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Wiktor Grygorenko

THEORETICAL PROBLEMS OF GENERAL CARTOGRAPHY

The increasing importance of the mathematical approach in sciences such as cartography (it asserted until recently that quantitative analysis was not possible) and the spreading use of computers made the scientists formulate anew the theoretical basis for cartography in terms of logical and formal concepts. The need for a new theoretical basis made the cartographers give up their old habits. It was also necessary to correct a false opinion about the purely illustrative role a map plays in the process of learning about the world around us and in the process of forming the natural environment so as to meet the demands of social life.

The first category to be defined in a new way was the concept of the map (Grygorenko 1973a) along with the function and the place cartography takes among other disciplines of science (Grygorenko 1984d). The subjective contents of various maps made on the basis of objective, mathematical elements permits to approach the map as strictly geometrical and graphic model of the Earth's surface on the one hand, and conceive the map as **the means of transmitting and supplying cartographic information** on the other. The outline of the map's contents in this sense is formalized to the extent which permits to present it as a numerical model, or, in other words, as the numerical description of both, the organization (structure) and the comprehensive characteristics of elements of geographical landscapes (Grygorenko 1982b).

These special features explain why maps remain an important, unigress in science and technology and the widespread use of computers.

However, traditional maps, where field objects and geographic phenomena are depicted by a code of graphic — pictorial symbols, need some modification. The need results from the already greatly advanced automation in map drawing and in studying its contents. The neversal means of **conveying information** about the phenomena occurring in the geographical space (Grygorenko 1984a, Ratajski 1971) and **the means of studying** them (Grygorenko 1977b), despite the general processary modifications can, naturally, concern mainly the graphic forms of maps, and thus be reduced to simplifying particular signs and their standardization in the general system of cartographic signs (Grygorenko 1984b).

The changes of conventional signs should be carried out in such a way, as to create a universal code of graphic markings, which, in turn, would allow automatic reading of the map's contents and transforming it into numerical form by a reading machine (Grygorenko 1973b, 1976b).

The contents of a map, when expressed numerically, can be subjected to interpretation by the digital method, as well as to the electronic processing (Grygorenko 1976a). The digital results of the processing can be transmitted to distant places, or can be used in preparation of cartographic office works on the spot, in such a way and approach as are required by the users, for example in the form of typologic maps.

The procedure of electronic processing of the cartographic information requires, obviously, the employment of the specialized electronic calculation equipment, mainly computers. The equipment for transforming the cartographic pictures into numerical form cooperating with the computer, and the electronic equipment for presenting the results of the processing of the numerical data in the form of pictures are organized to form an automatized cartographic system (ACS). The system is meant to facilitate the activities of the preparations and edition of maps and is a part of the general cartographic information system (CIS) (Grygorenko 1972a).

The functioning of the cartographic automatic system is impossible without the correct work of another link in the cartographic information system, that is the bank of information (IS) responsible for organising, gathering, storing and updating, as well as preparing and exchanging the cartographic data.

The preparation of the data on the socio-economic natural phenomena occurring on Earth for the cartographic information system is connected with numerous theoretical and practical problems. Many of them, being fundamental and applicable, have been subjects of research carried on in recent years at the Chair of Cartography of Warsaw University.

The most important tasks in the group of basic research include i.a.:

(1) Scientific systematization of the cartographic information, indispensable for processes of automatic organization, evidence, storing and searching for the necessary information and their source including book and graphic resources (Grygorenko 1979, 1984c).

(2) Co-ordination of the cartographic information on Earth with the help of a unified global system of co-ordinates (Grygorenko 1980a);

(3) Choosing of the cartographic projection in which cartographic information is presented on a map with a minimum loss (Grygorenko 1975a);

(4) Evaluating of the density and the degree of generalization of cartographic information on maps (Grygorenko 1975b);

The density of information D on the field phenomena studied directly in area A, or on the basis of resource materials M, and presented with the help of the set of symbols S, placed in the unit of the map's area, can be calculated according to the following formula:

$$D\ (S,\ M)=k^2\ c\ H\ (M)\left[\frac{\text{bits}}{\text{sing}}\right]$$

Where $H(M)$ is the entropy of the source, i.e. the entropy of the set of information on the basic material (in bits per sign), k — coefficient of the scale of information or the relation of the scale of resource material M to the scale of the map:

$$k=\frac{m_M}{m_S}$$

If the map is drawn in the field, or when $m_M = m_A = 1$, then the formula on the information density would take the simpler form:

$$D\ (S,\ A)=\frac{c\ H\ (A)}{(m_S)^2}$$

Where $c — 1 — G$; this is an index of effectiveness of information gathering which is related to the degree of generalisation (G) (Grygorenko 1975b, 1982a), or, in other words, information synthesis. The index of information generalisation (G) is equal to the relative entropy of information:

$$G=\frac{H\ (M/S)}{H(M)}$$

The above formulae make it possible to compare and evaluate the entropy of various resources of cartographic information, or, in other words, the study of the map's density of information.

To assess the density of the map by means of entropy one should select sets seperate object, i.e. set of settlements a_1, a_2, a_3, $...a_m$, the occurrence of which is characterised by the probablity p_1, p_2, p_3, $...p_m$. Next one calculates the entropy of each set of dot objects or the dividing line into dot objects by means of the formula:

$$H(M)=-\sum_{i=1}^{m} p_i \log_2 p_i \left(\frac{\text{bits}}{\text{cm}^2}\right)$$

Added entropies of sets of all objects making up the map's content will denominate the extent of the map's density. Two other important notions in cartography related to the idea of information density of the map are:
— information capacity of the map understood as the value of entropies of equally probable occurrences:

$$H_o (M) = log_2 m$$

— the reserve of the information capacity of the map or the extent of information density counted as deviation from the unity of the relative entropy of the map:

$$R = 1 - \frac{H\ (M)}{H_o\ (M)}$$

These indices along with some others discussed in our publication (Grygorenko 1982a) can be used in assessing the information value of the map.

(5) Numerical modelling of the content of general, thematic and special maps based on the information theory (Grygorenko 1982b).

(6) Mathematical modelling of the process of generalisation of cartographic information by using algorythm of automatic data processing (Baranowski, Grygorenko 1974; Grygorenko, Libura 1977a).

The most difficult problem in the respect of basic tasks in the theory of automatized cartography is the objective generalisation. Automatic generalisation does not take into account geographic peculiarities of the presented phenomena and their enviroment. This can lead to deformed or even altogether false representation of the generalised theme on the map.

Mathematical formalisation of the process of cartographic generalisation requires thus working out geographically justified, varied indices and standards that would describe quantitative and qualitative features of the particular constituents of field phenomena. The indices and standards should also characterize the relations in the accumulation making up different types of natural landscapes, geographical or economic regions.

There often arises a necessity to enlarge spatially small, but important objects in the process of scale cartographic transformation (Grygorenko 1972b) indispensable when drawing a map at a scale smaller than the original one. Cartographic out-of-the-scale signs or point signatures are applied in such a case. The enlargement of such objects in the areas densely cevered by them often leads to translocation of graphic signs. This brings about the contradiction between geometrical accuracy of the map and the conformity of the cartographic image of the map to the geographical requirements. The contradiction arises, when the limits of the map's graphic capacity are surpassed, or in other words, when all the graphic possibilities of diminution of cartographic picture (with limited density of signs) have been tried. This also happens when more complex (synthetized) elements of the map's content are depicted, when generalising the content of complex maps or when applying mathematical formulae in order to present the relations among various elements of the map's contents is either impossible or very difficult (Grygorenko 1980b).

Being very detailed, large-scale topographic maps are the best resource material used for drawing other topographic (thematic or special), maps. Although the minuteness of detail is very valuable in itself, it also causes many characterisic features of macrostructure of field objects. It can never be reconstructed in a traditional way (by means of generalisation when drawing small-scale maps). New possibilities, however, have been created nowadays thanks to satellite photographs of the Earth's surface. They make it possible to evaluate in an objective way the correctness of reflecting the singularity of big and very big field objects in cartographic (geographic) images of atlas maps. It is possible because a specific, not to say natural, macro-generalisation of external features of the landscape (spatial forms, water systems, the flora, geological structures, the exploitation of soli etc.) takes place when satellite photos are taken (Grygorenko 1976c).

As we know, general geographic, small-scale and atlas maps come as the result of generalisation of the content of resource material in the process of editorial work on the number of successive maps on continuously smaller scale. If these maps are thus compared with satellite photogtaphs, the resulting evaluation of geographical correctness of cartographic picture in these maps will also indirectly indicate if the rules formulated for the traditional, subjective generalisation are correct.

Periodically taken satellite photographs supply a lot of valuable information. It concerns not only the static state of phenomena, i.e. their spatial location, but also indicates the dynamics of changes. This brings about the present differentiation between the two kinds of generalisation: the traditional, spatial generalisation and the generalisation according to time and space. The examples of the latter type of generalisation are the master theses written at the Chair of Cartography of Warsaw University. They concentrate on changes of such phenomena as the occurrence of glaciers and icesheet, the reach of floods (Rybicka 1982), the vegetative development of the flora etc.

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