Chapter 6
Anamorphoses as a Method of Visualization

Sabir M. Gusein-Zade and Vladimir S. Tikunov

6.1 Introduction

Development of a number of Earth sciences, connected with the spatial-temporal analysis, presupposes not only an improvement of methods of representation of spatially-coordinated phenomena, but also demonstration of their relations and connections with other phenomena, especially in cases when we are analyzing them as systems. Often it is necessary to examine changing over the space characteristics of several phenomena at once. It is more convenient to carry out such an analysis in the case when one of the characteristics is uniformly distributed over the territory and we are regarding all other characteristics against this one as the background. Of course such a situation is very rare and the idea to create it artificially arises. For this it is possible to transform the image of the phenomenon taken as the base from usual Euclidean metric of the space into a conditional thematic "space" of the uniformed phenomenon. Under the term "transformation" we understand a transition from the ordinary cartographic image, usually based on the topographic metric of the Earth surface, to another image, based on a metric connected with the phenomenon under consideration. Geographers express growing interest to such transformed images which are called anamorphoses. In other words anamorphoses can be defined as graphical images obtained from the traditional maps, the scale of which is not constant and varies depending on values of some indices, on which they are based.

S.M. Gusein-Zade
Faculty of Mechanics and Mathematics, M. V. Lomonosov Moscow State University, 119991 Moscow, Russia

V.S. Tikunov (✉)
Faculty of Geography, M. V. Lomonosov Moscow State University, 119991 Moscow, Russia
e-mail: tikunov@geogr.msu.su; vstikunov@yandex.ru

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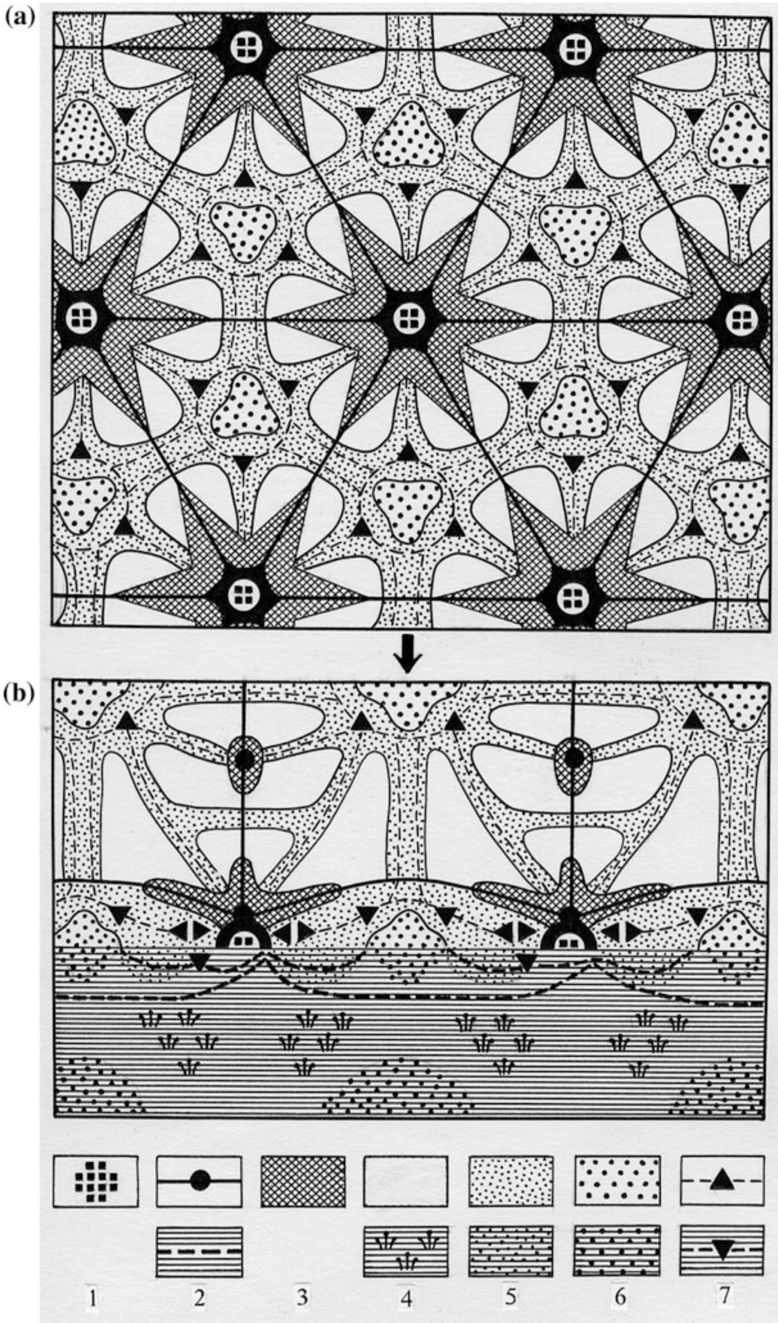
Fig. 6.1 Net polarized landscape on land and sea. Functional zones and ways of communication: ► **a** for a homogeneous plain inside a continent, **b** for a seaside. In the upper row of the legend for land, in the lower one for sea. *1* Urban historical-architectural reservations; *2* public service and utilitarian ways of communications; *3* permanent urban residences and manufacturing industry; *4* agriculture of high and medium intensity; *5* natural meadows, pastures, forest industry, hunting, suburban recreational parks; *6* natural reserves; *7* recreational residences and touristic roads (after Rodoman 1974)

In English speaking countries instead of anamorphoses terms including cartograms, transformed maps, pseudo-cartograms, topological cartograms and others are used. We prefer to use the term anamorphosis and to call an anamorphation (from the Greek word anamorphoo) the process of their creation. It seems that this term reflects the essence of the process, connected with the change of image proportions, more precisely. Besides that let us emphasize that this term is spread in a number of countries, first of all in the East Europe. In the Russian scientific language the word "anamorphosis" also has been used for a rather long time. Thus, as far back as well-known Russian linguist Dal' (1881) defined anamorphosis as a hideous but regularly deformed picture, which can be seen in a cut or curved mirror.

This definition coincides with one of the methods of creation of anamorphoses, which is still used today. However according to the contemporary concept of anamorphotic images the term "hideous" is hardly in its place. A transformation of cartographic images is produced for theoretical and practical purposes and serves as a tool of spatial analysis.

Anamorphated images differ from cartoids and from well-known mental maps (Gould and White 1974). Cartoids are abstract graphic images for compilation of which real spatial relations are not important, but there are shown some substantial characteristics: the main essence of phenomena, regularities in their allocation, in their development and in the reasons defining them. Examples of cartoids are: "the ideal continent", "typical relief forms", "inversion cartoid of the population system in Africa" (after Rogachev), reasons for rise of Moscow in the Russian state (after Saushkin and Rodoman), and polarized landscape (after Rodoman 1974; Fig. 6.1).

Mental images are graphic representations of ideas about spatial objects formed in human brains. They have been created by all of us when we drew schemes explaining, for example, how is it possible to find the desired place in a city. One can average such representations and obtain a collective mental image. A number of examples like characterization of different places of Los Angeles from the point of view of representatives of middle white, afro-american and hispanic-speaking population, ideas of Londoners about the North or the image of the world as it is seen from Van Hornsville village, USA (with such "provincial" centres as New York, London or Moscow) can be found in Gould and White (1974).


(a)
(b)
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6.2 Compilation of Linear Anamorphoses

Among anamorphated images one can distinguish linear, area and volumetric ones. Moreover all of them can be animated. Linear anamorphoses often look like graph images. Changes of lengths of edges of them permit to change the distances between the regarded units (vertices) depending on values of characteristics taken as the base of the anamorphosis.

As an example of characterization of time changes let us give linear anamorphoses (Figs. 6.2 and 6.3) which show changes of mutual transport remoteness of regions of Russia (Malinovsky et al. 2002). On them, there are drawn symbolic straight (azimuth) lines from the centre of Moscow connecting it with each centre of a subject of Russian Federation (and also with Surgut since Khanty-Mansijsk (the administrative centre of the Khanty-Mansi Autonomous Region) does not have a rail-road station). Then the value of the "price distances" from Moscow (Fig. 6.2) and to it (Fig. 6.3) in 1985 and 2001 are put on these lines with the chosen. As a result one gets linear anamorphoses depicting not only the "price" remoteness, but also its change.

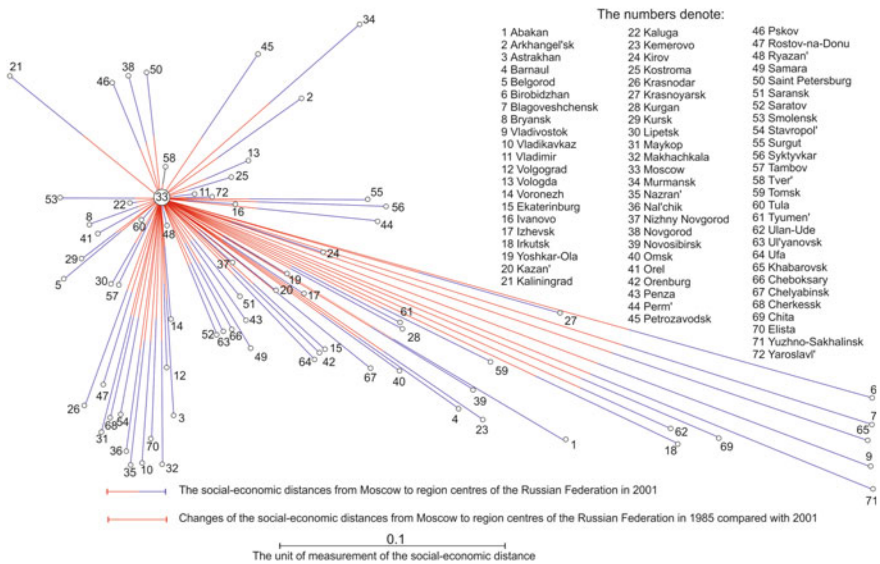

Fig. 6.2 Linear anamorphosis of change of the social-economic distance from Moscow to the centres of Russian Federation for the railroad passenger communications in 1985 and 2001

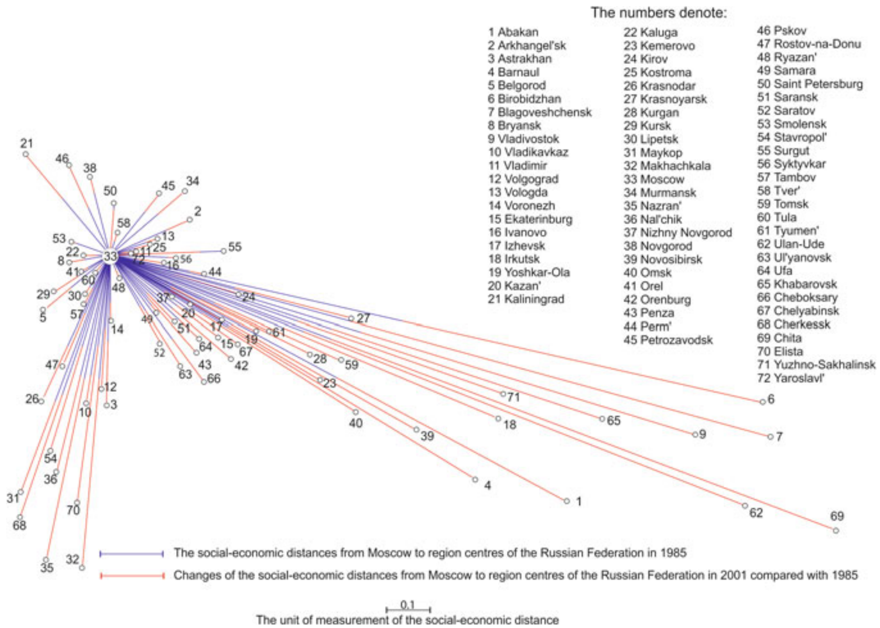

Fig. 6.3 Linear anamorphosis of change of the social-economic distance from the centres of Russian Federation to Moscow for the railroad passenger communications in 1985 and 2001

6.3 Compilation of Area Anamorphoses

Among anamorphoses the most widely distributed are area ones, which make uniform the density of an index (for example, the density of population, the density of the territorial distribution of incomes, the density of the territorial distribution of consumption of a product and so on). It means that in this case areas of images of territorial units become proportional to corresponding values of the index which is in the base of the anamorphosis. It is required that to the extent possible anamorphotic images preserve arrangement of territorial units with respect to one another and their shapes. Among compiled anamorphoses most often are found images, for which areas are proportional to numbers of residents of corresponding territories.

More rarely anamorphoses can be found in which gross revenue of population, gross yield of grain, gross national product and so on are shown. In the history of compilation and use of anamorphoses it is possible to find examples concerning very different fields. But most often they are used for representing various characteristics of population on territories, in electoral and medical geography, for representing quality of the environment, air pollution and so on (Levison and Haddon 1965; Forster 1966; Härö 1968; Ruston 1971; Malinovsky et al. 1977; Wonders 1980; Bochkareva 1981, 1983; Kadmon 1983; Pravda 1983; Selvin et al. 1984; Kelly and Neville 1985; Belov 1983; Uzan 1989). In spite of the variety of methods used earlier for compilation of anamorphosis, in this part of the paper we shall use only examples compiled with the algorithm, elaborated by the authors (Gusein-Zade and Tikunov 1993a).

First of all let us look at the images of the world. Let us give also a series of anamorphoses compiled by the authors on the base of data of the Department of Analysis of Economics, Social Information and Politics of the United Nations: actual and values of number of population of countries of the World for 1950–2050 (Fig. 6.4).

Countries are easily recognizable by their shapes (configuration). Of course the most attention is attracted by China and India. In Asia only Mongolia and Laos look more than unpretentious against the background of their encirclement. It is interesting that even such little “specks” on the initial map as Hong Kong and Singapore turn into considerable territories on the anamorphosis. Australia is “shrunk” rather heavily. In Africa, which is rather modest compared with Asia and even with Europe, first of all attention is attracted by the “ball-shaped” Nigeria. The most contrasts are inherent in Europe—compare the “tiny” Benelux and the countries of Scandinavia. Respectively uniformly are populated countries of America with the exception of Canada and Greenland.

Putting on an obtained anamorphosis characteristics connected with population, for example, the provision with food products, we shall get a more adequate impression about e.g. its deficiency. It will be so because it is related not to the territory, as it is on traditional maps, but more correctly—to the population which is needy in it. Now let us look at the second anamorphosis, compiled on the base of the data on the gross national product (Fig. 6.5).

Contrasts here are even sharper than on the previous one. First of all are striking three world “centres of welfare”—USA, Western Europe and Japan. Some countries of Europe are so heavily deformed that it is not easy to recognize them. However whereas in Europe the word deformation means expansibility, in Africa this process goes in the opposite direction. The majority of countries of Western and Central Africa are simply merged with each other. There are distinguished only the South African Republic and some oil-extracting countries. It is interesting to look at India and China—the leaders of the previous anamorphosis. Here they look more than modest. The relation between the areas of China and Hong Kong on the anamorphosis is curious. Australia acquires a more “worthy shape.” In America all other countries look unpretentious against the background of the “moneybag”—the USA. Alaska has been included into consideration as a separate territory (in the sense that its own gross product has been attributed to it). It led to its “compression” into a narrow strip.

The almost regular rectangular shape of the islands of Puerto Rico and Trinidad is explained by their small sizes on the initial map. Therefore they were digitized very roughly, only with the use of four points each. On the anamorphosis their territories become more noticeable. The series of anamorphoses of the World can be easily continued (Figs. 6.6, 6.7 and 6.8).

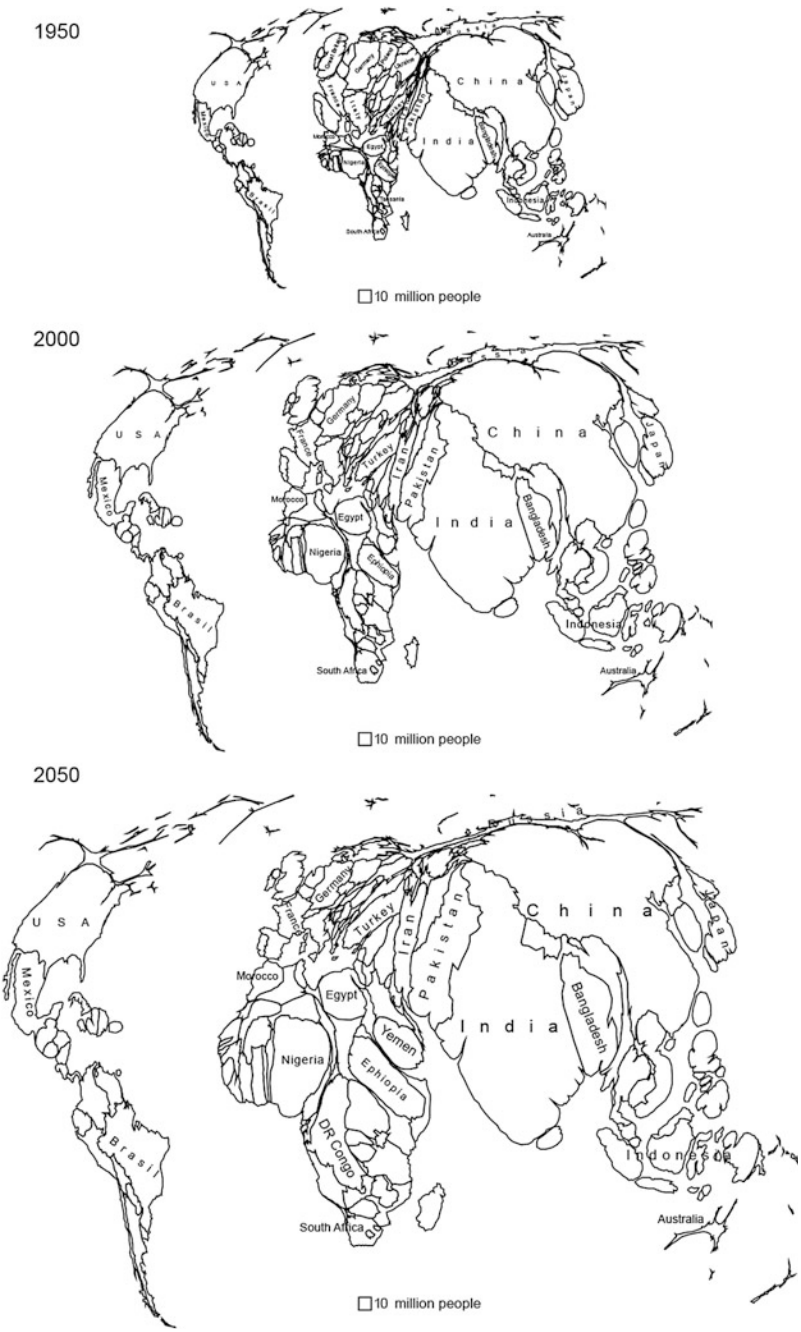

Fig. 6.4 Anamorphoses of the world compiled on the base of numbers of population of countries for 1950, 2000, and 2050

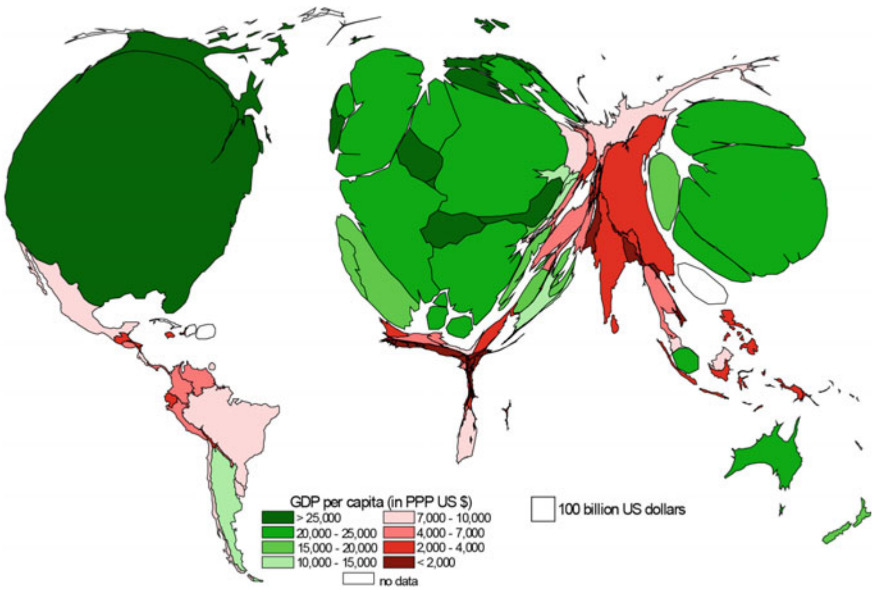

Fig. 6.5 Anamorphoses of the world compiled on the base of gross national product for 2003

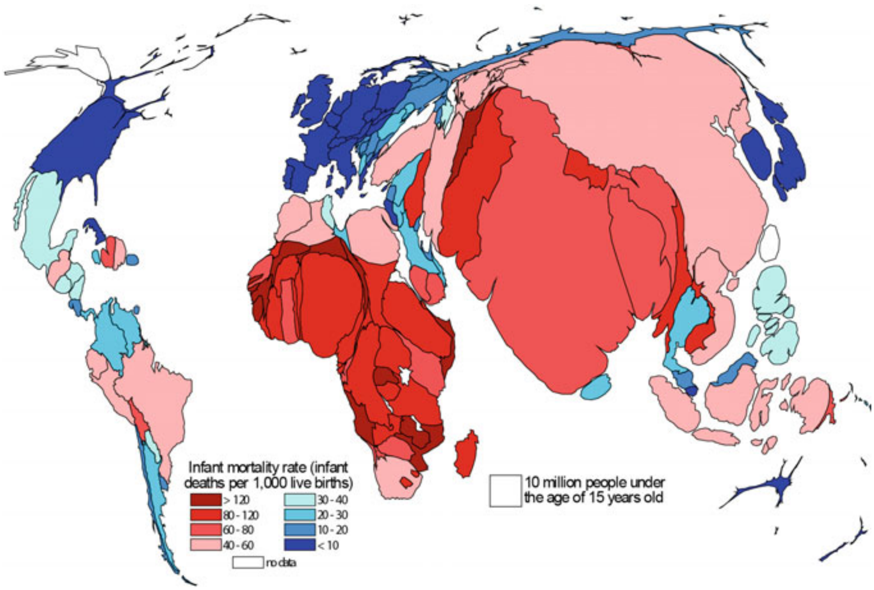

Fig. 6.6 Anamorphoses of the infant mortality, 2001

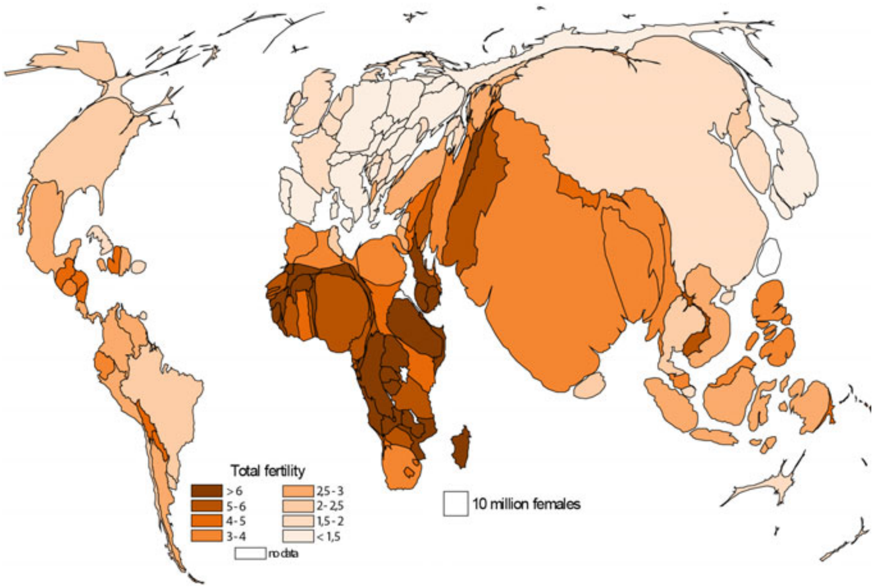

Fig. 6.7 Anamorphoses of the fertility, 1995–2000

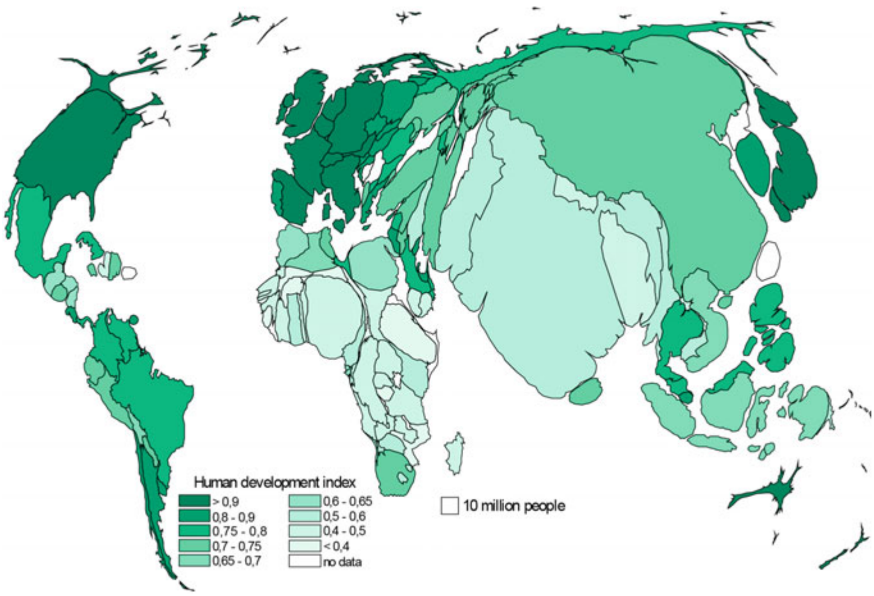

Fig. 6.8 Anamorphoses of the human development index, 1999

6.4 Compilation of Three-Dimensional Anamorphoses

It is known that classical cartography offers a widely used series of methods of representation of images such as colour, shading, symbolic marks etc. With the use of usual methods (for example, of column diagrams) one can show a lot of indices simultaneously (up to 30–40 of them), as one may meet on social economic maps. However, clearness of such a map drops catastrophically and the quality of its perception start to approach the quality of perception of the data table on the base of which it was compiled. Just because of that, on maps, one tries to use different representational means. Besides that, the effectiveness of the used representational method is of importance.

There were elaborated a method of compilation and use of a new style of representation, which, in principle, is somewhat similar to the classical method of column diagrams, but possesses a number of advantages and a higher effectiveness of representation of an index used for mapping. The essence of the method (Bogomolov et al. 2002) is the following. Assume that there are given two indices required to be mapped, for example, the real GNP and the number of population for countries of the World. In the example under consideration the indices were taken for the year 1996. Note that the real GNP is the GNP measured in international dollars on the base of parity of purchasing power of currencies. The international dollar has the same purchasing power with respect to the GNP as the US dollar inside United States. The real GNP of developing countries is usually considerably bigger than their nominal GNP and reflects the level of the well-being of their population more adequately. In contrast to that, the potential of interaction of the real GNP (i.e., of the GNP measured on the base of the parity of purchasing power of currencies) is determined by the value of the nominal GNP, which, in developing countries, usually is lower than the real one. In accordance with the number of population and the GNP, one compiles anamorphoses; the results are the three-dimensional images shown on Figs. 6.9 and 6.10.

Any one of them can be used as the base one. In the discussed examples the number of population was used as the base of anamorphoses and the GNP was shown on its background. For each country (if a country has several disjoint parts, then for each part) one chooses a point used as its “centre”. The choice is made manually; the necessary condition is that the point is inside the contour of the country (if a country has several disjoint parts, then for each part respectively). The choice of centres is made in the Cartesian (X; Y) system of coordinates on the anamorphated image. All points of the state boundaries are assigned with the value of the Z-coordinate equal to zero and all centres of states get the value of Z equal to the value of the index under consideration (in our case—the per capita real GNP). If now using the obtained set of points one constructs the corresponding surface (automatically, using the method of Delaunay triangulation), one obtains a set of polyhedral pyramids with bases coinciding with the country territories and with the numbers of faces equal to the number of vertices used for digitizing the boundaries of the countries.

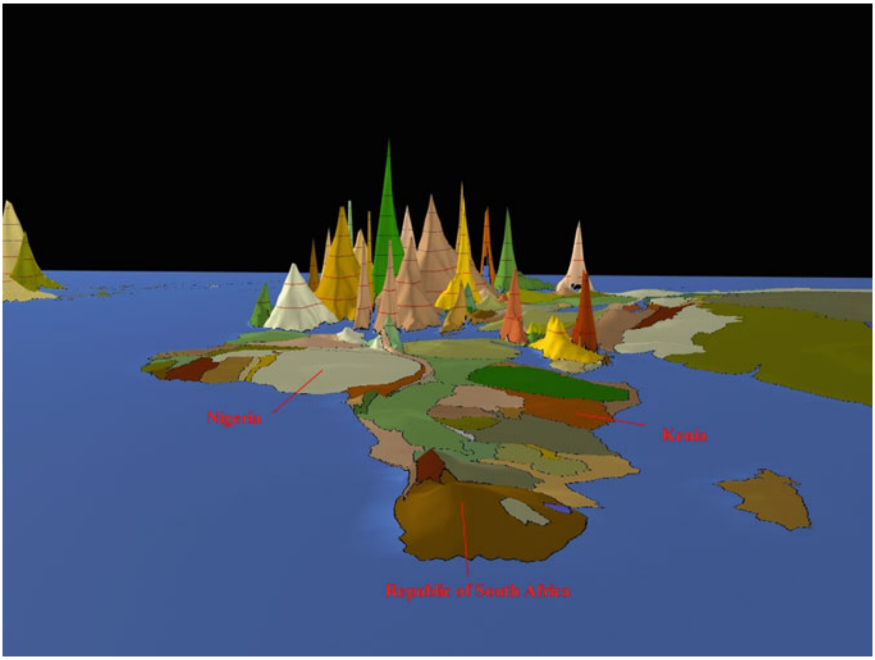

Fig. 6.9 Example of three-dimensional anamorphoses of real GNP

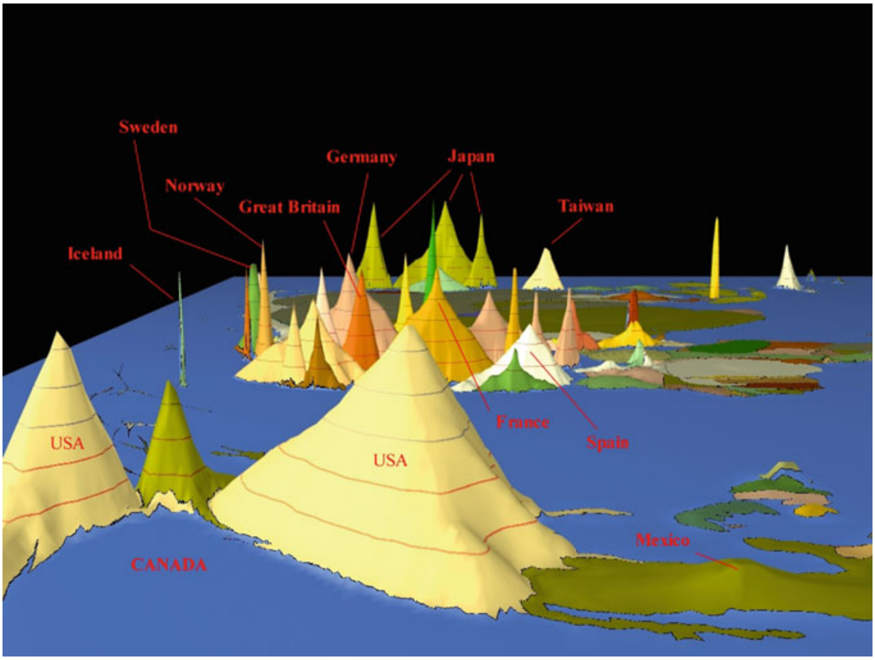

Fig. 6.10 Example of three-dimensional anamorphoses of real GNP

The anamorphosis of the World based on the population possesses the following property: the area of each country on it is proportional to its population. The height of the constructed pyramid is proportional to the per capita GNP. The volume of a pyramid is equal to $V = SH/3$, where S is the area of the base, H is the height of the pyramid. Therefore the volume of the constructed pyramid is proportional to the GNP of the country.

Let us note that it is somewhat difficult to compare GNPs of two countries by sight, since the outline of each pyramid is unique and all of them have rather irregular shapes. As a positive feature of this image, for sure, one should consider the showiness of the resulting image. It is more easy to make comparisons and to detect anomalies. One depicts two indices, in fact without using methods generally accepted in cartography, keeping them as a reserve. All the information about the two characteristics of objects are contained in the image.

It is also possible to construct column diagrams based on an anamorphosis, however the result is read and apprehended not so well since some countries cover other ones, countries with low GNP surrounded by neighbors with high GNP are simply not seen. The zero level is not well seen. Pyramid diagrams are free from this defect. They show the zero level for each contour of a country. One has a good field of vision, practically each country can be seen.

The technology of creation of such images is rather simple. The construction of the image was based on the political map of the World and the data on the number of population and real GNP for 1996. The initial map of the World was transformed into an anamorphosis using the algorithm of Gusein-Zade and Tikunov (1993a, b). The resulting data (files with the coordinates of points and with the topology of objects) were converted into the geographic information system (GIS) ArcView 3.0 format for subsequent export into the raster format *.JPG. There were exported two files of equal size rasters: one black and white (1) with contours of country boundaries and the other one coloured (2) with a unique colour shading for each country. The black and white raster was automatically converted into the vector format and polygons were attributed with central points with the help of the program Raster2Vector (Able Software). The result was saved in a file of *.SDL format and then converted into a *.CON file.

The latter one was the starting-point for the program DEMI, which constructs surfaces for a given set of irregularly arranged points. The result was saved in a file of *.DEM format, which represents a regular net of points with determined heights. With the help of a converter the file was saved in the *.BMP format (with grades of gray: more white for higher levels and more black for lower ones). After that (on the base of the obtained BMP file) the package 3D-Studio MAX 2.5 produced, from a regular net of size 300×300, the three-dimensional surface with the pyramidal block-diagrams. After that this surface was covered by a coloured raster image: for making it easier to use the image. Since for a detailed consideration of the surface one should look on it from different sides, there were created several images of different regions of the World.

6.5 Animations

As in the case of area anamorphoses, three-dimensional anamorphoses can be animated. Some general remarks first. With the start of the era of personal computers, which permit to reproduce full scale videos, one equates a possibility to show an object in dynamics to increasing the dimension of the initial static image by one level. Dynamic 2D-images (for examples cartograms where values of an index are shown by colour) are, as a matter of fact, three-dimensional.

Dynamic data for a series of indices are often met in the socioeconomic cartography. Construction of dynamic 2D images for each of the indices became a rather usual event. Analysis of one cartofilm is also not complicated. It is also possible to construct a cartofilm for each of the indices. However, it is somewhat difficult to find correlations between them. Thus we have arrived to the essence of one of the problems: depicting several dynamic indices simultaneously without constructing additional dynamic maps of correlations. To consider the problem, let us use three indices: population, per capita GNP, and average length of human life. All the indices were taken for each country of the World for the last 30 years. Showing the dynamics of all three indices on one model using methods of classical cartography is rather complicated. However, a solution can be the following one.

1. The population of the World: for each year one constructs an anamorphosis of the world population. Each of the images is two dimensional. If one shows the images subsequently, one after another, we see "inflations" and "compressions" of different countries. Since the images are raster ones, for each country let us choose a point which is not displaced for all the period and is situated approximately at the centre of the country and let us determine its XY-coordinates. One apprehends even small shape changes well enough and therefore the dynamic of the phenomenon can be seen very well.
2. Expected length of human life: its dynamics may be represented by colour. Let us choose a multi-level colour scale (say, 100 levels of colour) so that each level of the index is denoted by one colour). According to this, the dynamics of the length of human life in each country is reflected by a sufficiently continuous change of its colour. This is also well apprehended.
3. Per capita GNP. For that one uses the method of 3D-pyramidal block-diagrams. The essence of the method is as follows. Assume a 2D map of countries (or of other territorial units). For each country one chooses (by sight) a centre (X; Y) and the corresponding value of the Z-coordinate is the per capita value of GNP for this country in a given year. All vertices of contours of countries have their own XY-coordinates and let the value of Z for them be equal to 0. If, for the obtained XYZ-mass, we construct the surface in 3D space and, for better orientation, cover it by the initial 2D map, we shall see that each country became "a mountain", the base of which has the shape of the country and the height is proportional to the value of the index under consideration (per capita GNP in

our case). The initial two-dimensional map may be both the classical political map of the World and an anamorphosis, static or dynamic. A necessary condition is that XY-coordinates of the “mountain summit” for each country should not change in time.

Taking into account all discussed above, there were constructed dynamic pyramidal block-diagrams for GNP, moreover their “summits” were kept (on the image) at the same places and their heights changed in time. Shapes and areas of bases of these “mountains” changes depending on the country population (a dynamic anamorphosis). At the same time each “mountain” changes its colour in complete accordance with the expected length of human life. To make such images metric, values of the indices can be simply written over the summits of the “mountains”. It is also possible to draw the level lines. “Dimension” of this image is very high. Indeed, a static non-coloured image would be a visualization of a certain surface. In time there are changing heights of the “mountains”, shapes of their bases, and their colours.

6.6 Conclusion

Completing the chapter let us fix most essential reasons for practical use and perspective of anamorphoses. First of all, and this is not the most principal, they are convincing as illustrations, which permit one to imagine visually some non-evident facts and even to see some hidden geographical regularities. For example, theoretical principles of W. Christaller and A. Lösch about regularities of arrangements of hierarchical systems of centres get their confirmation only in regions with uniform distribution of population. It is possible that search of regularities in arrangements of populated places in the plane with the uniformed phenomenon could make the Christaller-Lösch principle much more often observable or even universal. It has good prospects to use anamorphoses for optimization of arrangement of nets of education, medical facilities and other service centres which, in general should be distributed uniformly on the artificially uniformed demographic plane. In the second place, anamorphoses make the relations between phenomena more visual if they are analyzed on the background of an image based on characteristics connected with them. Thirdly, it is reasonable to use anamorphoses for prediction of development of diffusive processes which take place in a non-uniform environment. If one transforms the resistance to the development of the diffusion into the uniform one, then most probably the diffusion will develop concentrically from the initial point. Thanks to that it is possible to forecast its development in time and to represent it in a graphical form. To get the picture of the spreading of the diffusion in the non-uniform environment, one should restore the image into the initial form. Anamorphoses can be used for the study of the diffusion of pollutions in the atmosphere and hydrosphere and also for a number of other problems.

The same can be said about compilation of maps of transport accessibility, which are created on the background of uniform practicability.

Thus compilation of anamorphated images in a number of cases is reasonable for modeling the structure, interconnections and dynamics of geographical phenomena. We hope that anamorphated images will attract attention of geographers of different interests and will become not eccentric illustrations, but tools of real geographical analysis. This field can appear to be a non-upturned scientific virgin land, which will give a rich harvest after a skillful processing.

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