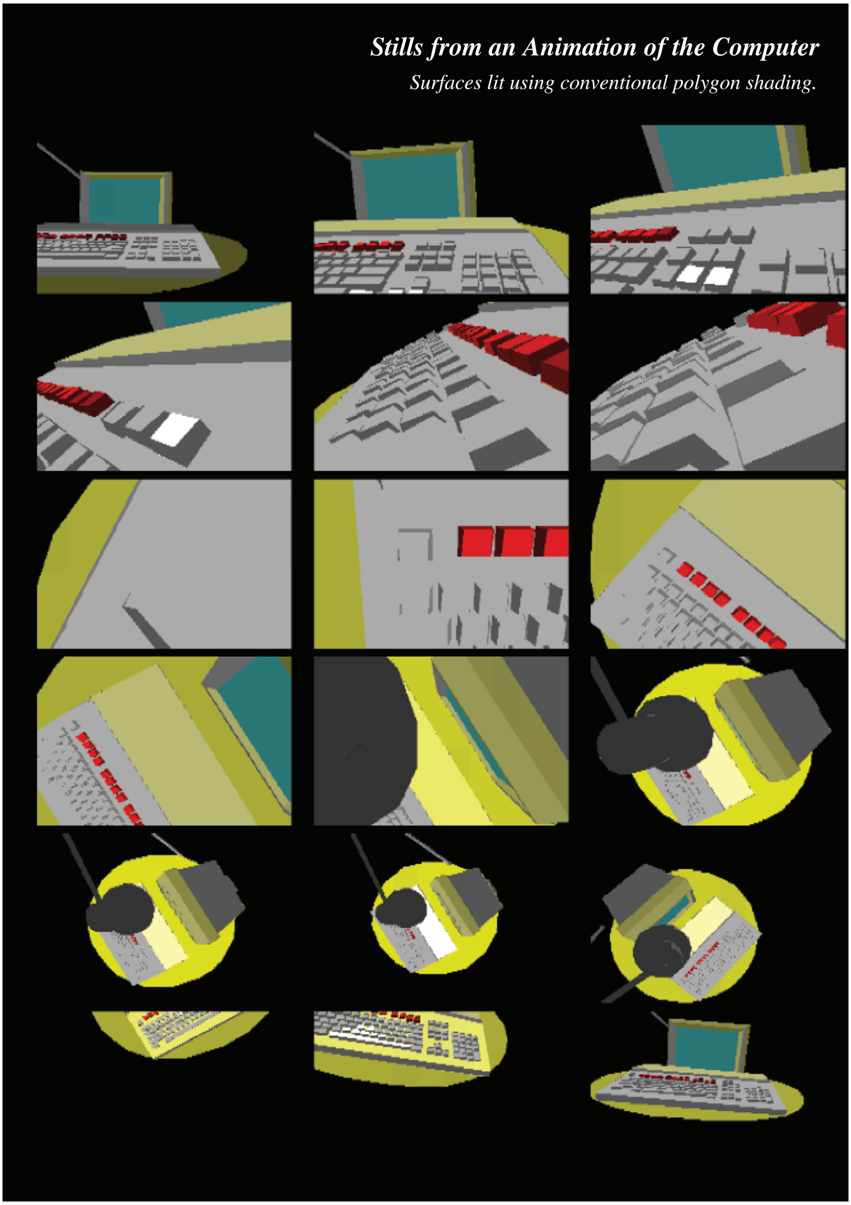


Figure 1.1 *Software by Ace Computing was used to produce these still illustrations from a conventional video animation of the Acorn Archimedes computer. Polygon shading colours the entire surface of each facet a constant shade, which is determined by its colour and the light and shadow falling on it. The scenes produced are therefore crisp, but somewhat unrealistic. Note: this very early race tracing software produced images at even a low resolution very slowly and so parts of these 18 frames can appear jagged.*

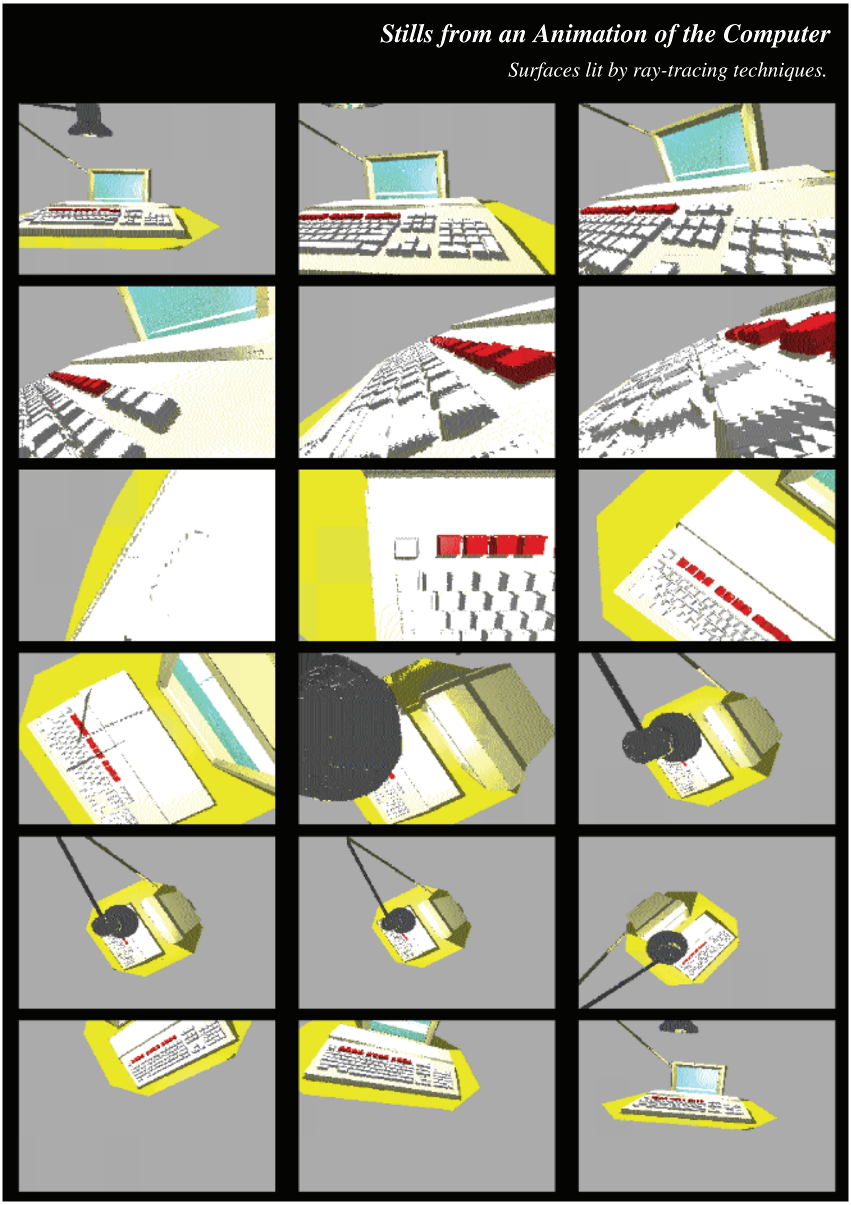


Figure 1.2 Ray-tracing involves estimating the colour of every pixel in the image plane by calculating the trajectory of a ray of light on to the surface of a hypothetical object, where it can be reflected, diffracted or absorbed, and then through the screen to the eye of the viewer. During the late 1980s the algorithms were still in development. Later the advantages of this technique became more apparent. Note: the jagged nature of some of these images is accentuated when the virtual camera was very close to objects and it was then easy to over-expose the virtual 'film'.

When you look out of the window you can see a great deal in an instant.[3] The mind has an extremely powerful system for processing imagery that can instantly analyse a pattern of colours, of light and shade, and know that these are trees, houses or people. How long would it take to describe all that you can see in words?

Pictures alone are insufficient. This little book is only held together by its text. We have travelled a long way with our little symbols, the letters of the alphabet, which exist only because they were easy to scratch with a stick or form quickly with lips and tongue. Did our ancestors develop the most efficient means of communication or did they make do with what was possible?

The spatial structure of 1980s British society, which is envisaged in these pages, was made up of far more than a few large regions that can be named and divisions that could be measured. Social structure has a texture to it, a fine pattern, an elaborate organization, not unlike the fractal patterns to what were thought to be chaos, which were first revealed in the 1980s (Figure 1.3).

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 (and not everyone can see). An artist will take days to paint a single portrait. My parents' generation were the first to have easy access to the camera and mine were the first to receive the computer, which can turn a huge amount of data into pictures – snapshots of our society. In the future we may be able to speak visually and may be able to summon up an image to explain what we are trying to say. For now we still have to learn how.

1.2 Pictures over time

> *One of the great potentials of computer graphics is to provide a vision of what we might not otherwise be able to see in a photograph or real life.*
>
> *(Dooley and Cohen, 1990, p. 307)*

Our first permanent communications were cave paintings and our first textual scripts were made of pictures. Today the liquid-crystal display screen, which abounds with icons, is the modern cave wall (Figure 1.4); we have rushed forward to the beginnings of visual communication.[4]

[3] 'Humans can recognize unexpected objects in around 100 neuron-firing times' (Plantinga, 1988, p. 56).

[4] Although now the touch screen means the cave wall can react back. The subject matter of the earliest maps concerned people, the first map was a cave painting of figures dancing in a field. Later: 'Chinese literature tells us that maps were being used in the East as early as the 7th Century BC, while the earliest surviving examples of maps are clay tablets found at Nuzi, in northern Iraq. Believed to be from the period circa 2300 BC, they show rivers, settlements, land-holdings and hills' (Brannon, 1989, p. 38).

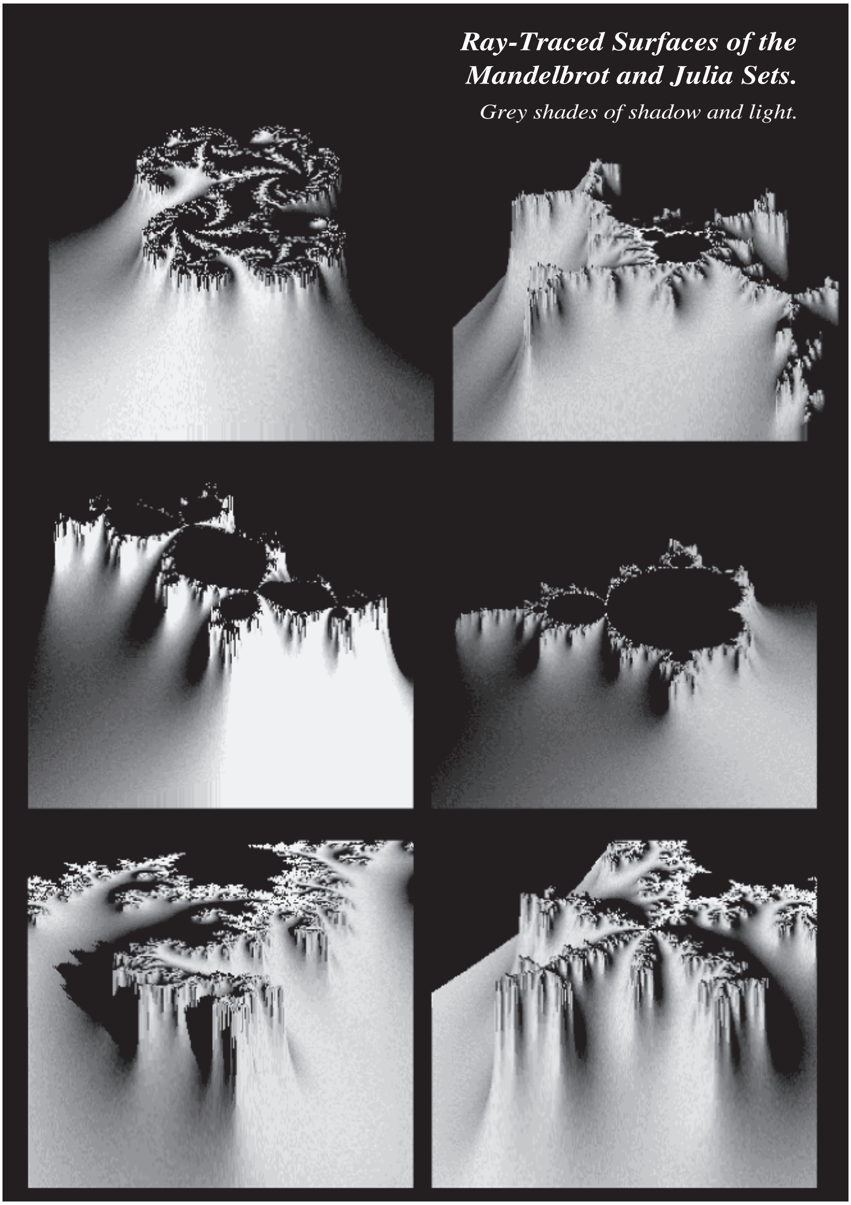


Figure 1.3 Height of the surface shows the rate of divergence of each point on the complex plane, to infinity. The Mandelbrot and Julia sets essentially trace out one-dimensional lines in two-dimensional space. These are of such complexity, however, that a three-dimensional projection can be illuminating. These pictures are derived from simple equations. Note: the resolution reflects the original pixel sizes of the six screen shots are shown here.

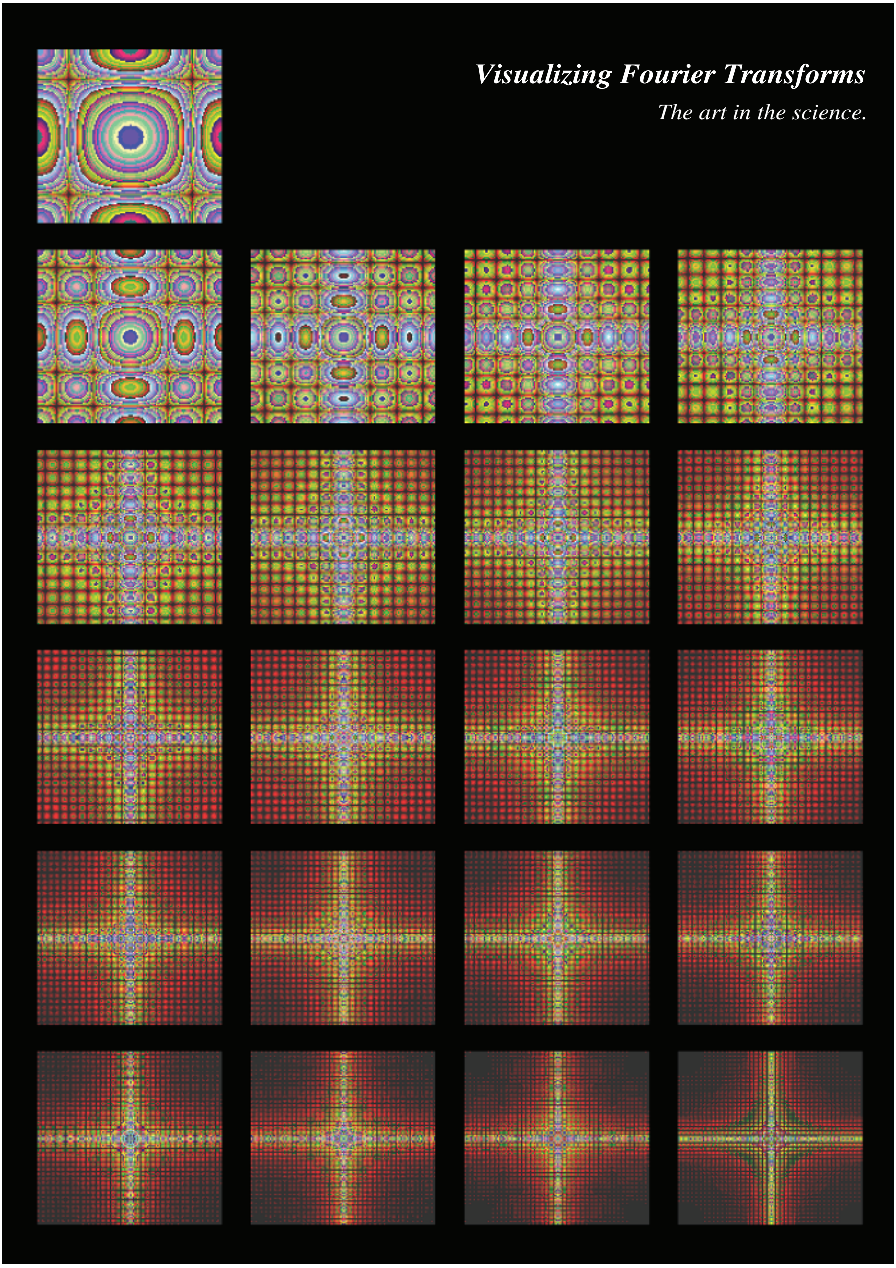


Figure 1.4 *These images show the distribution of patterns of differing frequencies on the complex plane. The patterns show how science and art can merge. This is understandable when their objectives become less dissimilar. Different people might notice different patterns in the same pictures – there is some subjectivity in visualization because we have different experiences and expectations.*

The first detailed maps were drawn on clay. They were invaluable objects for the control of territory or the projection of religious truth about the world. Maps were accumulations of innumerable stories, reams of parchment and hordes of figures, but they were also about power.

As map-making developed into the art of cartography, rules were formalized and conventions defined. Cartography is no longer a major discipline or even an important aspect of geography. Its modern tools can be used by children (Figure 1.5) and its conventions have been challenged as stale. It may currently be merging into a new, as yet unlabelled, discipline. This could be the discipline needed to collate knowledge on the graphical design of all that which now appears within touch-sensitive liquid-crystal displays, now that the displays interact. Disciplines change.

The nineteenth century saw the growth of an aversion, in science, to pictures. The graphs, which instruments traced on to paper, were immediately turned into supposedly more accurate and readable tables. Even in the early 1960s diagrams were said to be for people without mathematical imagination.[5] Nevertheless, statistical graphics did germinate in these surroundings.

The graph, bar chart and scatter diagram were invented and formalized. Rules for their construction were produced, while their supposed subservience to more advanced methods was made clear. By 1990 the cycle had come round again and a new breed of statistician appeared who saw visualization as paramount.

Computer graphics in the 1960s changed the picture. Swirling images were produced from simple formulae. It was immediately obvious that reading an equation told you little about what secrets it held. Before computer graphics, people were blind to the behaviour of relationships they thought they could easily understand (Figure 1.6). The programmers then turned their efforts to the possibilities of rendering abstract worlds.

Graphics have come in and out of favour in cycles through time. Their resurgences usually have more to do with taking advantage of new printing technologies and the availability of more abundant information than a basic understanding of their value.

Box 1.1 shows how computer graphics are constructed. At the time it was first drawn, being able to combine all these separate elements in a single ‘graphics file’ was novel. Creating such files required knowing that to place an island in a river within a park in a town in a county required the paths describing the boundaries of these objects to follow specific winding rules, to alternate from travelling clockwise to anticlockwise to clockwise again as you move outwards.

Today such graphics are routine on screens and ubiquitous on hand-held devices, but hardly anyone who uses them knows about things such as the

[5] ‘In mathematics, it is considered the most flagrant gaucherie to use a diagram. “Graphics” is thought to be an inflated title for “mechanical drawing”. In fact, all the intrinsically visible subjects; geography, graphics, and geometry, are suspected of being really grade school subjects, fit only for brains that are still undergoing biological maturation and whose harmfully misleading approach will have to be undone later’ (Bunge, 1968, pp. 31–32).

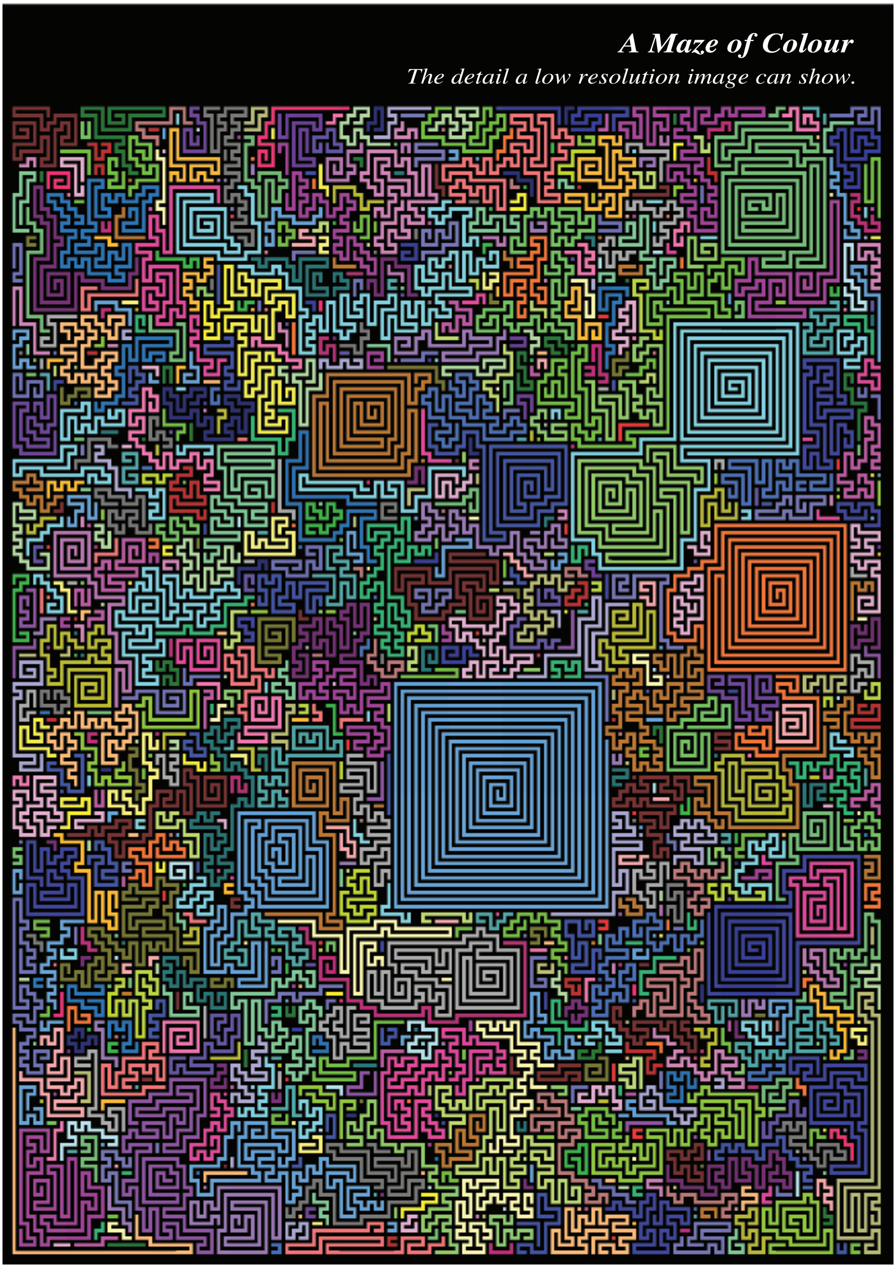


Figure 1.5 The maze is created by repeatedly choosing a starting position and colour at random, and then reversing direction, again at random, avoiding any obstacles. Great detail can be seen in this image, which consists of only 320 by 250 pixels. Some of the most detailed pictures shown in this book are made up of just over one million pixels. Often, though, only eight colours are used.

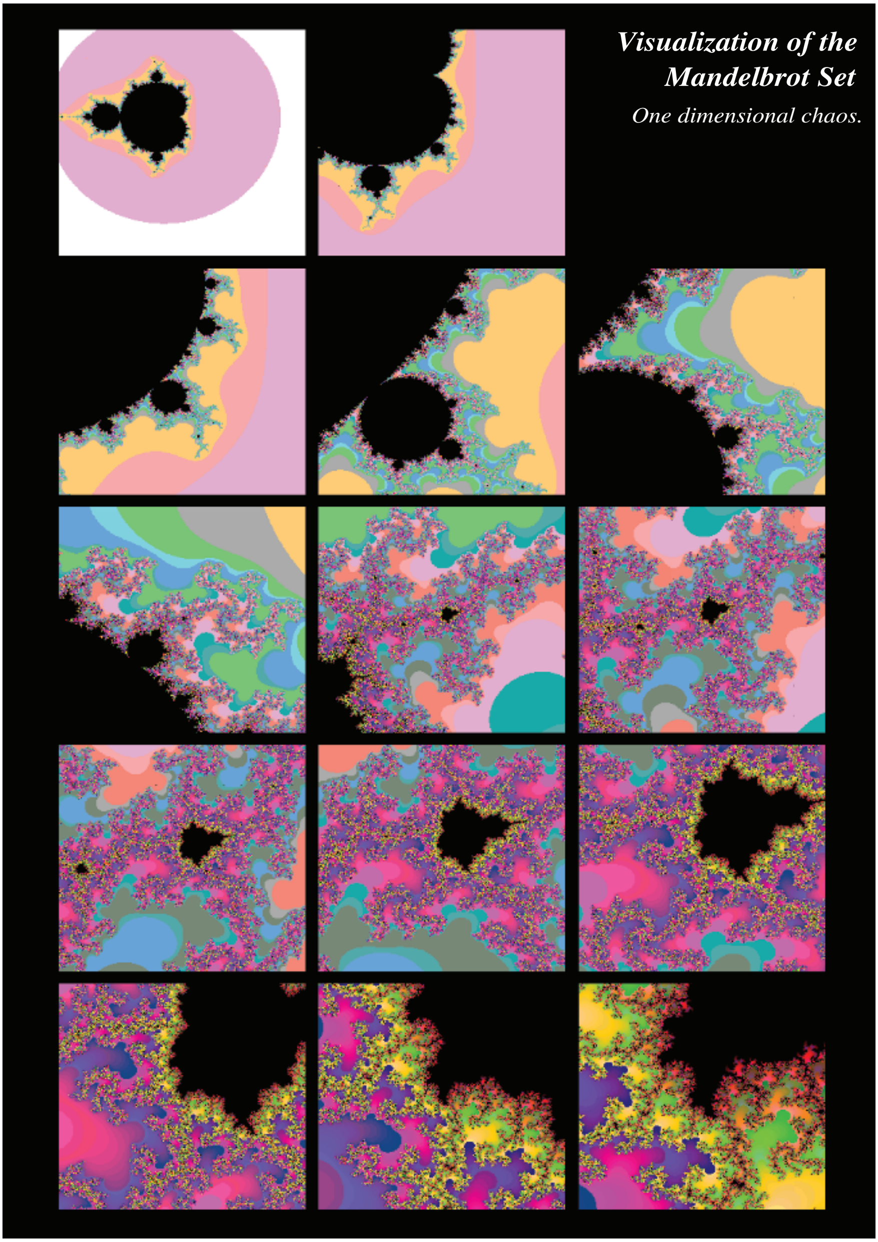


Figure 1.6 The same point in the plane is being repeatedly magnified in this visual series. By the end of the series the image is a million times larger in resolution. At this point the arithmetic accuracy of the computer used begins to fail. We can naturally appreciate complex images. There is no need to smooth out the beauty and diversity of reality either.

Box 1.1 Creating the graphics

Acorn drawfiles were used to create the illustrations in this book.

In 1989 a library of procedures was written specifically to produce these illustrations from data files.

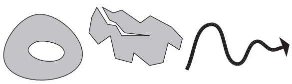
Drawfiles are a sophisticated type of computer record. The record contains a list of objects, which can themselves be a list of objects.

Object can include **relationships** (with other objects), **information** (data from other files) and:

text – of a particular font, size, style and colour;

sprites – a pixelmap image (raster graphics);

paths – lines, curves and shapes (vector graphics).



In the example above the Greater London ‘object’ has been shrunk. In the drawfile it is tagged with its identification as County no. 1 and the relevant boundary date (1981). Making up the group is its perimeter, the river Thames and any islands in the river. All aspects of scaling, appropriate placement and hyphenation of names and colouring are automated. This automation was achieved by splitting names before parts of words such as ‘shire’ and scaling label font size to the boundary box of each area drawn on the map. Any feature of an object or group of objects can then be edited – interactively on the screen – as has been done here.

Once a drawfile representing a particular geography has been created, it can be transformed and additional information incorporated. For example, the places could be represented by faces instead of polygons, re-coloured and then merged with another drawfile.

‘winding-rules’ required to render complex topology. The rules have become embedded in machine code, the hidden instructions that make the computer work. As a result many more people can use computers, but a much lower proportion of those who use them can alter what it is the computer does as compared to the many programmers who could in the past. This lacuna was problematic for the development of visualization in the 1990s but, as software improved, what once had to be programmed became easier to create.

1.3 Beyond illustration

Visualization is a method of computing. It transforms the symbolic into the geometric, enabling researchers to observe their simulations and computations. Visualization offers a method of seeing the unseen.

(McCormick, DeFanti and Brown, 1987, p. 3)

Visualization is now a way of working – a methodology as much as a process. Not only does it differ from the use of script and figures – reading and calculating to understand – but also from conventional graphics, which aim to illustrate. Illustration is used to convey a discovery from one person to another, a discovery that was usually found by other means. Visualization is the transformation of numbers into pictures in order to see what a mass of figures cannot tell us, let alone could not inform others about (Figure 1.7).

Visualization, its early advocates suggested, is how discovery is made. For a time the method became the message.[6] Most visualization research today relies on huge quantities of numerical information.[7] Before you have such information, you can only write about what you think is happening. However, the problem for positivists (people who like countable things) is that once you have counted what is happening – who does what, who has what – how do you understand it?

How should we analyse information? Without visualization, statistical analysis gives you single figures, averages, correlations, parameters of assumed relationships, probabilities and so on. Such numbers are only of use if you know exactly what you want, but knowing what questions to ask is much harder than finding the answers to questions set. Social science is not about defining and testing simple hypotheses; it is about understanding societies.

There are many ways to begin studying society. All involve some form of ordering, of which the spatial is the most common. The patterns that visualizing society reveals usually turn out to show complex and subtle relationships that tax our mental capabilities to comprehend and explain. This is not a bad thing – stretching the mind forces the imagination. Hundreds of thousands of

[6] 'Computer graphics and image processing are technologies. Visualization, a term used in the industry since the 1987 publication of the National Science Foundation report "Visualization in Scientific Computing", represents much more than that. Visualization is a form of communication that transcends application and technological boundaries' (DeFanti, Brown and McCormick, 1989, p. 12).

[7] In the social sciences this was traditionally provided by voting data: 'In many ways elections are a positivist's dream. Millions of people go through the process of voting in numerous countries every year and these decisions are put together and published by areal units ready for analysis by social scientists' (Taylor, 1978, p. 153).

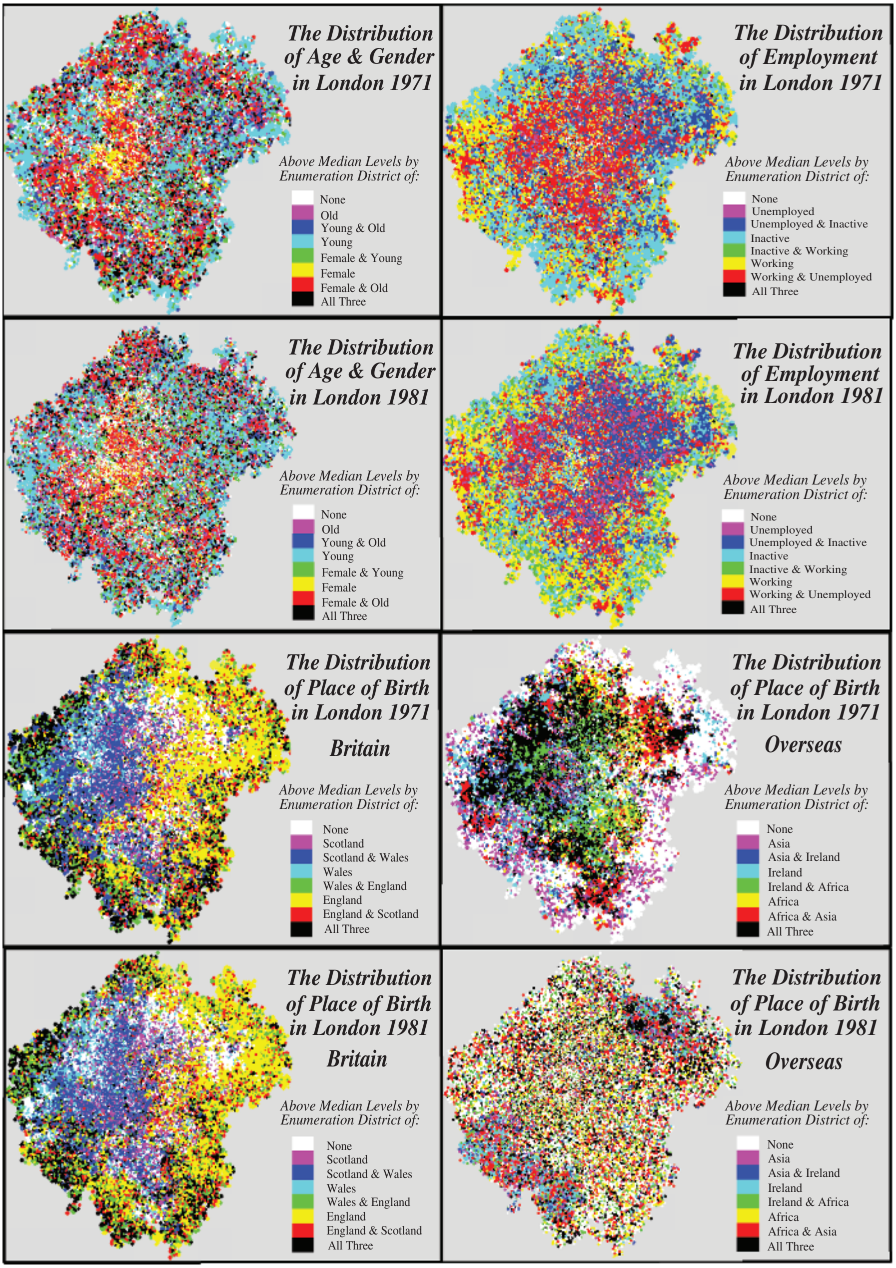


Figure 1.7 Each one of London's thousands of enumeration districts is shaded one of eight colours on each of these eight maps according to whether there are over-average or under-average numbers of old, young, male, female, working, unemployed or inactive people working in each, and by birthplace. Note how rapidly overseas birthplace distributions diffused during the 1970s.

digits are turned into a single picture. In terms of storage, most of the pictures in this book required more disk space individually than the entire (typeset) text.[8]

Illustration is to clarify – to make clear, pure or transparent. Visualization does not aim to see through the data; it aims to see into it. Methodology is about transforming reality to fit particular conceptions. The more we simplify, the more reality is blurred. Turning people and the events of their lives into numbers is bad enough. Throwing away almost all of those numbers is worse, and yet this is what we must do, in one elaborate form or another, if we are to try and understand without images.

1.4 Texture and colour

> *Colour is most useful, after position, to show information ... Colour deserves more attention than the others, especially in view of the hope for synthesis.*
>
> *(Tukey and Tukey, 1981, p. 193)*

If we are to envisage information we must first know what can be seen as well as what there is to see. To decide how to turn numbers into pictures we must know what pictures can contain and what is seen in them. The simplest pictures are constructed of pure black and white from basic geometrical shapes. What they contain, what the eye searches for, is pattern – from order, repetition, grouping and texture.[9] What the eye then does is to find breaks in that order and discover inconsistencies while ignoring irrelevancy. The eye does this because that is what it evolved to do, and to do so extremely quickly. In our minds we then compare what we see with what we have seen before; we learn to do that but evolved to be able to learn.

The eyes are constantly engaged in focusing, panning and zooming. They compare different sections of the image and home in on interesting detail (the eyes are designed to scan continuously – they cannot focus for long on a fixed point). The resolution of the eyes is enormous, but far finer at the point on which they are centred. This action can be enhanced when pictures are electronically produced, and can be instantaneously enlarged or reduced.

Research has provided explanations for some of the mechanisms through which vision may operate and suggests that it is easier for people to compare objects horizontally rather than vertically.[10] It also suggests that colour is an invaluable embellishment to basic vision (Box 1.2). It is wrong to think of it either as adding another dimension or merely supplying some further minor tagging of data to existing features of the graphic. It alters the character of the image.

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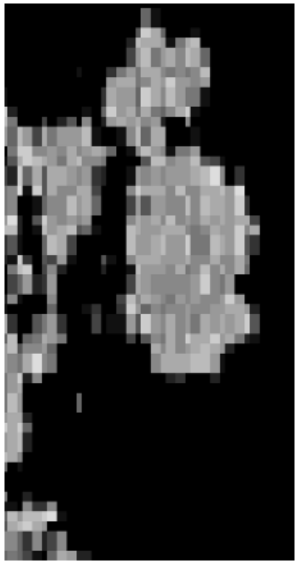
[8] Even the most complex image shown here could be fitted on a single 1.4 Mb floppy disk!

[9] See Bachi (1968), Hunt (1968), Tobler (1973b) and Levkowitz (1988, p. v).

[10] '... because the eyes are spread apart horizontally – as is, presumably, the spatial medium they feed – they have a greater horizontal scope' (Kosslyn, 1983, p. 71).

Box 1.2 Printing in colour

The device first used to print the colour illustrations in this book was a ColorView 5912 plotter printer manufactured by CalComp in 1988. The plotter could produce pixels of eight colours by overlaying sheets of magenta, cyan and yellow film with an A4 resolution of 2048 by 1600 pixels. A greater range of colour was possible by using dithered patterns of the eight colours actually available. On-screen text could be more satisfactorily produced through the use of anti-aliasing techniques built into the computer software.



A driver was specifically written to convert red-green-blue output from the screen to the magenta-cyan-yellow form suitable for printing.

Each colour print, originally A4 size, could have over three million individual *bits* of information, and took half an hour to print.

Different colours are perceived variably and convey loaded meanings on their own, even more so in combination. The human eye is poor at focusing on blue. Red and green do not combine to form reddish-green. Colour adds another level, but not dimension, of complexity. The careful use of colour can convey more of the depth of spatial organisation. In particular, when used in bivariate and trivariate mapping, colour can show how several variables are related to each other on a single map, although the keys are complex (Figure 1.8).

Trivariate mapping is both a contentious and potentially highly effective technique.[11] It has been suggested that the printer's primary triplet of cyan, yellow and magenta be employed[12] (or the computer's red, blue and

[11] 'It is far more difficult to distinguish the amounts of the three primary colors painted simultaneously onto a point in space, but it is possible (barely possible) to do so. Therefore a crude, but effective, way exists for displaying three functions of three independent variables' (Staudhammer, 1975, p. 183).

[12] '. . . maps with the same scale can be superimposed three by three. It is sufficient to transcribe them on three different color films: cyan-blue, yellow, magenta-red' (Bertin, 1981, p. 163).

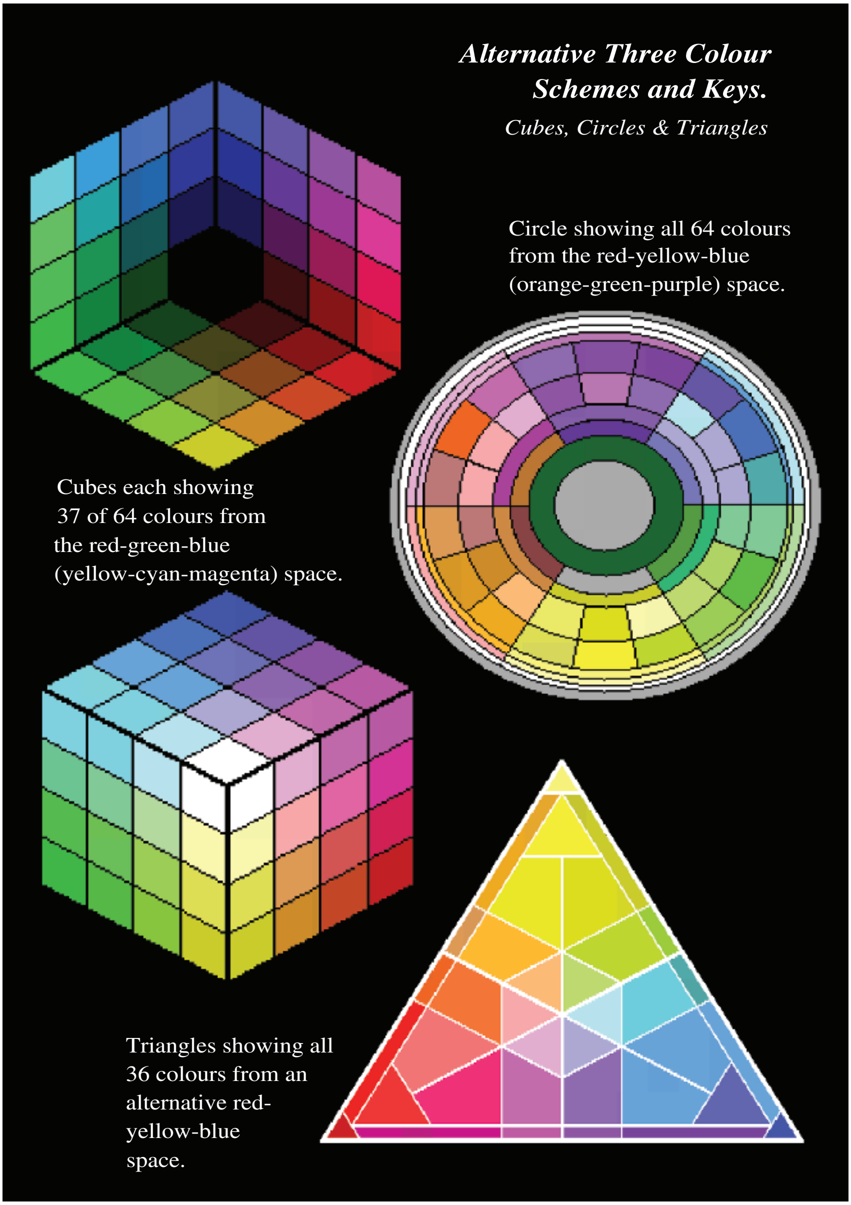


Figure 1.8 Several of the visual techniques that were used to define the various three colour schemes in this work are shown. The triangle was eventually deemed the most successful. However, as in a triangle, the three quantities must sum to unity; it is only showing a two-and-a-half-dimensional range. The colours here vary slightly from those intended and produced by the original printer used. Note: these four images were originally produced as a bit-map of pixels of colour not as a vector graphics files and so are pixilated.

green)[13]. However, in this book I suggest that the most intuitively appealing combination is the painter's red, blue and yellow – which fortunately also coincide with Britain's major political parties' symbols and also with national colours, and have many other useful associations.

1.5 Perspective and detail

Generalization, if you wish to call it that, occurs spontaneously in all perception. Complex though a map may be, the mind derives from it a simplified pattern.

(Arnheim, 1976, p. 9)

The most powerful ability of the eye–brain working in combination is generalization.[14] The brain only ever sees through the constantly changing light intensities, which are measured by the retina. These are analysed by the brain to allow instant assumptions to be made, before more careful inspection is undertaken (Figures 1.9, 1.10 and 1.11). Such ability is essential to our survival in everyday life; it was even more so in the past. Through visualization we are utilizing one of the most finely tuned pieces of evolutionary good fortune.

We live in a three-dimensional world, despite having as near to two-dimensional vision as often makes little difference. Perspective is the name given to the effect of projecting a three-dimensional scene on to our two-dimensional retinas; we use it to try to reconstruct three-dimensional form. Although we do have binocular vision, if you close one eye you lose little feel for the three-dimensional reality. For the most part we move about in two dimensions and, in fact, have a far weaker grasp of the real three-dimensional world than we may imagine (as illustrated here in Chapter 9).

It is often claimed that expensive equipment which allows volumes (commercially known as '3D') to be created and seen is at the forefront of visualization. Stereoscopic vision, though, might not be as great an asset to visualization as it is often thought to be in seeing the real world. Stereo vision works well at gauging position when nothing is moving behind or in front of anything else. Once things begin to move, though, it can become a confusing irrelevancy. In visualization, if we want things to move, then it is usually through animation that they move.

Animation can be used for much more than understanding three-dimensional form. As the creation of a changing or moving image, it can add another level of sophistication to two-dimensional visualization. However, like colour, animation (employing time) is not the same type of dimension as the spatial. In animation

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[13] 'It is possible to express a trivariate distribution by mapping each variable onto one of the dimensions of (red, green and blue) color space' (Sibert J.L. 1980, p. 214).

[14] See Tobler (1968, 1969, 1989b), Rhind (1975c), Lavin (1986) and Herzog (1989).

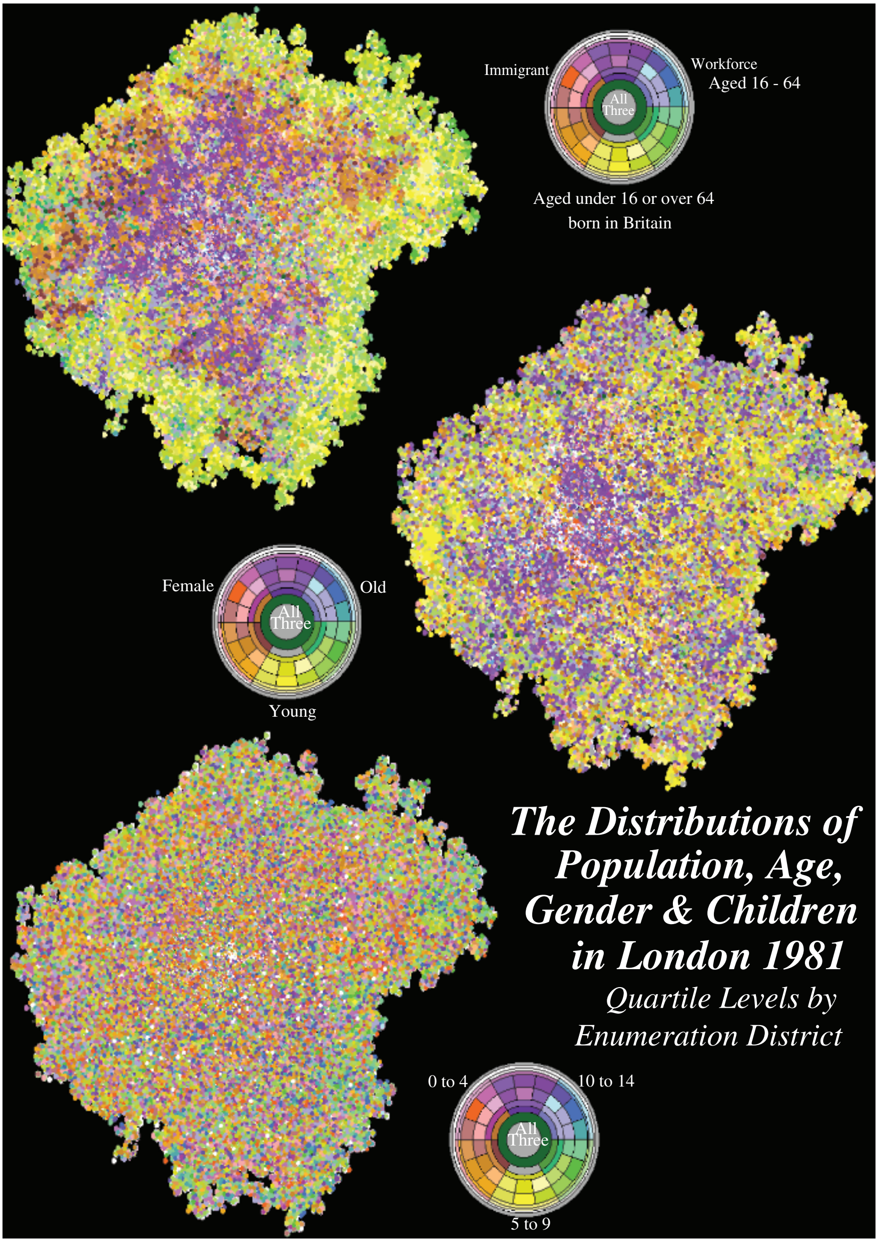

Figure 1.9 Showing three equal population projections of the 16 975 enumeration districts of the 1981 census in London. Here the scales are set to highlight the distributions within the Capital. The centre is dominated by people who have migrated in, by the old and by slightly more of the youngest children, before they move outwards. The images show these are generalisations.

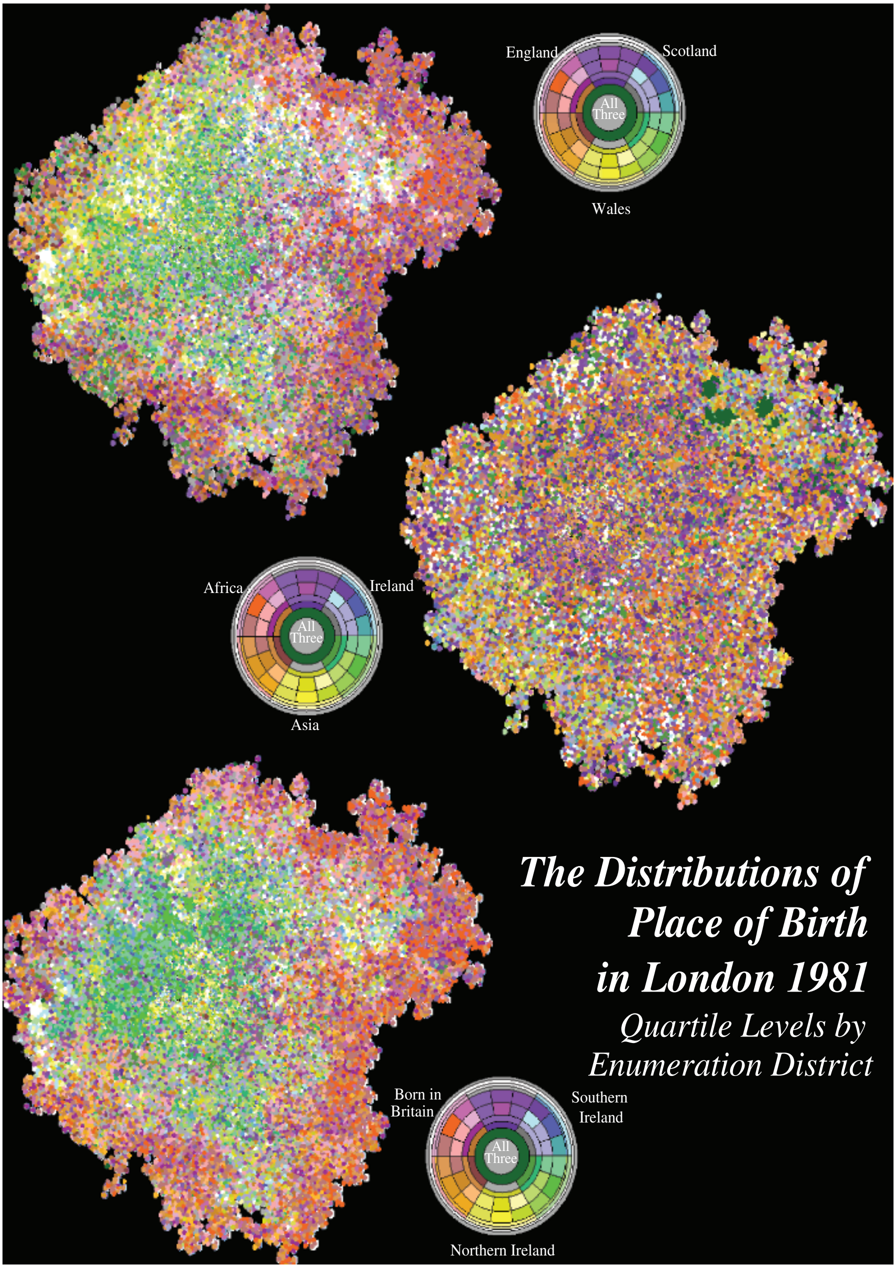

Figure 1.10 The Scots and Welsh dominated the West end of the Capital in unusual numbers, while those from other countries were, by 1981, more spread to the East. The Irish immigrants tended to fill the holes left between the patterns for other nations. North and South of the Irish border are differentiated here to illustrate how they were subtly differently distributed in London then.

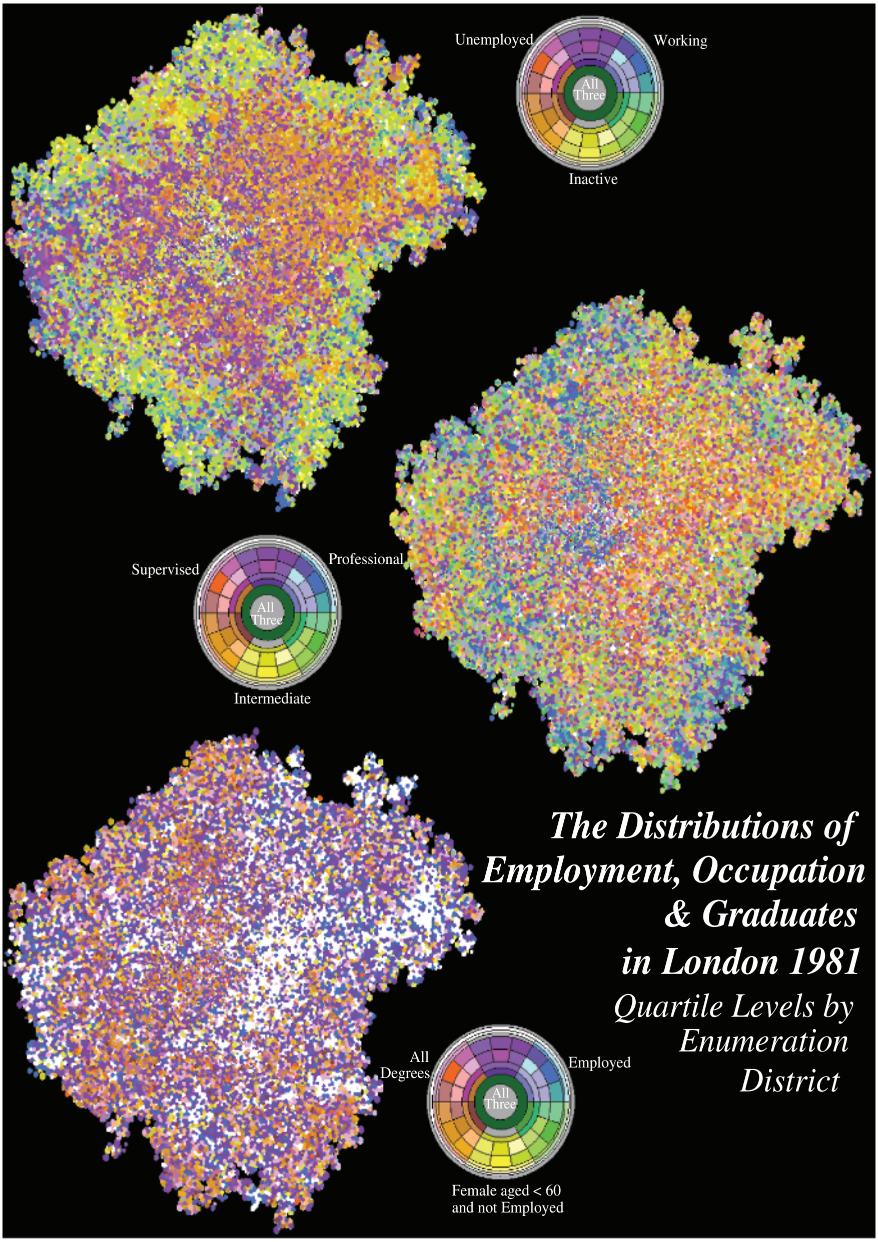

Figure 1.11 Notice how these three sets of three distributions mirror each other. A serpentine streak of affluence snakes through the centre of the City, closely flanked by areas of the highest unemployment and lowest job status. In the bottom picture, white areas are where all three categories were in the lowest quartile. More had degrees where women under 60 did not work.

things must change smoothly and relatively slowly.[15] If objects change their colour it can confuse; if too much is happening we will not have enough time to comprehend it.

Surprisingly, animation takes us back towards illustration. It requires simplicity to work. Far more useful are interactive graphics – moving pictures that the viewer controls. An App on a mobile phone is an easy contemporary example of an interactive graphic. The viewer has control. This is not only control over how fast or slow or where the pictures move, but simultaneously over what they contain and how they are presented. This interactivity is a possible next step in visualization that may allow more of the types of image shown here to be created, understood, manipulated and used.

1.6 Pattern and illusion

> *. . . the differences between maps and other forms of graphic information are not as great as they appear. All types of graphic information are different solutions to a common problem: our limited capacity to remember unprocessed information. By removing the limitations of short term memory, graphic information allows us to do kinds of thinking which are difficult or impossible in other ways.*
>
> *(Phillips, 1989, p. 25)*

We do not think in a three-dimensional geometry – many tests have shown this, although a variation in propensity for such thinking may exist between men and women.[16] The geometry of visual thinking is essentially two-dimensional. We also have a poor visual memory; we remember what we extract from images rather than the images themselves. Furthermore, the emotional overtones of colour are perceived differently by different people.

The colour blind cannot see the full trivariate range. Advocating trivariate mapping went against many of the embryonic tenets of visualization, but it is questionable how much they were guided by what was possible, rather than what was desirable. Why use the illusion of three dimensions if it adds so little information to an image while causing so much confusion? Perspective views

[15] In a visualization, involving animation is often best if objects don't move very much: 'Several trial films revealed one very necessary characteristic of animated mapping: simplicity and extreme clarity are essential. In a static map, the reader has time to interpret complex or unclear information. However, this is not the case in animated mapping where the image must be interpreted immediately' (Mounsey, 1982, p. 130).

[16] The kind of test that uncovers our general inability to think in 3D geometry is to try to imagine the shape made by a hot cube pressed, point down, into a think sheet of ice (Parslow, 1987). The answer is an equilateral triangle (if the cube is held steady). Many people say 'square'. Men are, apparently, on average a little better at such imagining than women. It is one of the very few tests where men do perform better. Researchers speculate that it helps in throwing spears better, but also that throwing spears may have been more important for impressing women than for catching meat.

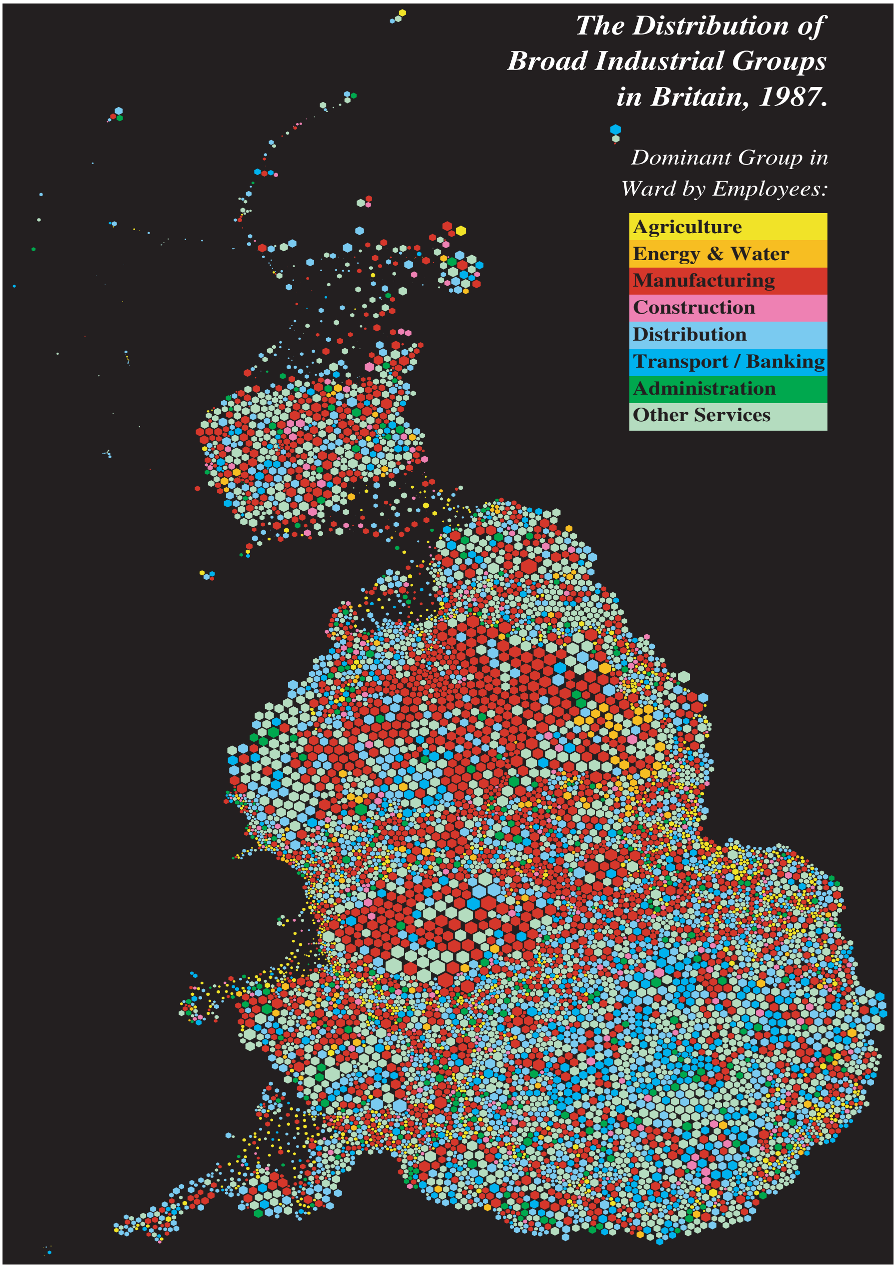

Figure 1.12 The 1987 census of employment by 10 444 frozen census wards on the equal population cartogram. Manufacturing industries were more dominant in Northern England and service industries more prevalent in the South, but both were mixed about the other. The coalfields of Yorkshire can be clearly made out (Energy), while agricultural workers are visible in smaller rural wards.

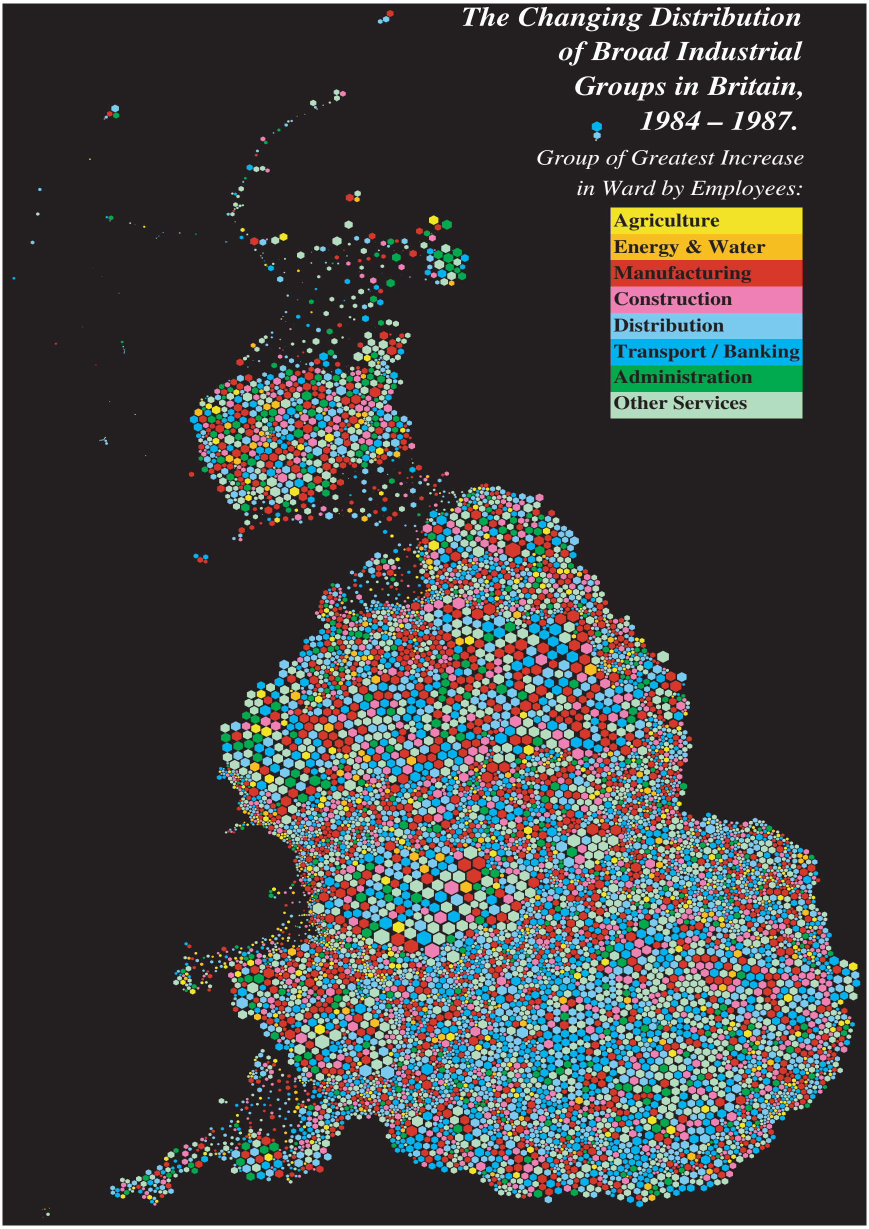

Figure 1.13 The changes show no clear pattern, although agriculture may have increased a little near many large towns. The blue and green of growing service industries became more common in the Capital, but expanding industries were scattered everywhere. This is only the change in three years and the industrial landscape tends to change more slowly than that.

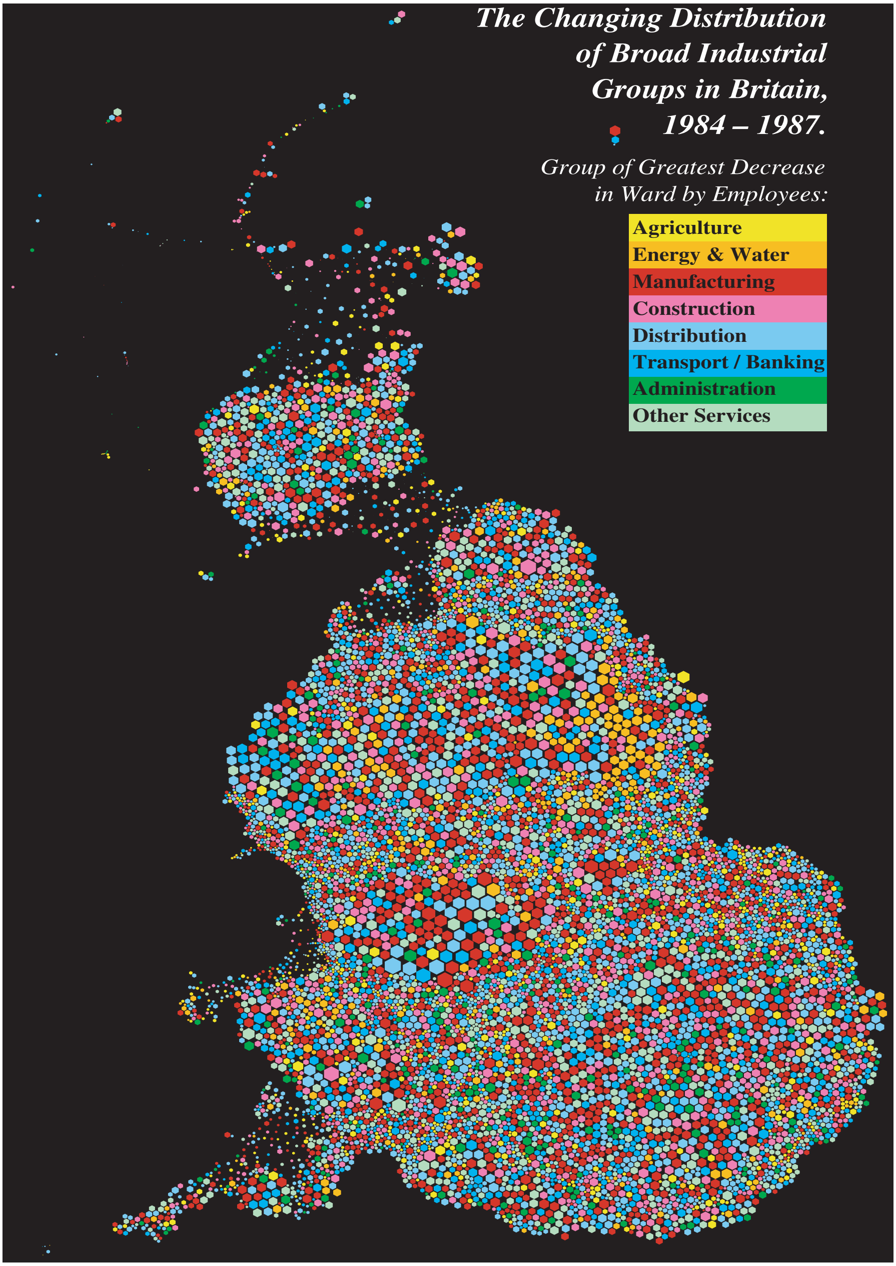

Figure 1.14 *The most noticeable pattern here is of the mining jobs, which were lost after the national miner's strike of 1984. They were lost in greatest numbers in Yorkshire, where support for the strike had been strongest. The National Coal Board was the biggest employer in many towns in that county. Manufacturing declined much more than service industries.*

are pretty, but not especially useful unless it is three-dimensional geometry in which you are interested.

Animation, like perspective viewing, is also not as invaluable as has been claimed. You cannot hold a moving picture in your mind as well as you can hold a static image, and comparison of two dynamics, of two animations, is very difficult.

Animation can tell a story. Visualization, more often, allows you to find a story to tell (Figures 1.12, 1.13 and 1.14). Much more importantly, with both animation and perspective views, you are limited to producing very simple pictures if you are to be able to understand them. Both perspective views and animation are included in this work and they produce nice illustrations, but until the viewer can easily control what is viewed, through interactive visualization, their utility is limited. Even if you are reading this on a Kindle (book reader) or on a different kind of computer screen, you (probably) cannot as yet spin the images in this book.

The use of colour greatly augments what can be seen in a two-dimensional image. However, use of colour is still expensive in publishing, even in 2012. Duplicating the prints shown here was almost impossible 21 years ago.[17] Colour can also invoke unintended ideas: good and bad, hot and cold, near and distant hues – but these can be used intentionally too.

In this book colour is generally not included to make the pictures prettier. I have used colour to include extra information in the image and to show how to display more complex data. Often it is added as a final embellishment to elaborate on how all is connected as other facets of the social structure are added as further elements in an image (Figure 1.15). Sometimes removing colour clarifies (Figure 1.16).

1.7 From mind to mind

> *That very ancient merger of Geography, Geometry and Graphics still exists and, if anything, with increasing vitality. Many breakthroughs still lie ahead. The map is the geographer's laboratory.*
>
> *(Warntz, 1973, p. 85)*

The argument in this chapter has developed from the initial desire to allow people to convey what is in their mind, in a form others can see, to the point where individuals are able to see and paint their own information. If we had all been mute and suddenly were able, with the aid of a machine, to make sounds,

[17] It may shock people today to read how expensive colour used to be, even more expensive than computers used to be: 'Currently, however, the cost of publishing two-color plates in some scientific journals represents more than half the cost of the laboratory computer that controls the experiment, stores the data, and displays the results. Therefore, the use of color figures (which can best present the results) might be hard to justify' (Long, Lyons and Lam, 1990, p. 138).

Box 1.3 Recording the places

All information about places, concise enough to be edited manually, was stored in ‘Comma Separated Value’ (CSV) files. These files can be read by many applications on different computer systems, in particular by spreadsheets – allowing complex manipulation to be easily accomplished. An example of the beginning of a CSV file containing information used to create a drawfile of counties is:

```
"$.GIS.Area.Ward.County.Sheet", 1,64,4
"County Topology and Statistics"
"Number", "Name", "Residents", "Neighbours", "Neighbour"
"1981"
1, "Greater London", 6713130,6,0,29,22,43,26,11
29, "Kent", 1467079,5,0,1,21,43,22
22, "Essex", 1474126,6,0,12,42,1,26,29
43, "Surrey", 1004332,8,21,45,1,29,0,24,10,11
26, "Essex", 1474126,6,0,12,42,1,26,29
11, "Buckinghamshire", 567979,7,43,26,34,9,38,1,10 ...
```

The first line gives the filename, number of tables, number of areal units and fixed variables. The second line describes the file, the third has variable names and the fourth holds temporal information. This header is followed by the relevant numbers and text for each place. Notice that the records can be in any order and of variable length. They are easily edited individually as this is a text file.

A library of procedures was written to manipulate these files, in particular to allow any other application to read and write to them, taking advantage of an interpreted language, which allowed the procedures themselves to invoke routines from the applications that had called them.

what sounds should we make? In the past we made sounds by knocking sticks together, so we get the machines to imitate those noises (drum machines). But surely, we think, is there more? According to Aristotle, ‘thought is impossible without an image’.[18]

Our vision has a much higher bandwidth than our hearing. We can see thousands of stars, watch sunsets, view landscapes and survey half a million people in a crowd. Naturally we begin to paint things by getting them to look like recognisable objects, chaotic functions to look like mountain ranges or an island archipelago, flowing energy to appear as running water. In this work pictures are often based on natural things that have two-dimensional structures, ranging

[18] ‘Memory, even the memory of concepts, does not take place without an image’ (Kosslyn, 1983, p. 5).

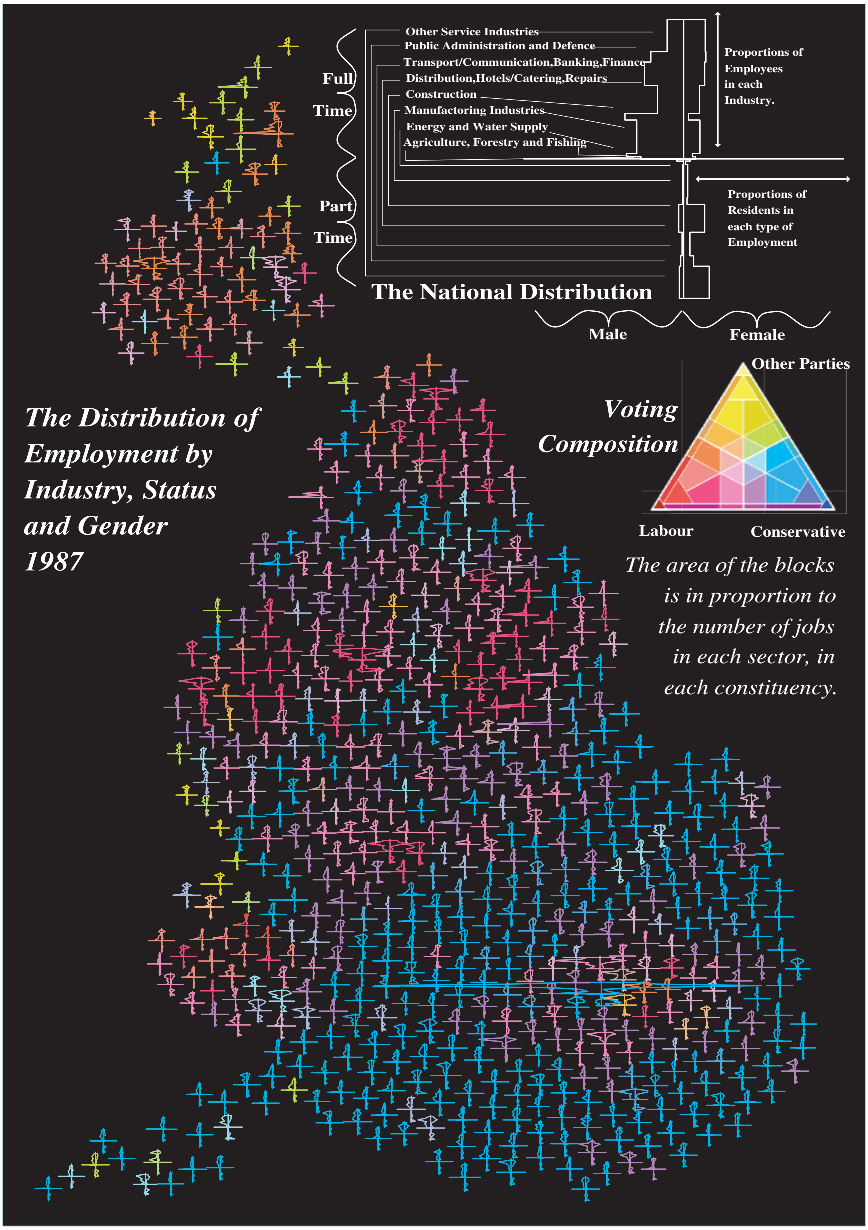

Figure 1.15 *The 1987 census of employment figures for 633 parliamentary constituencies on an equal population cartogram, coloured by the 1987 general election results. Each glyph shows the share of full-time employment by industry above the line, part-time below the line, male employment to the left, female to the right. The area within the glyph is proportional to the number of jobs.*

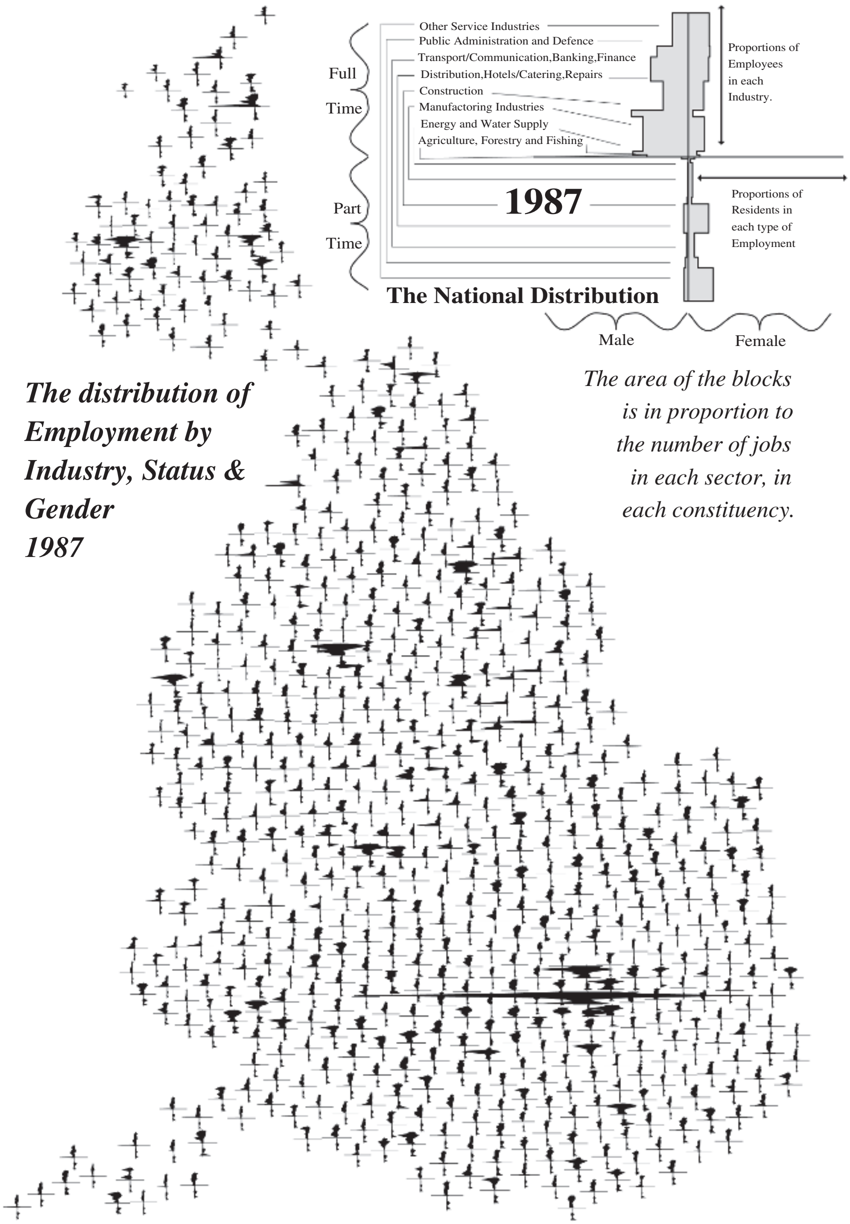

Figure 1.16 When the voting pattern is taken off this image and just the industrial composition of employment is shown other features become apparent. Regional service centres are clear with their mushroom-like structure. Although change is not shown here those areas that gained jobs did not necessarily swing to the Conservative Party who were in power and those that lost employment did not always turn towards the Labour Party.

Figure 1.17 *This series of images all show the Northern half of the 705 consistent parliamentary constituencies on the equal population cartogram. In the North the picture is dominated by the Labour Party. These are key frames taken from a video that shows how the vote swung to make Scotland the major Labour stronghold and took Northern Ireland away from the Conservative Party.*

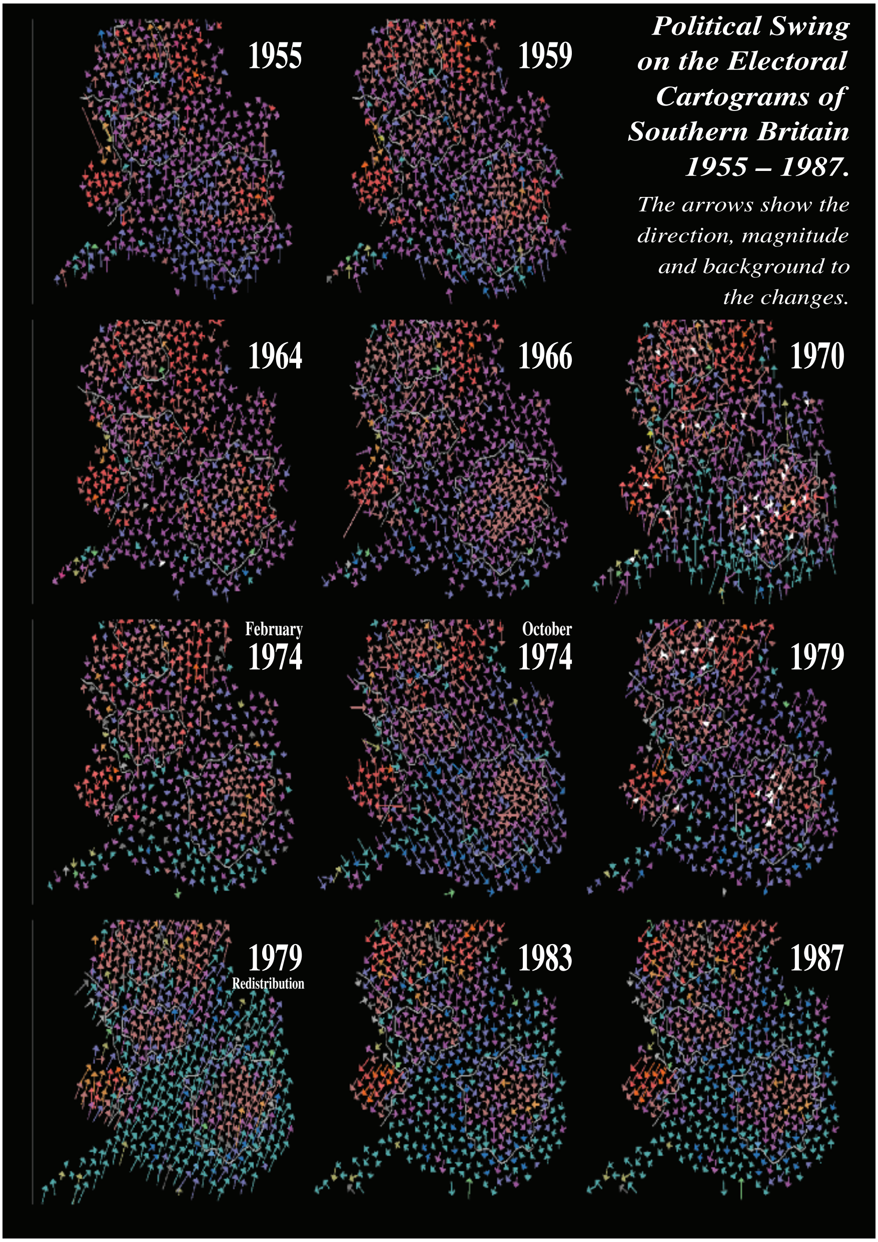

Figure 1.18 Southern Britain: the major conurbation boundaries can just be made out in the graphics. In the animation, to which these are the key frames, the arrows can be seen swivelling around between elections like so many synchronised swimmers, in near unison. The consolidation at the end of the period, as groups of places begin to move in different directions, is particularly well marked.

from honeycombs and cobwebs to crowds of upturned faces and flocks of arrows (Figures 1.17 and 1.18).

Here visualization is used to make millions of figures understandable without massacring their meaning, without reducing them to tables, graphs, crude maps or models. Visualization is not about simplifying; it is about revealing, through the process of aiding understanding. If we are to understand the structure of society we must find ways of imagining it. This book demonstrates how large amounts of simple information can be shown and then goes on to increase the potential of the graphics by conveying increasingly detailed information (Box 1.3).

The pictures shown here are of things that cannot be easily (or adequately) described, discussed or modelled, and yet many people who see them expect to understand them in an instant, even when they may fail to understand the long complicated narratives, which explain them badly, or the intricate mathematical models, which could represent them inadequately.[19]

If you want to know the shape of Britain you look at a map. You can then go on to investigate rivers and mountains, lakes and bays. Here you can look at the shape of 1980s British society – not the physical landscape but the human one. However, to know the shape you have to look at the picture, you cannot just describe it in words.[20]

[19] It remains the case that we cannot produce images at will. 'The unhappy thing about all this, of course, is that whereas I have the ability (and we all have the ability if we're sighted) to take images in at a fantastic rate, I have no ability to create images with the same facility. This is a one-way street. On the other hand, I can create language and symbols at about the same rate I can take them in, which means I can create speech at about the same pace that I can listen to it. So it is not at all unexpected that for most of us language seems to be the main carrier of our thoughts because that is the thing we can hear ourselves saying and were conscious of its use' (Huggins, 1973, p. 37).

[20] One day soon you may be able to create images as quickly as words, but at that point a new form of language will have been created. The last time humans invented a new form of language was when they became human over 60 000 years ago. It can take as long as 21 years to draw an image and then have it printed (as in this book). Try to imagine if that process took 0.21 of a second and then you showed me how you imagined it too. Do this and we have a visual conversation; we change the pictures in our minds as we draw them for each other, agreeing, disagreeing and learning.