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The Problem of Displacement in Cartographic Generalization Attempting a Computer-Assisted Solution

(with 7 figures)

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SUMMARY: Starting from the results obtained from the investigation of practical cases of displacement in official topographic maps of the Federal Republic of Germany, an order of the map elements is proposed, which should be observed during displacement. Subsequently, complete solutions are given for three different cases (displacement of a road by a trigonometric point, displacement of a brook, partly covered by an exaggerated road, generalization of a double hairpin bend). These solutions free the cartographer from routine tasks thanks to the application of EDP and have the further advantage that they are to a great extent independent of the operator.

RÉSUMÉ: A partir des résultats obtenus lors de l'examen de cas pratiques de décalage planimétrique dans des cartes topographiques officielles de la République fédérale Allemande, l'auteur propose un ordre des éléments de ces cartes qui devrait être respecté lors de décalages. Ensuite, l'auteur propose des solutions élaborées pour trois différents cas de décalage d'éléments linéaires (décalage d'une route par suite de la conservation de la position d'un point trigonométrique, décalage d'un ruisseau couvert en partie par une route élargie, généralisation d'une double épingle à cheveux). Ces solutions permettent de libérer le cartographe de tâches routinières grâce à l'emploi d'un ordinateur et offrent de plus l'avantage d'être indépendantes de l'opérateur dans une large mesure.

ZUSAMMENFASSUNG: Von den Ergebnissen der Untersuchung praktischer Verdrängungsfälle in amtlichen topographischen Karten der Bundesrepublik Deutschland ausgehend, wird eine Reihenfolge der Kartenelemente vorgeschlagen, die bei der Verdrängung eingehalten werden sollte. Anschließend werden für drei verschiedene Verdrängungsfälle von Linienelementen (Verdrängung einer Straße durch einen Trigonometrischen Punkt, Verdrängung eines von einer überzeichneten Straße teilweise überdeckten Baches, Generalisierung einer Straßen-Doppelspitzkehre) fertige Lösungen angeboten, die es gestatten, den Kartographen durch Einsatz der EDV von Routinearbeiten weitgehend zu befreien. Diese Lösungen haben den weiteren Vorteil, daß sie vom Bearbeiter weitgehend unabhängig sind.

I. Introduction

Automation is applied in cartography to contribute to a more homogeneous and more up-to-date map face. It is already introduced in numerous worksteps of map production, like the automatic plotting of single points, graticule lines, ect. An important step, though, was eluded while dealing with automation: generalization. However, several papers have been published recently, which make the treatment of this field by automatic means possible, too [1]—[10]. A single step of generalization, displacement out of settlements, was so far considered only for general cases [11]—[13].

This paper includes the results obtained from the investigation of cases of displacement in maps of the FRG, a proposition about the order of map elements which should be observed during displacement, and finally algorithms for the computer-assisted treatment of single displacement cases of line elements. This paper is an extract of a dissertation [14].

II. Results of the investigation of displacement cases in topographic maps of the FRG

The material of the investigation consisted of the mapped representation of the areas Assmannshausen/Rhine, Bernkastel-Kues/Mosel and Dahlerau/Wupper of the official German map series at 1 : 5 000, 1 : 25 000, 1 : 50 000, 1 : 100 000, and 1 : 200 000 scale. In these map extracts, narrow river valleys with several traffic lines and buildings are shown. As the scale gets smaller, the available surface to represent these map elements which are particularly close together shrinks, their true position cannot be exactly kept while drawing the map at a smaller scale. Displacements, therefore, appear especially often and clearly. Furthermore, the examples of generalization, which are inclosed in the map specification for the 1 : 25 000 scale [15] were investigated, too, in order to include such areas where displacements are not so extreme.

As a result, the following was stated:

1. Trigonometric points are always plotted in their true position.
2. Normal gauge railways, superhighways, federal main roads, main and secondary roads, banks of rivers (as far as they are represented by two lines) alternate as axis of displacement (the element in the map which causes the displacement of all others is called thus).
3. The same applies to rivers (represented by a single line), minor roads, tracks and narrow gauge railways among one another.
4. The remaining map elements are displaced in the following order: paths, buildings, administrative boundaries, relief features, vegetation.

III. Suggestions about the order of map elements in displacement cases

The following considerations are to contribute to set up appropriate criteria of succession:

1. Trigonometric points are used as points of reference for all measures on the earth's surface.
2. Roads in West Germany have a part of 91% in passenger traffic and of 27% in goods traffic. Railways have a part of 7% and 40% respectively. (These statistics refer to the year 1973.) [16].
3. Rivers represented by two lines are, as a rule, a lot wider than roads and railways. If their banks are displaced on the map by a small amount in the direction of the middle of the river, the thus obtained narrowing cannot be noted by the naked eye.

4. Roads and railways facilitate the orientation better than small rivers, because they shape the landscape a lot more.
5. In the modern development of the infrastructure of an area, first the communication network, and then the plants, houses, etc. are built.
6. Administrative boundaries refer to the aforementioned map elements.
7. Relief features must follow the elements cited under 1−6, so that those do not appear in a wrong height.
8. In topographic maps, vegetation boundaries are of lower importance than the aforesaid elements.

For all these reasons, the following order should be observed for displacements:

1. Trigonometric points.
2. a) Superhighways, b) federal main roads, c) main and d) secondary roads. If a normal gauge railway lies near a road, both elements are to be displaced by equal amounts. An exception is made with secondary roads, which should give way to the railway for it is of lower importance.
3. Banks of rivers represented by two lines and banks of seas. However, the displacement of the two banks should not be greater than two line widths of the banks (0.2−0.3 mm).
4. Rivers represented by a single line, minor roads, tracks and narrow gauge railways get the same priority. If two or more elements of this priority lie near one another, they are to be displaced by equal amounts.
5. Paths.
6. Buildings.
7. Administrative boundaries.
8. Relief representation.
9. Vegetation boundaries.

IV. Algorithms for the computer-assisted treatment of single displacement cases of line elements

Besides the statement of the order of the map elements during displacement, a special interest was devoted to the manual solution (i. e. without the aid of a computer) of the following cases while examining the cartographic representations cited under II: Displacement of a road by a trigonometric point, displacement of a brook partly covered by an exaggerated road, generalization of a double hairpin bend (without interspaces in the generalized map face).

1. *Preliminary remarks about computer-assisted generalization*

Computer-assisted generalization requires a cartographic automation system, in which a given map consists of coordinate-values of points (single or belonging to a line) and of numerically coded labels (headers) of the map elements. When speaking about lines in the following, the sequences of the points of support of these lines are meant, the coordinates of which are stored in the memory of the automation system behind the single headers.

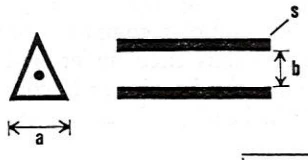
2. *Displacement of a road by a trigonometric point*

Let in a map a trigonometric point (TP) lie on the limiting line of a track (fig. 1). Table 1 shows the dimensions of TP and track at 1 : 25 000 and 1 : 50 000 scale according to the map specifications for the FRG. If the layout of generalization for 1 : 50 000 is prepared at 1 : 25 000 scale, the TP and the track are to be plotted nearly two times larger than for the 25 000 scale: they are exaggerated. Normally, the axis keeps its true position when the track width is exaggerated. As the TP should not be displaced because of its high priority (see section III), the limiting line of the track, on which the TP lies, is kept in its true position in the vicinity of the TP (see fig. 1). Thereby the problem arises, as to how the displaced and non-displaced portions of the limiting lines of the track are to be joined together without creating artificial sharp bends.

In the conventional (manual) method, the generalizing cartographer links the segments intuitively by a smooth curve, the geometrical form of the exaggerated track thus being not altered to much. In the computer-assisted method, the problem should be solved in the following way:

1. According to the non-displaced axis and the track width at the scale of the derived map (S_d), the TP should lie in P_n^* (see fig. 2). Its position in the extraction scale (S_e), however, is P_n'', and it must be observed in S_d, too. The point of the displaced axis which corresponds to P_n'', is $\tilde{P}_n$. Thus, P_n has been displaced to $\tilde{P}_n$ by the amount $v = \overline{P_n \tilde{P}_n} = \overline{P_n^* P_n''}$.
2. v is distributed on the neighbouring points of the axis: the next point, P_{n-1}, is displaced from its position in S_e by $v - 0.1$ mm. P_{n-2} is displaced by ($v - 0.1$ mm) $-$ 1.0 mm, etc., until v is completely redeemed.
3. The same applies to the points P_{n+1}, P_{n+2}, etc.
4. The coordinates of the corresponding points of support of the limiting lines of the track are calculated according to the track width and are joined together by polynomial splines of the third degree during the automatic plotting.

   Adequate algorithms are developed in [14] for the cases with or without intersection (with roads shifted or not, roads of different width, junction).



	Scales		
	1 : 25 000	1 : 50 000	1 : 50 000 enlarged to 1 : 25 000
a	1.4	1.0	2.0
b	0.4	0.4	0.8
s	0.1	0.1	0.2

(lengths in mm)

Table 1

Side length of a TP a, line gauge of the limiting line of a track s, inner width of a track b

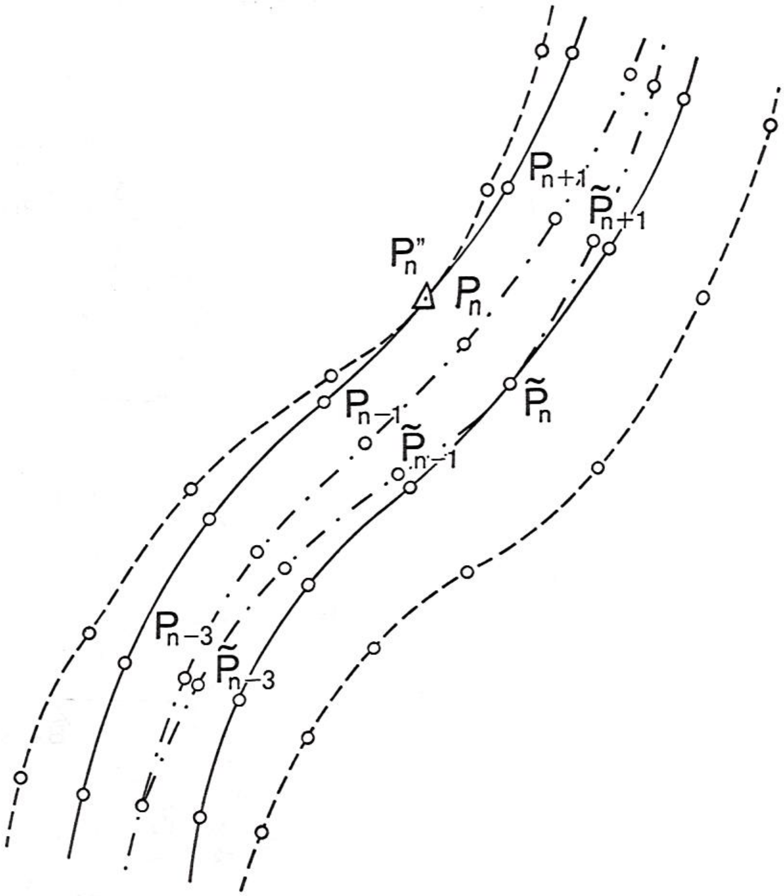


Figure 1

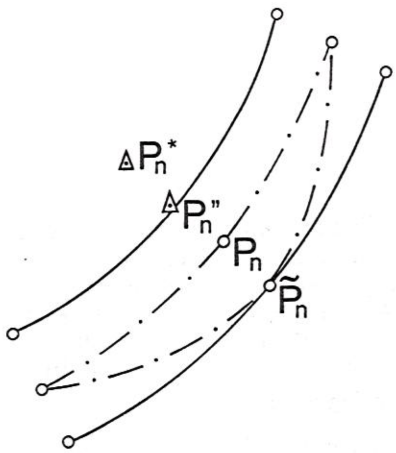


Figure 2

3. Displacement of a brook, partly covered by an exaggerated road

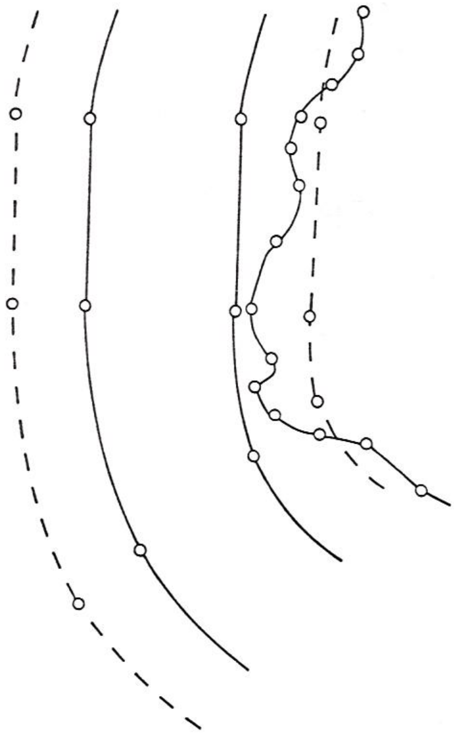


Figure 3

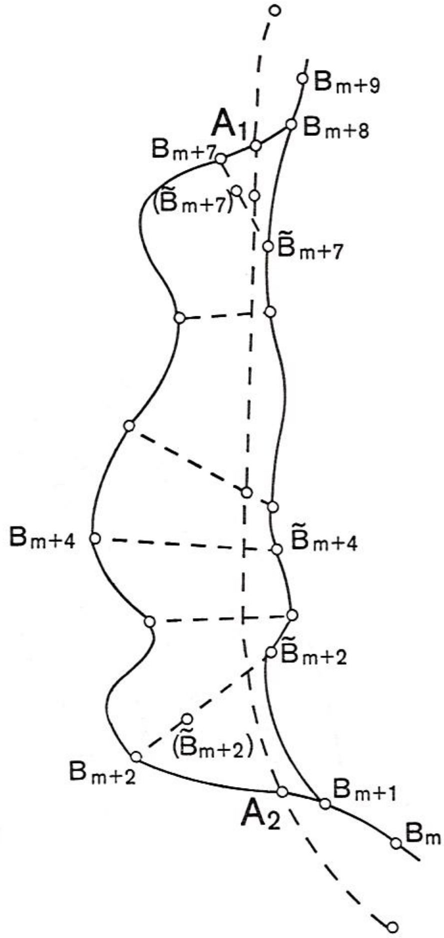


Figure 4

In fig. 3, a road and a winding brook flowing near it are represented. This situation is to be generalized for a derived map scale. Let the prescribed road width be such, that while keeping up the true position of the map elements the exaggerated road would cover the brook partially. As this is in accordance neither with reality nor with cartographic principles of representation, the brook must be displaced (and not the road, for it should have the higher priority according to section III). This should be carried out by the computer in the following way:

1. Thanks to an adequate algorithm, the computer detects which sections of the brook have to be displaced.

2. The point which should be displaced by the greatest amount (point B_{m+4} in fig. 4) is determined automatically. Its displaced position is $\tilde{B}_{m+4}$: it lies at the minimal distance of the limiting line of the road in S_d.

3. Between the points B_{m+8} and B_{m+4}, and between B_{m+4} and B_{m+1}, the single points of support of the covered portion of the brook are displaced according to a linear law along the normals of the course of the brook.

4. If the displaced point lies within the exaggerated road (point $(\tilde{B}_{m+2})$ in fig. 4 e. g.), it is brought to the minimal distance of the limiting line of the road in S_d (point $\tilde{B}_{m+2}$).

5. The direction of the tangent in the connection points is computed after numerical differentiation for the cases of displaced and non-displaced course of the brook. The difference between the two directions be $\Delta\alpha$. If $\Delta\alpha \leq 5°$, the displacement procedure is terminated. Otherwise, it is repeated, the points B_{m+9} and B_m being taken as connection point, this time. (Thus, the points B_{m+8} and B_{m+1} are displaced, too). Subsequently, $\Delta\alpha$ is again computed, for B_{m+9} and B_m. If $\Delta\alpha > 5°$, the next points are taken, etc., until $\Delta\alpha \leq 5°$. It has been stated while examining numerous similar cases of displacement, that in the connection point $\Delta\alpha \leq 5°$.

4. *Generalization of a double hairpin bend*

Fig. 5 shows a double hairpin bend (DHB). Its points of extreme curvature are W_1 and W_2. The situation is to be generalized for a derived map. The interspaces, reduced according to $\frac{S_e}{S_d}$, be smaller than the prescribed minimal distance in S_d. The road width given in the map specification be such, that the strict observance of the position of the axis of each branch leads to mutual coverings. Therefore, these branches have to be displaced. According to the manual method, the computer-assisted generalization process should be the following:

1. The operator makes the starting (A) and end (E) points of the DHB known to the computer. Subsequently, the following elements of the DHB are determined by the computer (see fig. 6):
2. The two points of extreme curvature.
3. The most characteristic change of direction in the whole DHB (angle w).
4. The apex 0 of w.
5. The bearings of the oriented sides s_1 and s_2 of w.
6. The bearing of the oriented bisectrix b of w.
7. The center U of the DHB.
8. The points of support for the drawing of the generalized DHB, according to the road width in S_d, the distances $\overline{W_1 U}$ and $\overline{W_2 U}$, and the bearings of the sides of w. (These points are shown on fig. 7 by black dots.)
9. Finally, plotting can be carried out. The result can be seen on fig. 7.

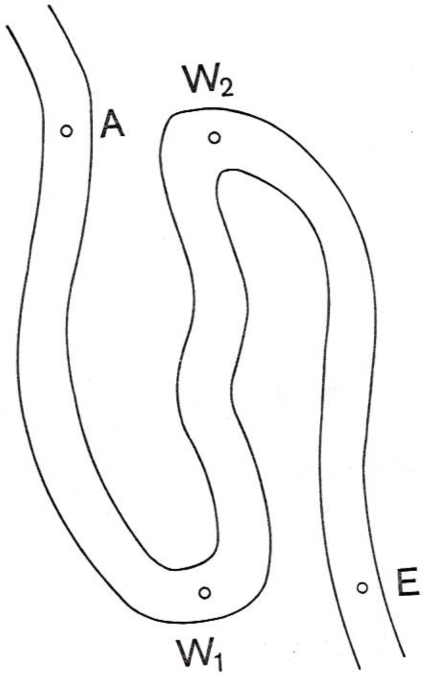


Figure 5

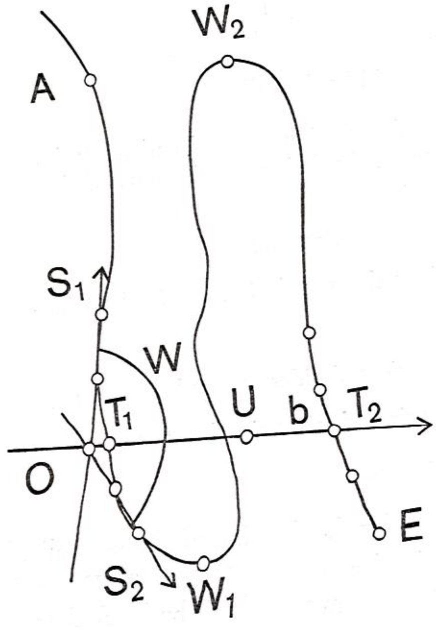


Figure 6

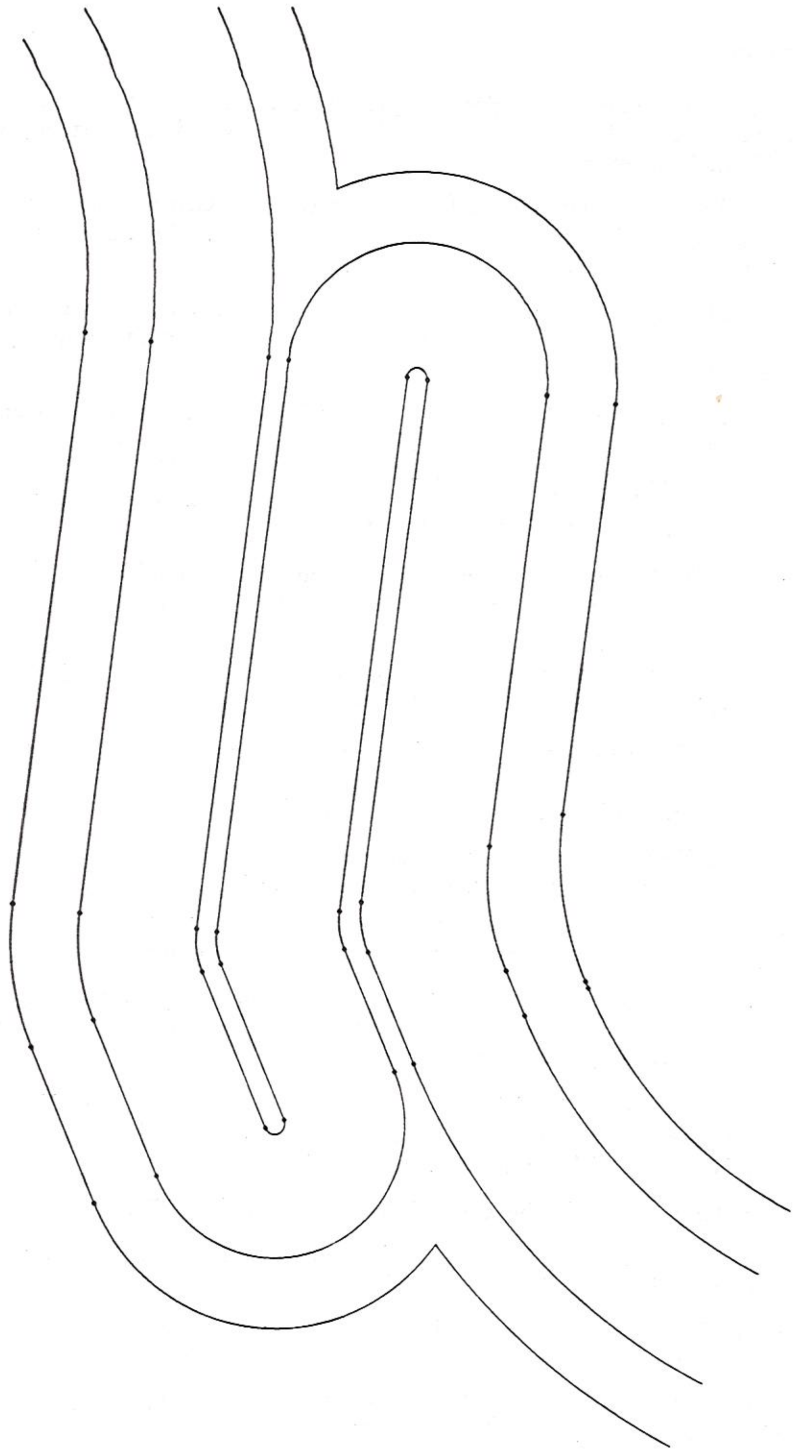


Figure 7

V. Literature

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