FUZZY KNOWLEDGE IN STUDIES OF SPATIAL PHENOMENA

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Abstract

The article deals with those lines of geographical studies where the fuzziness of geographical knowledge is the most obvious. Fuzzy ways to put the tasks and fuzzy definitions used by geographers are described, as well as the impact of fuzzy data. Fuzzy knowledge resulting from various stages of classification of geographical objects is presented as an example. Some aspects of fuzziness associated with cartographic representation of geographical phenomena are discussed. Fuzzy semantics of mapped objects in the Euclidean space are shown proving that the transition to some other metrics is sometimes necessary.

1 Introduction

In the process of creation and accumulation of geographical knowledge geographers regularly run into both "settled" knowledge which has been included in textbooks and manuals and forms the "gold reserve" of science and forming knowledge which is yet unadequately described indefinite and requires more precise definition. The aim of this article is to attract attention to this very block of geographical knowledge which has both theoretical and practical importance as it contributes to the classification of accumulated knowledge. Besides we shall address the problems of formalized construction which are of great importance for geoinformation technologies in geography.

Let us first of all note that we shall distinguish between data, information and knowledge which are considered to be synonyms in popular and sometimes in scientific publications. Difference in their characteristics in reference to cartography and geoinformatics is analyzed in [3]. The time succession of technical systems based on these notions is also noteworthy. According to the time of development at first data banks have been compiled, then GIS have been formed and, finally, knowledge -based, or intellectual, systems have appeared. The same was the evolution of interest shown by geographers to data, information and knowledge. This article will address merely knowledge which is the reflection of semantic aspects of geographical reality in human brains or in technical systems.

The most interesting problem is how to represent knowledge in technical systems. In publications on artificial intelligence knowledge is usually divided into subject, or popular, and individual, or empiric [1, 6]. Popular knowledge includes sets of data, from textbooks and other publications, for example. Individual knowledge is of empiric nature, it is based on the rules and approaches which the experts themselves cannot define clearly and unambiguously. The important feature of expert systems is that they are capable to work with both fuzzy data [7, 8, 13] and with fuzzy knowledge. Let us show the spheres the fuzzy nature of geographical objects is the most distinct.

2 Spheres of fuzziness

First of all, the way to put the problem should be discussed. Here are some typical examples of fuzzy problems: to optimize the country's ecological situation, to estimate the level of social and economic development, to find the most typical forms of land use, etc. Unambiguous delimitation of low and medium-developed countries is hardly possible; the line between them is indistinct, different researchers give different definitions of such a limit. though the existence of countries with different levels of development is beyond all doubts. In other words, when the task is put in "general", without exact criteria which are unambiguously defined and understood, it becomes fuzzy.

Turning from abstract categories, such as social and economic development of countries, to the most simple geographical notions we are still coming across the fuzzy definitions. For example, the notion of "a broad river" will undoubtedly have different parameters for Amazonian inhabitants and those living in desert. In different countries the notion "town" varies according to both number of population (which is also different in its values) and administrative status; thus the same settlement would have different status in different countries.

Fuzzy definitions used by geographers led, in their turn, to fuzzy knowledge. To characterize such facts the "fuzzy" logic is used in expert systems, and the indices of sertitude are used to estimate the degree of confidence in any statement [4].

Another factor causing the fuzzy nature of knowledge in the fuzziness of available data. It is mainly because of imperfect statistics which can be shown by a great number of examples. Fuzzy data of remote sensing can also cause the fuzziness of knowledge.

3 Fuzziness and classifications

Fuzzy nature of knowledge about geosystems is redoubled during data processing with the help of mathematical algorythms. Let us take various classifications widely used by geographers as an example. In the process of modelling the fuzzy nature of geosystem can manifest itself during: 1)the description of geosystems at the stage of determining tasks and aims of classification; 2)the selection of characteristic parameters; 3) the search for classification algorythms; 4)the selection of results of alternative classifications; 5)the selection of means to represent the results; 6)the assessment of how the results correspond to the aims of classification and the interpretation of conclusions [9].

Geographical publications have several times pointed out that the methods of the theory of fuzzy sets are quite useful for these purposes. According to this theory, proposed by L.A. Zadeh [13] and improved by other scientists, it is possible to attribute territorial units not only to one of the given classes (as standard algorythms of multidimensional classifications) but to several classes with different functions of belonging (in the case of transitional nature of units). Such classifications are quite purposeful when the real boundaries are fuzzy and transitional and it is necessary to consider this fact in the process of mathematical modelling and to depict it on geographical maps. The indistinct character of boundaries is sometimes regarded as their common feature [7, 10].

One should pay a special attention to the following statement: "It is necessary to point out the fact which has a vital importance. The classifications based on indistinct measurements of identity should always be regarded as only more or less acceptable and reasonable, as the lesser of two evils typical for the situation requiring the grouping of objects which can hardly be described or cannot be at all described by traditional means of formal characteristic. The matter is that such classifications have "fuzzy" nature themselves, therefore speaking of the identity of their results is quite senseless" [10, p.20]. Let us notice that the indistinct nature of a phenomenon can manifest itself even without the direct use of the theory of fuzzy sets, within the traditional methods of geography. The article [8] gives the examples of fuzziness at different stages of classification.

The possibility of accounting for the semantic aspects of classification of geographical objects during the application of expert systems should also be noted. While classifying such geographical objects as Moscow, Orel, Bryansk, a man won't hesitate to group them as "towns". But the same Moscow (Russian synonym for the Moskva-river) in combination with Volga and Lena will be classified as "rivers", while the words "orel"(Russian for eagle), "sokol" (Russian for falcon), "yastreb" (Russian for hawk) will be put to the group of "birds of prey". The same should be provided by an euristic system too, because geographers are usually operating with fuzzily indicated objects.

4 Cartographic aspects of fuzziness

A number of problems is associated with fuzzy nature of cartographic representation of geographical objects. First of all, there is a problem of characterizing the indistinct boundaries, especially those of natural phenomena. Drawing the landscape boundaries with solid lines we automatically teach school-children or students that the change of landscapes is sharp. However, the descriptive texts give another knowledge which seems to be much closer to reality. The representation of indistinct boundaries still has no adequate cartographic form despite the number of attempts made by scientists [2, 7, 8, 11, 12, 14]. Even the simplest cases of gradual changes of phenomena (fig.1,a) are more likely represented by techniques shown at fig. 1,b, c, d, than by those at fig.1, e, f, g.

Fuzzy nature of semantic parameters of thematic maps is even more difficult to represent. In case of classifying the countries according to the level of their social and economic development it is possible to identify those ones which undoubtedly belong to this or that level. But many countries would occupy somewhat intermediate position; and this fact should be represented on maps. As an example the maps showing fuzzy characteristics of external trade relations between Europe and the former USSR could be referred to [8].

Fuzzy knowledge could also appear due to the application of Euclidean metrics for those phenomena which have more important interrelations in other metrics. For example, the distance from a given site to other places in the town can be described more efficiently by turning to the metrics of time or transport costs, because they give more correct visual estimates used in the everyday life. If you ask your colleges how far their homes are, the usual answer will be expressed in the units of time (30 or 35 min., etc.), not distance. It is more important for people to know how long does it take them to travel from their place to their work than to evaluate the exact distance.

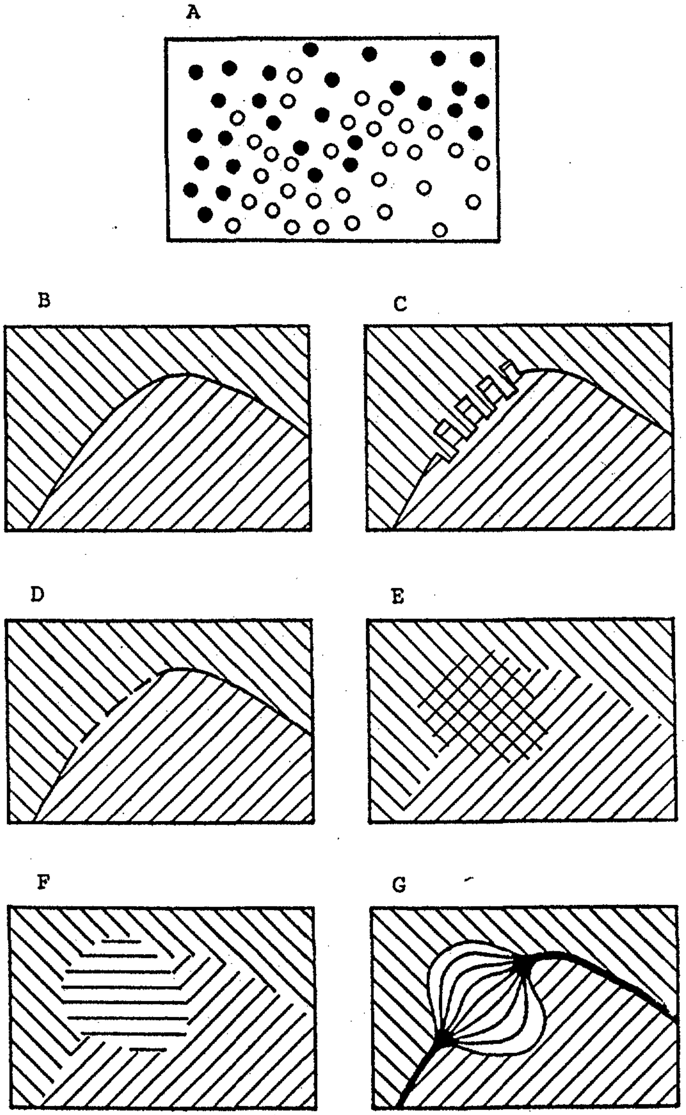

Fig.1. Examples of representing the fuzzy boundaries.

The same is true for areal anamorphoses. Techniques of their compilation are discussed in details in the article [5]. Fig.2 shows the map of the former USSR (within the 1990 boundaries) which bears the grid of political division units overlayed by the sickness rate values for infectious hepathite for the period of 1970-1985. Fig.3 represents the anamorphosis based on data about population numbers for 1990, which is also overlayed by the sickness rates for hepathite. Correlation of fig.2 and 3 shows that it is more correct to analyze the sickness rates using the anamorphesis which relates corresponding values to the population numbers, not to the territory as at fig.2.

A great number of spheres where the fuzziness is obvious results from the peculiarities of human perception of the surrounding world and forming the knowledge about this world. If these peculiarities are accounted for it becomes possible to improve the spheres to data acquisition, modelling of geosystems and their representation on maps. In its turn this would provide for more adequate knowledge about the surrounding world.

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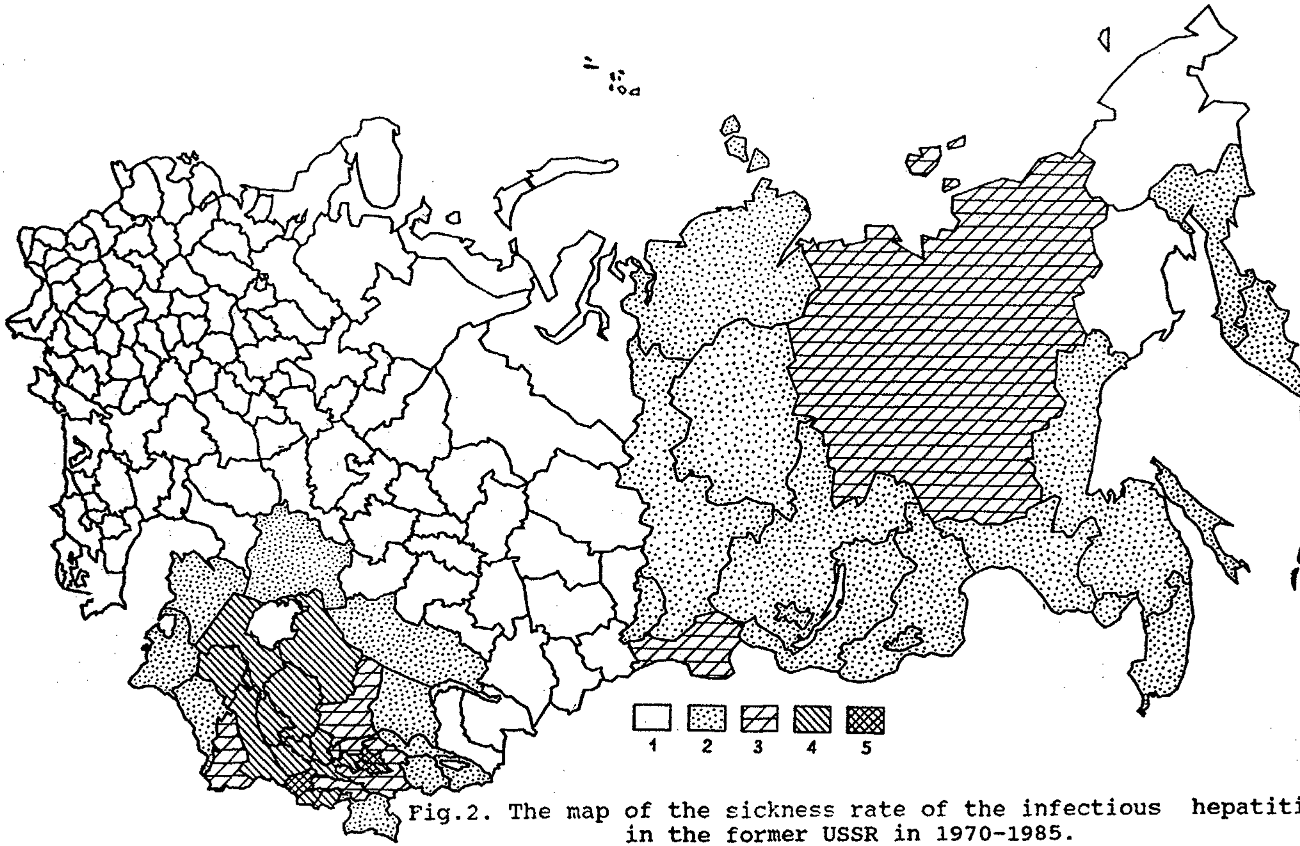

Fig.2. The map of the sickness rate of the infectious hepatitis in the former USSR in 1970-1985.
Sickness rate (per 100 000 residents):
1 - low (<200), 2 - middle (200-400), 3 - heightened (400-600), 4 - high (600 -800), 5 - very high (>800).

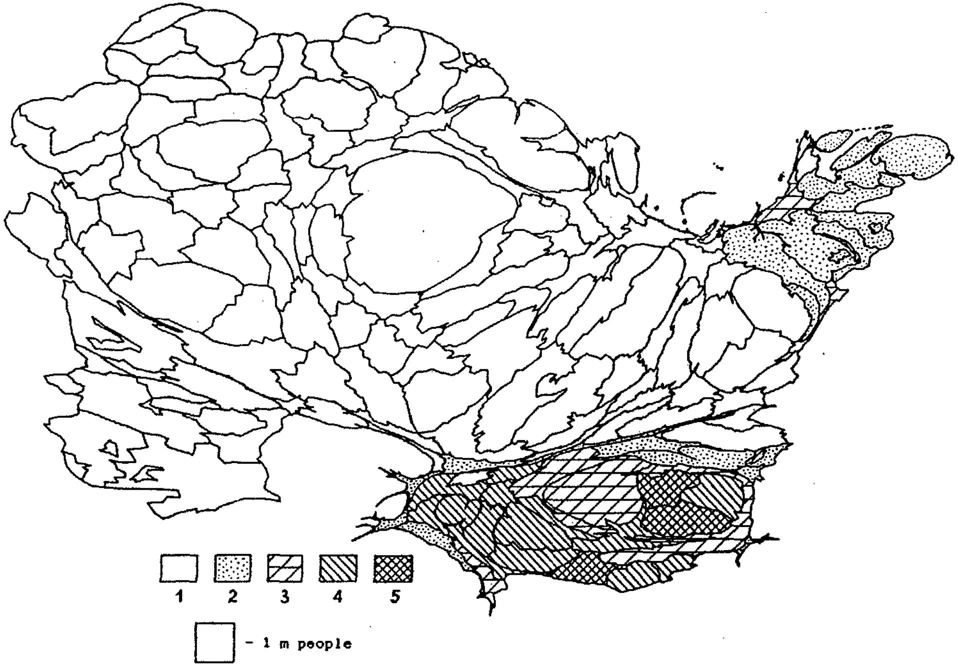

Fig.3. The sickness rate of the infectious hepatitis shown on the anamorphosis of the former USSR based on the data on the number of population (1-5 see fig.2).

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