Construction of such algorithms requires the introduction of two additional cartographical terms, connected with computer presentation of thematic maps content. These terms are connected with the rules of coding cartographic data in the system of marked sites and with inadequacy of ranges of mapped thematic units and the system of networks of these sites. Such situation is schematically illustrated in fig. 1.

The point of the matter and limitation caused by the computer presentation of thematic map content in the system of marked sites is the possibility of presentation only one thematic unit in the given marked site. This unit receives the term a „basic unit" (representing the given marked site).

For improvement of the accuracy of calculations of a size of the mapped elements, in the course of coding arises a possibility of marking an occurence in the given marked site of the range of the second thematic unit which is designated as the term of an „occuring unit".

During the process of computer map elaboration the generalization takes place at the stage of coding the cartographic data, formation of the image of the basic thematic map, creation of the generalized files of thematic data and during the process of forming the resulting map.

3. Generalization in the course of coding the spatial distribution of the mapped elements

Coding the mapped elements of a map content relies upon assigning particular marked sites to thematic units distinguished on the map. The above mentioned inadequacy of the ranges of these units with the system of networks of the marked sites induces the necessity of generalization of the borders of contours of the thematic units in relation to the network of these sites. This operation may be called as the origin generalization.

This generalization is of essential meaning, because it is closely connected with preserving the spatial structure of the mapped elements, presented on the generalized map. Simultaneously, the principle of equivalent equisuperficiality must be strictly kept in order to preserve the superficial structure of the thematic units.

The base of the algorithm of this generalization is formed by the following cases:

1. The marked site $(P_{x,y})$ belongs to one thematic unit Jn: $P_{x,y} \in Jn$ (Fig. 2).

2. The marked site $(P_{x,y})$ belongs to two thematic units Jn and Jm. If the region occupied by one unit within the marked site is larger than

the region occupied by the second unit ($Jn > Jm$ or $Jm > Jn$), then $P_{x,y} \in Jn$ (Fig. 3) or $P_{x,y} \in Jm$ (Fig. 4), respectively. If the regions occupied by both units are equal (Fig. 5), i.e. $Jn = Jm$, the decision if $P_{x,y} \in Jn$ or $P_{x,y} \in Jm$ should be undertaken on the basis of analysis of spatial structure of coded part of the map and the determination which of these units will become the basis unit, i.e. the unit presented on the map.

3. The marked site ($P_{x,y}$) belongs to three thematic units Jn, Jm, Jp. If the region of one of these units is larger than the region occupied by each of the remaining units ($Jn > Jm$ and $Jn > Jp$ or $Jm > Jn$ and $Jm > Jp$ or $Jp > Jm$ and $Jp > Jn$) then $P_{x,y} \in Jn$ (Fig. 6), either $P_{x,y} \in Jm$ (Fig. 7), or $P_{x,y} \in Jp$ (Fig. 8), respectively. In the case when the regions of all units within the given site are equal (Fig. 9), i.e. $Jn = Jm = Jp$, then the decision whether $P_{x,y} \in Jn$ or $P_{x,y} \in Jm$, or $P_{x,y} \in Jp$ should be taken on the basis of the analysis of the spatial structure of the coded fragment of the map, and determination which of these units will gain the term of the basis unit, i.e. that presented on the map.

4. Cases of attachment of the marked site ($P_{x,y}$) to the greater number of thematic units do not occur in practice, and therefore they are not considered in the paper.

In the case of coding the map contents being characterized by a significant number of elementary units (for instance, soil cover), the direct presentation of which on the source map would be impossible, due to the necessity of preserving the legibility of this map, arises the necessity of an initial generalization of the thematic units content. It is connected with the process of inventory of elementary units and is performed manually by a specialist — cartographer. The algorithm of this generalization is comprised in the so called „generalization tables" expressing the principles of merging the elementary units into the generalized units.

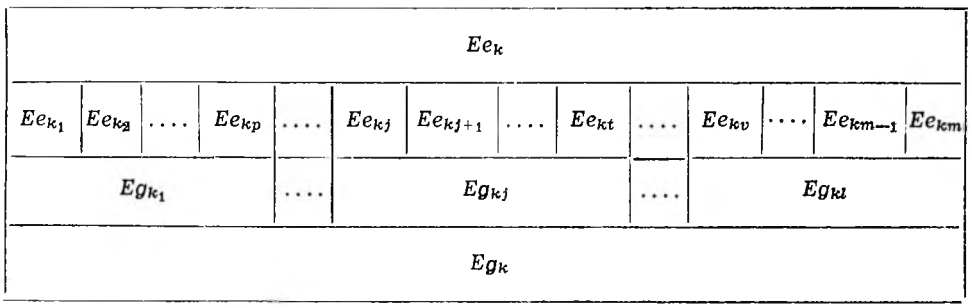
In some cases the initial generalization may be realized automatically by the computer.

It is possible in a case when particular elements of contents of the elementary units (Ee) maye be generalized and assigned selectively to appropriate elements of contents of generalized units (Eg). The model of such generalization may be presented in the following way:

J					
Ee_1	Ee_2	.....	Ee_k	.....	Ee_n
Eg_1	Eg_2	.....	Eg_k	.....	Eg_n
JG					

where

$k = 1, 2, \ldots, n,$
J — the elementary thematic unit,
JG — the generalized thematic unit,
Ee_k — the k-th element of the elementary unit content,
Eg_k — the k-th element of the generalized unit content



where

$i = 1, 2, \ldots\ldots, p, \ldots, t, \ldots, v, \ldots, m,$
$j = 1, 2, \ldots\ldots, l,\ 1 \leqslant l \leqslant m,$

Ee_{ki} — i-th distinguishing of k-th element of the elementary unit content,

Eg_{kj} — j-th distinguishing of k-th element of the generalized unit content.

Thus constructed model constitutes a basis for formulation of the following algorithm of generalization:

$J = \langle Ee_1, Ee_2, \ldots, Ee_k, \ldots, Ee_n \rangle,$
$JG = \langle Eg_1, Eg_2, \ldots, Eg_k, \ldots, Eg_n \rangle,$
$Ee_k = \langle Ee_{k1}, Ee_{k2}, \ldots, Ee_{ki}, \ldots, Ee_{km} \rangle,$
$Eg_k = \langle Eg_{k1}, Eg_{k2}, \ldots, Eg_{kj}, \ldots, Eg_{kv} \rangle \quad 1 \leqslant l < m.$

$$\left.\begin{array}{l} Ee_{ki} \\ Ee_{ki+1} \\ \cdot \\ \cdot \\ \cdot \\ Ee_{kt} \end{array}\right| \xrightarrow{G_p} Eg_{kj},$$

where

$1 \leqslant t < m,$

G_p — the operation of the simple generalization.

Elaboration of a certain system is connected with the necessity of preparing the generalization tables or algorithms of the initial generalization for these thematic maps, on which elementary units will not be presented.

Coding spatial distribution of the thematic units and their initial generalization are related to the regional part of the TEMKART system, because at this stage the elementary files of cartographic data will be formed.

4. The superficial generalization in the course of making the base thematic map

The determinant of the smallest area covered by the thematic unit, marked on the computer map, is the single marked site, the so called „one-site" contour. The possibility of its presentation is connected with specifications of the drawing of a map content, i.e. with dimensions of the part of a map covered by the marked site, and with construction of the identifying symbol of the mapped thematic unit as well as with preserving its legibility on a map.

In the TEMKART system, the marked sites serving to coding the map content, have approximately 10×10 mm, whereas their size on the resulting map is four times reduced, what gives the possibility of readable marking the smallest contour by means of single-character symbol. Sometimes such a procedure is impossible. Usually the number of symbols of recognition exceeds the number of characters or distinguishable graphic symbols. Then it is necessary to apply the multi-character symbols.

The investigations of the superficial generalization of the thematic content with reference to preserving the structures of space variability of the mapped elements displayed a possibility of including two bordering one to another marked sites, belonging to the same thematic unit, as the minimum area presented on the map — the so called „two-site" contour. Establishing of such determinant of the minimum contour allows to put into practice two — or three — sign symbols.

On the other hand, however, formulation of such a criterion implies the necessity of superficial generalization the essence of which (in the assumption) is liquidation of the „one-site" contours.

In order to construct the algorithm of this generalization, the following principles are assumed:

1. „One-site" contour occuring inside the larger contour of the thematic unit is included in this contour. This principle may be presented in the following form:

if $P_{x-1,\,y} \in Ji$, $P_{x,\,y} \in Ji$, $P_{x+1,\,y} \in Ji$, $P_{x-1,\,y+1} \in Ji$, $P_{x,\,y+1} \in Jk$, $P_{x+1,\,y+1} \in$
$\in Ji$, $P_{x-1,\,y+2} \in Ji$, $P_{x,\,y+2} \in Ji$, $P_{x+1,\,y+2} \in Ji$,
then $Kj\langle P_{x-1,\,y}, P_{x,\,y}, P_{x+1,\,y}, P_{x-1,\,y+1}, P_{x,\,y-1}, P_{x+1,\,y+1}, P_{x-1,\,y+2}$,
$P_{x,\,y+2}, P_{x+1,\,y+2}\rangle \in Ji$,

where

$P_{x,\,y}$ — the basic site designated by the x, y coordinates,
Ji — i-th thematic unit,
Kj — j-th contour of the thematic unit.

Distribution of thematic units within the marked sites and their division into contours is presented in fig. 1.

2. „One-site" contour occuring on the border line of two or more contours is included in the contour adjacent on the left-hand side. This principle facilitates computer drawing of the map content.

It may be presented as follows:

if $P_{x-1,\,y} \in Ji$, $P_{x,\,y} \in Ji$, $P_{x+1,\,y} \in Jk$, $P_{x-1,\,y+1} \in Ji$, $P_{x,\,y+1} \in Jp$,
$P_{x+1,\,y+1} \in Jk$, $P_{x-1,\,y+2} \in Ji$, $P_{x,\,y+2} \in Ji$, $P_{x+1,\,y+2} \in Jk$,
then $Kj\langle P_{x-1,\,y}, P_{x,\,y}, P_{x-1,\,y+1}, P_{x,\,y+1}, P_{x-1,\,y-2}, P_{x,\,y+2} \in Ji$
and $Kl\langle P_{x+1,\,y}, P_{x+1,\,y+1}, P_{x+1,\,y+2}\rangle \in Jk$,

where denotations as quoted above, and the distribution of the thematic units in the marked sites illustrates fig. 2.

3. In the case of the neighbourhood of two „one-site" contours, the „two-site" contour is formed and designated by the symbol of the unit being presented by the site occuring on the left-hand side or above the generalized site.

This principle has thus two variants:

I — if $P_{x-1,\,y} \in Ji$, $P_{x,\,y} \in Ji$, $P_{x+1,\,y} \in Ji$, $P_{x+2,\,y} \in Ji$, $P_{x-1,\,y+1} \in Ji$,
$P_{x,\,y+1} \in Jk$, $P_{x+1,\,y+1} \in Jp$, $P_{x+2,\,y+1} \in Ji$, $P_{x-1,\,y+2} \in Ji$, $P_{x,\,y+2} \in Ji$,
$P_{x+1,\,y+2} \in Ji$, $P_{x+2,\,y+2} \in Ji$,
then $Kj\langle P_{x-1,\,y}, P_{x,\,y}, P_{x+1,\,y}, P_{x+2,\,y}, P_{x-1,\,y+1}, P_{x+2,\,y+1}, P_{x-1,\,y+2}$,
$P_{x,\,y+2}, P_{x+1,\,y+2}, P_{x+2,\,y+2}\rangle \in Ji$,
and $Kl\langle P_{x,\,y+1}, P_{x+1,\,y+1}\rangle \in Jk$,

where denotations as in item 1 and distribution of the thematic units in the marked sites illustrates fig. 3.

II — if $P_{x-1,\,y-1} \in Ji$, $P_{x,\,y-1} \in Ji$, $P_{x+1,\,y-1} \in Ji$, $P_{x-1,\,y} \in Ji$, $P_{x,\,y} \in Jk$,
$P_{x+1,\,y} \in Ji$, $P_{x-1,\,y+1} \in Ji$, $P_{x,\,y+1} \in Jp$, $P_{x+1,\,y+1} \in Ji$, $P_{x+1,\,y+2} \in Ji$,
$P_{x,\,y+2} \in Ji$, $P_{x+1,\,y+2} \in Ji$,
then $Kj\langle P_{x-1,\,y-1}, P_{x,\,y-1}, P_{x+1,\,y-1}, P_{x-1,\,y}, P_{x+1,\,y}, P_{x-1,\,y+1}$,
$P_{x+1,\,y+1}, P_{x-1,\,y+2}, P_{x,\,y+2}, P_{x+1,\,y+2}\rangle \in Ji$
and $Kl\langle P_{x,\,y}, P_{x,\,y+1}\rangle \in Jk$,

where denotations as in item 1 and the distribution of the thematic units in the marked sites illustrates fig. 4.

4. If the greater number of „one-site" contours occurs side by side, the „two-site" contours are formed out of them, according to the principle given in the item 3.

5. „One-site" contours being the characteristic elements of the spatial structure of the thematic units are not generalized.

In order to make the perception of the above considered principles much easier, the set of marked sites used in the writing down of the algorithm is presented (see fig. 5).

In the case of occurence of rather small number of the thematic units being distinguished on the map, the algorithm of generalization can be based on the criterion of application of a hierarchy of similarity of the distinguished units, which can be established on the principles of an essential analysis of elements of their contents or in a formalized way by using the so called „identicality method" [1]. As a standard to the TEMKART system, the aggregation of sites in virtue of neighbourhood is assumed.

5. Generalization of thematic map contents connected with creation of generalized files of cartographic data

Creation of the generalized files of the data is connected with the scale conversion of the resulting maps. It is assumed that this scale will be two times smaller than the scale of the base map. Such line reduction causes fourfold surface reduction. This reduction is the determinant of the degree of the superficial generalization of the base map. It is expressed by the necessity of presentation of the content included in four sites of the base map in only one site of the higher order (corresponding to the spatial reference system of the resulting maps).

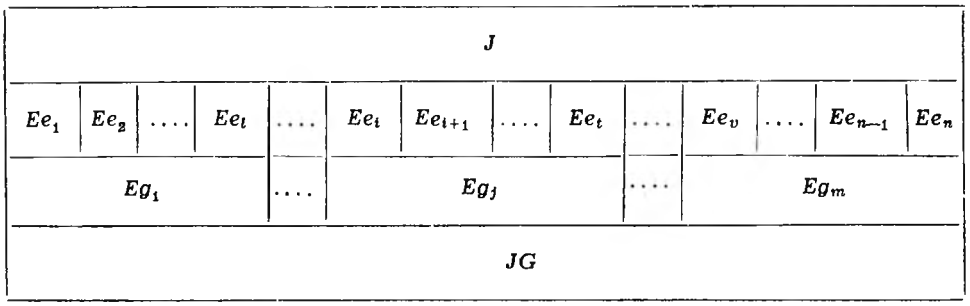
This principle determines the character of the algorithm of the generalization which combines two procedures: the essential generalization and the superficial (formal) generalization.

Considering the need of carrying out the superficial generalization, it is necessary to carry out the essential generalization first, since in the result of generalization of the thematic unit content the increase of the probability of identity of the content coded in the marked sites belonging to different elementary units is obtained. It causes the considerable limitation of the necessity of the superficial assigning of adjoining marked sites. The essential generalization should thus precede the formal (superficial) generalization.

Generalization of the content of the thematic units in the process of essential generalization depends on the degree of the compression of the content elements of the generalized unit.

If the compression of the content elements of thematic units does not occur, then we have to do with the simple essential generalization, the principles and algorithm of which have been discussed in the final part of Section 2. In the case of compression of the elements of content of the mapped thematic units, the complex generalization of meritum is applied.

Automatization of the process of this generalization is based on the following model:



where

$i = 1, 2, \ldots, l, \ldots, t, \ldots, v, \ldots, n$, $j = 1, 2, \ldots, m$, $n > m$,

Ee_i — i-th element of content of the elementary unit,

Eg_j — j-th element of content of the generalized unit,

the remaining designations as in the earlier parts of the paper.

The algorithm of the complex generalization, formulated on the basis of the above-mentioned model takes the form a follows:

$$J = \langle Ee_1, Ee_2, \ldots, Ee_i, \ldots, Ee_n \rangle,$$
$$JG = \langle Eg_1, Eg_2, \ldots, Eg_j, \ldots, Eg_m,$$

where

$n > m$

$$\left.\begin{array}{l} Ee_i \\ Ee_{i+1} \\ \cdot \\ \cdot \\ \cdot \\ Ee_t \end{array}\right| \xrightarrow{Gz} Eg_j,$$

where

$1 \leqslant t < n$,

Gz — operations of the complex generalization.

The complex generalization ought to be preceded by the simple generalization. Since its essence consisting in the linking of the elements

of content is expressed by assigning the specified determinants of the content element of the generalized unit of the lower order to the given element of content of the generalized unit of the higher order. Developing of this principle on the basis of the algorithm of complex generalization points out that the determinants of the greater number of elements of content of the generalized unit of the lower order may be assigned to the given element of content of the generalized unit of the higher order. Thus, the complex generalization algorithm may be precised as follows:

$$\left.\begin{array}{l} NEg_{kj} \\ NEg_{kj+1} \\ \cdot \\ \cdot \\ \cdot \\ NEg_{kt} \\ \cdot \\ \cdot \\ \cdot \\ NEg_{pi} \\ \cdot \\ \cdot \\ \cdot \\ NEg_{pi+1} \\ \cdot \\ \cdot \\ \cdot \\ NEg_{pq} \end{array}\right| \xrightarrow{Gz} WEg_{lw},$$

where

NEg_{kj}, NEg_{kt} — the j-th and the t-th determinants of the k-th element of content of the generalized unit of the lower order, respectively,

NEg_{pi}, NEg_{pq} — the i-th and the q-th determinants of the p-th element of content of the generalized unit of the lower order, respectively,

WEg_{lw} — w-th determinant of l-th element of content of the generalized unit of the higher order.

The essence of the formal (superficial) generalization illustrates fig. 6,

where

$P_{x,y}$ — the marked site determined by means of x, y coordinates,

$PG_{k,l}$ — the site of the higher order determined by means of k, l coordinates,

$B_{t,v}$ — the block of the marked sites determined by the column t and the strip v.

The algorithm of generalization formulated on the basis of such a scheme is constructed by the following principles of assigning of the marked sites within the given block ($B_{t,v}$), which have been additionally illustrated by graphs (see the Polish text, items 1 to 14 — given above), where the symbols of parameters are the same as have been given in the ealier part of this paper.

Such a formulation of the algorithm of the formal generalization renders a possibility of an analysis of homogeneity of contours on the resulting thematic map.

As can be observed on the presented figures, the principles of assigning corresponding to the items 6 to 11 and 14 have their mutations, considering the mutual position of the marked sites occupied by the thematic units different from *Jn*. However, for maintaining the clarity of the „essence" of the algorithm, these mutations have been disregarded here, because they do not influence the decisions of generalization.

The decisions of generalization of the equivalent systems (items 12, 13, 14) may be still more accurately defined by an investigation of similarity of the units included in the quaternary sequence of the marked sites with the units occuring in the neighbouring sites of the higher order (for which the process of generalization has been carried out). This fact, however, will complicate the algorithm, and will lengthen considerably the time of the study of the marked sites content similarity by the computer. It may be inadequate to the attained increase of fidelity of the projection of the spatial structure of the mapped elements.

The above-mentioned principles of the essential generalization will be applied in the national part of the system, in which creation of reference files (i.e. the reference information) by means of direct coding of the spatial distribution of the mapped elements is not foreseen.

6. Superficial generalization in the course of making the generalized thematic map

The sequence of the computer thematic maps resulting from succeeding stages of generalization is based on the succeeding twice reducing the map scale. It is connected with the construction of the spatial reference system, and in particular with the principle of transitions of quaterion of the marked sites of the lower order into one marked site of the higher order [2]. This problem has been analyzed in the former Section of the paper. It is of particular importance for computer drawing of the map, since it preserves the equidimensioning of the marked sites, creating the images of resultant maps.

The investigations carried out and dealing with the maximum approximation of the contours marked on the computer maps to their natural location and to the maximum preservation of natural shapes of the contours pointed out that the most rational dimensions of the marked site — representing the smallest area of occurence of the mapped element should not exceed 2,5 × 2,5 mm at the scale of the generalized map.

Preserving the same dimensions of the marked sites, independently of the map scale, allows to accept the principles of the superficial generalization utilized for making the resulting thematic maps — analogical to those as are in use in the case of elaboration of the base map. They are presented in Section 4.

If in the generalized file of data the information related to the homogeneity of the sites of the higher order will be comprised, then this information may be utilized for defining exactly the principles of generalization of „one-site" contours.

It refers to the case when the „one-site" contour borders upon two contours of different thematic units. The algorithm of the generalization may be then supplemented by an investigation of similarity of quaternary sequence of the „one-site" contour. The occurence in this sequence of the quarter identical with one quarter from the adjacent units will settle the question on the result of generalization of such a contour.

This principle may be utilized also in the case of symbolization of „two-site" contours composed of the different units.

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Translation: Regina Majewska

ЯНУШ ОСТРОВСКИ

ПРОБЛЕМА ГЕНЕРАЛИЗАЦИИ ТЕМАТИЧЕСКИХ КАРТ ПОЛУЧЕННЫХ С ПРИМЕНЕНИЕМ ЭВМ В ИНФОРМАЦИОННОЙ СИСТЕМЕ ТЕМКАРТ

Резюме

В работе представлены принципы генерализации карт полученных с применением ЭВМ на основе координатной сетки основных полей в зависимости от степени и формы обобщения содержания тематических карт.

Первый этап генерализации связан с кодированием пространственного размещения картированных элементов и обусловлен несовпадением границ картируемых тематических единиц с координационной сеткой основных полей. Это требует сохранения единства сочетания границ тематических контуров с координационной сеткой.

Второй этап генерализации осуществляется во время создания рисунка тематической карты и обуславливается предельным размером контуров представленных на карте полученной с применением ЭВМ. Заключается он в ликвидировании контуров с размерами одного основного поля и подчинения его соприкасающемуся или окружающему контуру.

Третий этап генерализации связан с изменением масштаба карты и размеров основных полей. Осуществляется он на основе принципа объединения состава основных полей с различным содержанием картируемых элементов, представленных на карте большего масштаба, в одно основное поле, являющееся элементом карты меньшего масштаба.

Проведенные попытки создания соответствующих алгорифмов дают возможность объективизировать процесс генерализации тематических карт и автоматизировать их редакцию с применением ЭВМ.

Перевод: Janusz Ostrowski