

## **CARTOGRAPHIC DISPLACEMENT BY MINIMIZATION OF SPATIAL AND GEOMETRIC CONFLICTS**

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### **Abstract**

Emphasizing of important objects and suppressing of irrelevant objects is the duty of generalization and visualization of spatial data.

Therefore different basic generalization-functions are available. In this spatial context the most difficult method is displacement.

As a consequence of symbolization or enlargement of map objects, above all on small-scale maps, displacement is also the most complex phase within generalization of maps.

Zones of high or too high information density must be relieved by appropriate methods in order to guarantee the content of information of a map. Special requirements of the users have to be taken into account, i.e. the geometric accuracy of some objects is more important than of other objects.

The article suggests handling signatures as individual objects in map-space. The objects own their special attributes and methods to interact with themselves.

Introducing with a general description this approach transfers the characteristics of map objects into a pseudo-physical model with attributes dynamic behavior to each object of the map. So it is made possible to model characteristic displacement for all different kind of signatures. The approach describes on the one hand the persistence behavior of the map objects to their original location and shape by simulated suspension of elastic springs. Changing the geometry of map objects will induce an internal potential.

On the other hand the spatial conflicts or external potential is described by intersecting signatures and buffers around these object-shapes. The external potential is determined by the overlapping area and importance of the signatures.

The optimal solution is found by minimization of the displacement potential which consists of the sum the internal and the external potential. To find the optimum of this integral function it is necessary to apply an algorithm, which is operating without derivation of the functions. This heuristic optimization-algorithm is called the "downhill-simplex-algorithm"

and uses only function-values on the examination-points. There are three methods to minimize the conflicts: point by point, object by object and in meshes. The meshes are build up by fixed objects, for instance rivers, railways, highways.

In case of addition, deletion or modification of spatial data, we have to update only the separate mesh. Because of the generalization-independent border of the meshes we can reduce the amount of data and unnecessary calculations.

## Introduction

The cartographic displacement belongs to the geometrical part of the cartographic generalization and is used for small-scaled maps.

The enlargement of map-objects, caused by symbolization leads to graphical conflicts (Figure 1).

Following /LICHTNER/, the gradual reduction of the displacement effect towards the edge of the displacement zone VZ of the displacing object is described by the displacement operator OP.

$$OP = 1 - \frac{s_i - \frac{b}{2}}{t}$$

the corresponding displacement value  $v_i$  is

$$v_i = v_0 * OP \quad \text{and} \quad v_0 = \frac{s}{2} * \frac{m_F}{m_A} - \frac{b}{2}$$

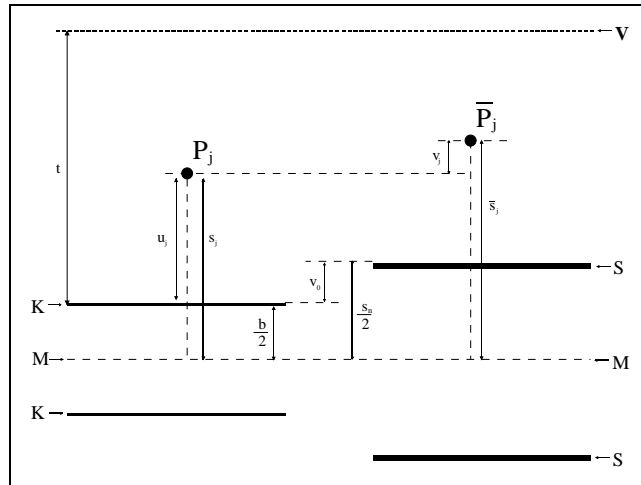


Figure 1: Geometric relations of displacement by Lichtner

with

M	axis
K	initial contour-line
S	signature contour-line
V	boundary of displacement zone VZ
$P_j$	initial neighbor
$\bar{P}_j$	displaced neighbor
$m_A$	initial scale denominator
$m_F$	target scale denominator
b	initial width
t	depth of displacement zone
$s_i$	distance from neighbor to axis
$u_i$	distance from neighbor to contour-line
$v_i$	displacement value
$s_N$	target signature width

The point  $P_j$ , which lies within the displacement zone V of an object, has the distance  $u$  to a map-object, and must be shifted by the amount  $v$  from the initial position, in order to obtain an appearance similar to the initial.

The parameters of the displacement zone, the amount and direction of displacement can only be determined and evaluated by an experienced cartographer.

A model was developed, which considers the displacement properties of single objects and the relationships and effects between different objects.

## Conception

The approach is describes on the on hand the persistence of map-objects in their original characteristics:

- position,
- shape and
- orientation

This behavior is depict by different kind of elastic springs /BOBRICH/ (Figure 2).

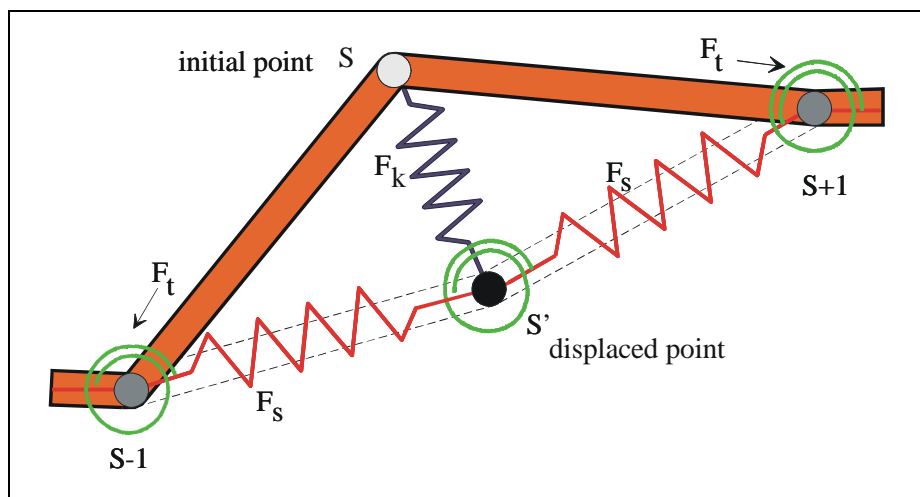


Figure 2: usage of elastic springs

Supposing a road-signature build up by several points ...S-1, S, S+1, we can move every point of the signature. Looking only at point S, we can displace it to the position S'. In this model the possibility of displacement is limited.

The “initial-position-spring” ( $F_k$ ), which describes the behavior to stay on the original position, is modeled by a compression-spring. Less important map-objects can be more flexible in their position than e.g. highways.

The linear character of signatures can be described by “signature-compression-springs” ( $F_s$ ). All successive points of the signature are connected with these springs; so we can compress and stretch the segments of map-objects. The installation of “signature-torsion-springs” ( $F_t$ ) implements the characteristics of curvature.

The arrangement of springs allows to describe all modifications of the signatures. The resulting potential energy is called “**internal potential**”.

On the other hand an “external potential” will be induced by

- intersection of signatures and
- remaining under minimum spaces between map-objects.

To calculate the external potential we use the overlapping area, which is weighted by the importance of the map-objects. Compliance with minimum spaces can be reached by buffering map-objects with specific width and height. Figure 3 shows a 2/3D-view of these signatures and buffers.

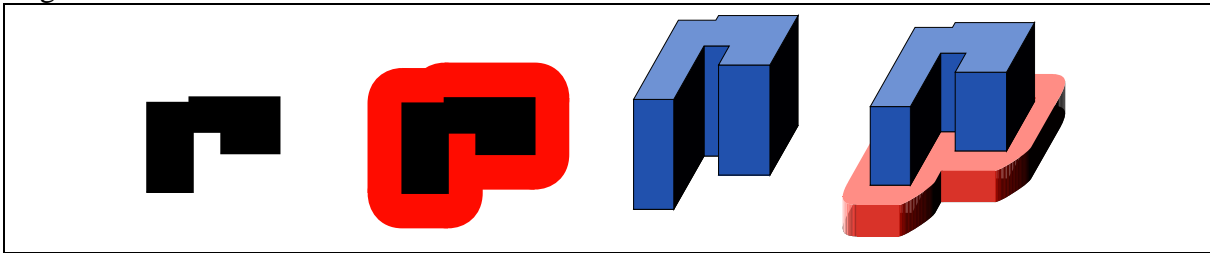


Figure 3: weight of signatures and buffers

Conflict zones can be classified in 5 categories. In figure 4 these categories are shown in a side view of a house (gray) and a highway (yellow).

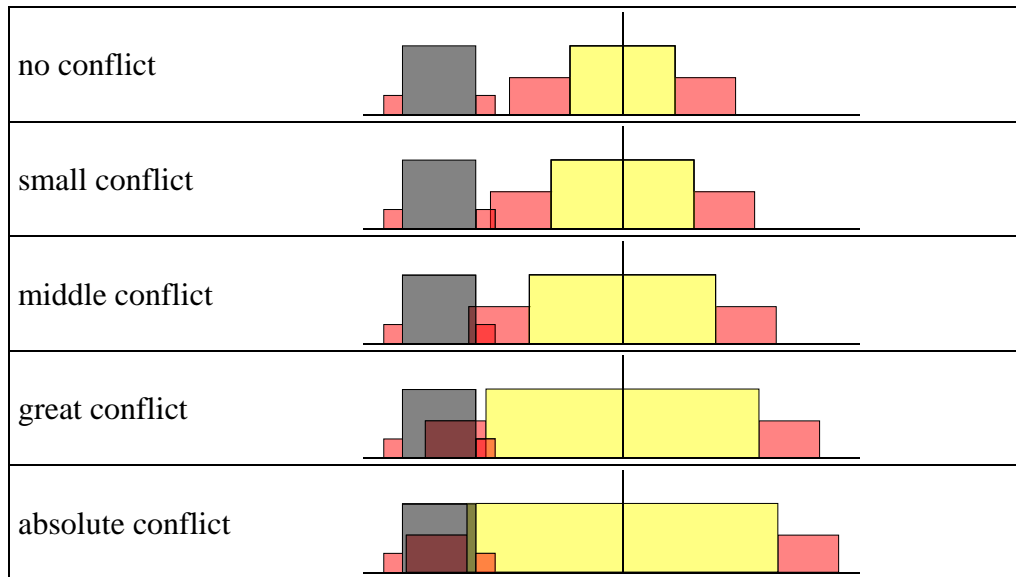


Figure 4: different conflict zones

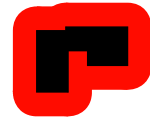
On account of readability the highway is continuous widened and the rising conflict potential can be seen. The height of the signatures is the same, whereas the buffers have different weight (height). Every overlapping area gets the smallest weight of all involved signatures and buffers.

The total potential  $POT_{tot}$  is:

$$POT_{tot} = POT_{int} + \left( \begin{array}{l} SIG_0 \cap \sum_n SIG \\ + BUF_0 \cap \sum_n SIG \\ + BUF_0 \cap \sum_n BUF \\ + SIG_0 \cap \sum_n BUF \end{array} \right) \text{ Formula 1}$$

where

$POT_{int}$  = internal Potential  
 $OBJ = SIG + BUF$  a map-object OBJ is represented by the signature SIG (black) and the buffer BUF (red).



index<sub>0</sub> = current signature/buffer  
 index<sub>N</sub> = all other signatures/buffers

In case of overlapping or remaining under minimum spaces we may have different situations. On the one hand there are some composition of map-objects, which pushes themselves of one another. On the other hand other kind of objects wants to pull up. E.g. cartographers would move a house nearby the road directly to the road. So each map-object has to know whether the other one is a “friend” or an “enemy”.

The implementation of a friendly, attracting behavior is a specific negative potential between two features.

So the total potential  $POT_{tot}$ , considering “enemy/friends“, is:

$$POT_{tot} = POT_{int} + \left( \begin{array}{l} + SIG_0 \cap \sum_E SIG \\ + BUF_0 \cap \sum_E SIG \\ + BUF_0 \cap \sum_E BUF \\ + SIG_0 \cap \sum_E BUF \end{array} \right) + \left( \begin{array}{l} + SIG_0 \cap \sum_F SIG \\ - BUF_0 \cap \sum_F SIG \\ - BUF_0 \cap \sum_F BUF \\ - SIG_0 \cap \sum_F BUF \end{array} \right) \text{ Formula 2}$$

where, in addition to formula 1

index<sub>F</sub> = friend  
 index<sub>E</sub> = enemy

## Optimization

To determine the optimal position of the signatures, the total potential has to be minimized. We cannot build the differential of this model; only the function values can be terminated. The applied heuristic procedure is called the “downhill simplex method”, which detects the minimum by moving a “simplex” through an n-dimensional space. In case of n-dimensional minimization there is a simplex with n+1 edges, i.e. in two dimensions (position) we need a triangle (Figure 5). The point with the highest function-value is to be investigated to reduce the maximum function-value in the triangle.

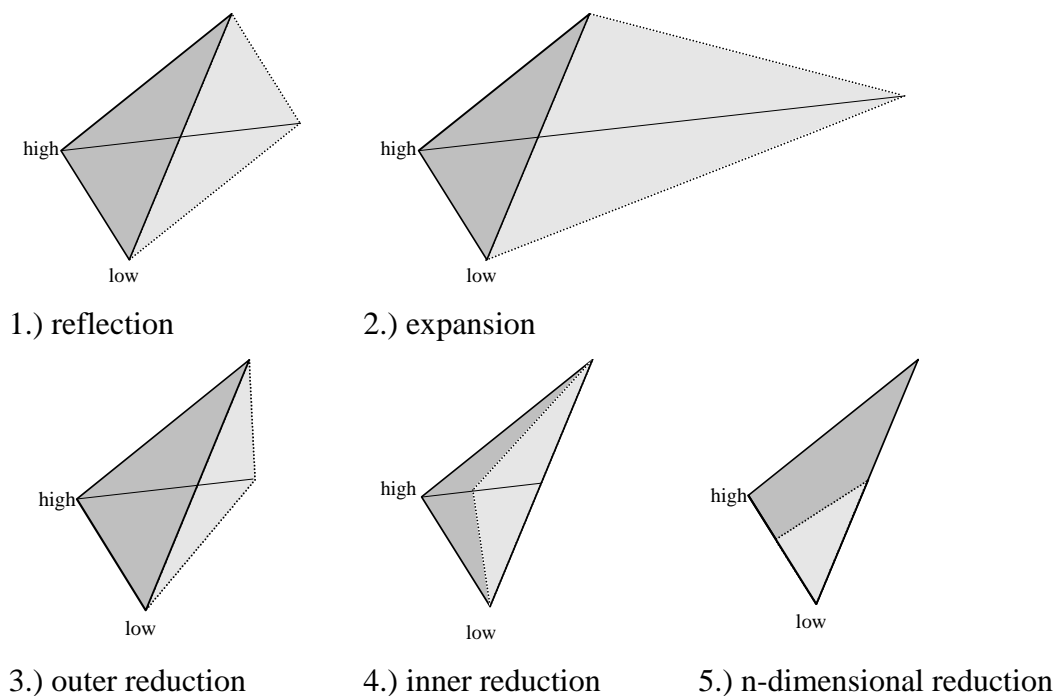


Figure 5: downhill-simplex minimization

There are five possible steps to find the valley.

1. Reflect the solution on the opposite side, if this solution is better, try to
2. expand in this direction.
3. If there is no success, reduce the way out of the solution-space.
4. In case of no better results, the solution must lie inside. Try the inner reduction, which is on the half way to the opposite side.
5. Provided that there is no better solution found, the simplex has to be reduced on the way from the highest to the lowest function-value.

Figure 6 shows the course of the downhill simplex method, starting with the big red triangle, sliding down to the minimum. The minimum-function is the distance to the known position.

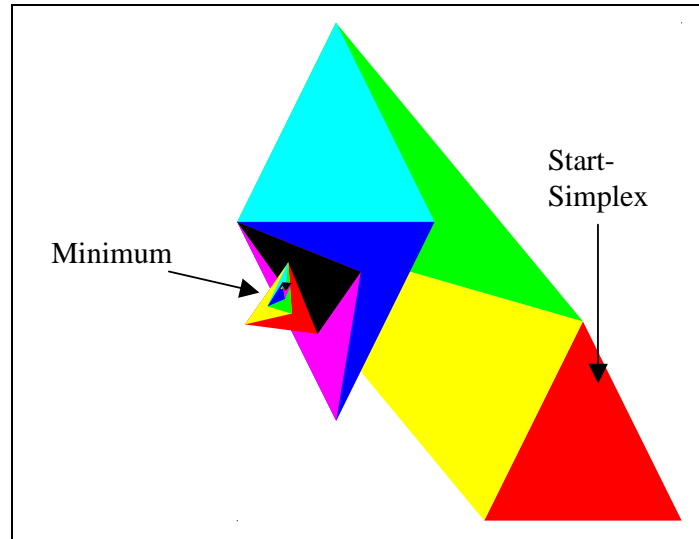


Figure 6: sliding into the minimum

These steps causes on the one hand the simplex to slide into the minimum, on the other hand the size of the simplex will be reduced until no further optimization can be made or the size of the simplex is small enough.

## Examples

To study the practicability of the approach, some synthetic map-objects with critical situations are generated.

These examples are:

- crossroads with overlapping signature (Figure 7)
- tight river valley (Figure 8)



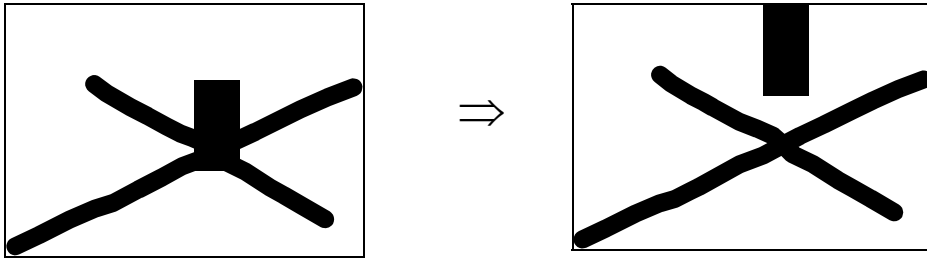


Figure 7: crossroads with overlapping signature

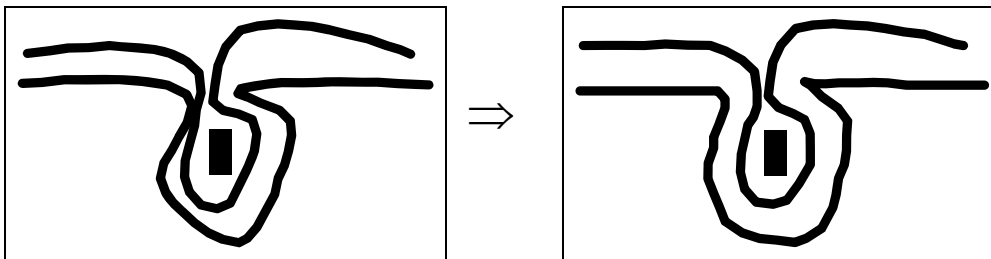


Figure 8: tight river valley

After these tests, a huge area has to be computed. For this purpose the town of Ostercappeln/Lower Saxony was chosen. To save computing time, the input-data were separated into meshes by using buffering and polygon-cutting techniques. At first all interesting features like houses, garage, etc. were buffered. These buffers could now be summed up to the buildings buffer.

The same was done with “cutting” features, e.g. roads, rivers...Here the width of the buffers is very small. The resulting polygons were now subtracted from the buildings buffer. These obtained polygons are the meshes of the map.

The figures below show the different steps in generalization. Starting with data from the cadastral map, some other methods in generalization has to be done:

- Selection
- Simplification
- Aggregation

For this CHANGE (Institute of Cartography, University of HANover, GEneralization - Software) was used /STAUFENBIEL/ and /MENKE/. Afterwards the minimization of the potential could start (Figure 9).

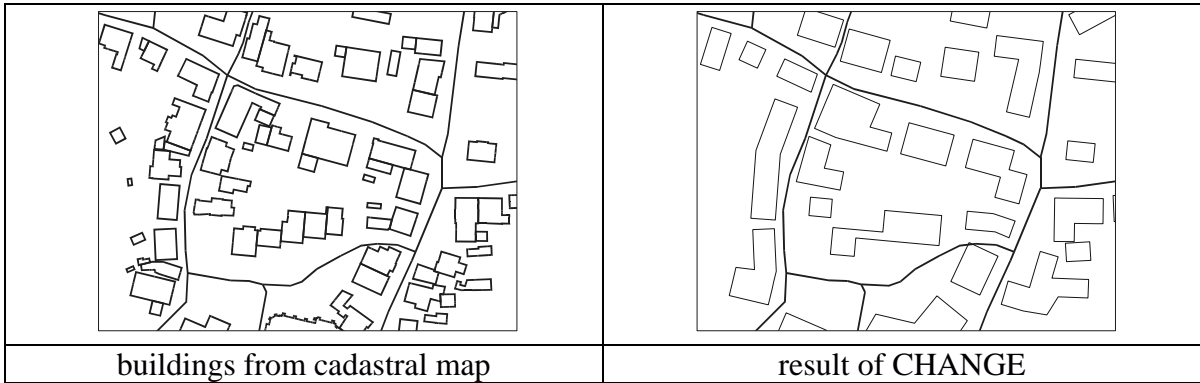


Figure 9: preprocessing

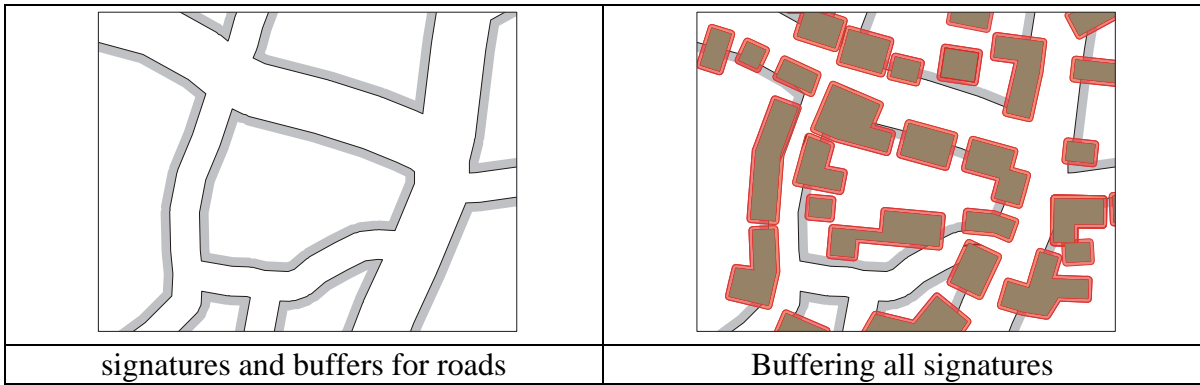
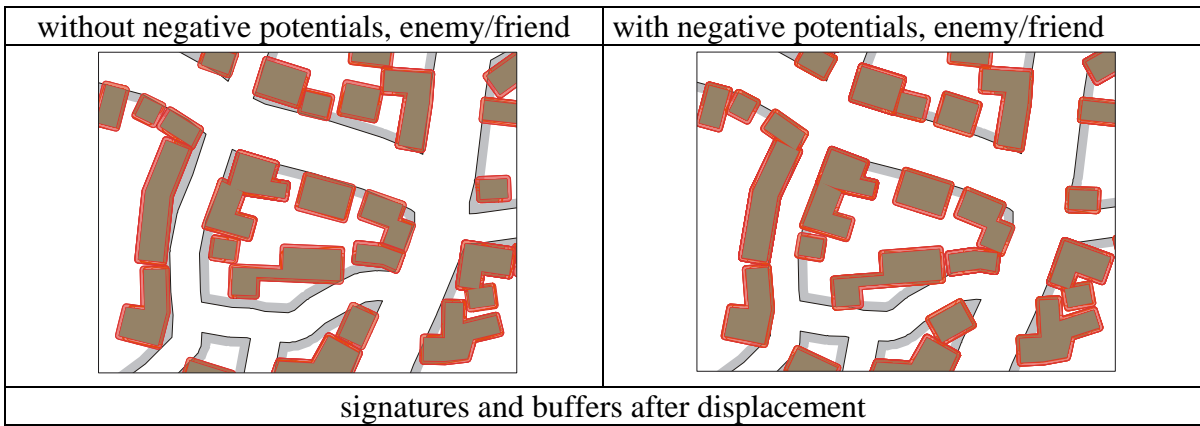


Figure 10: buffering



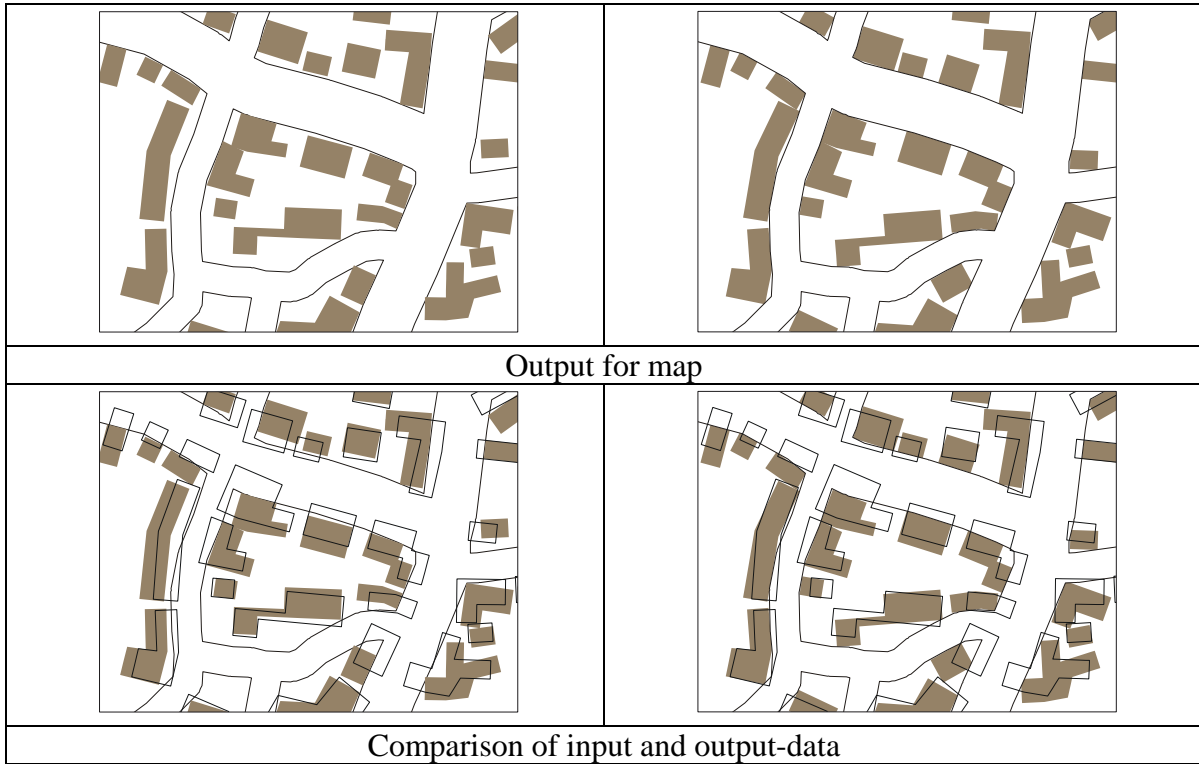


Figure 11: results of displacement

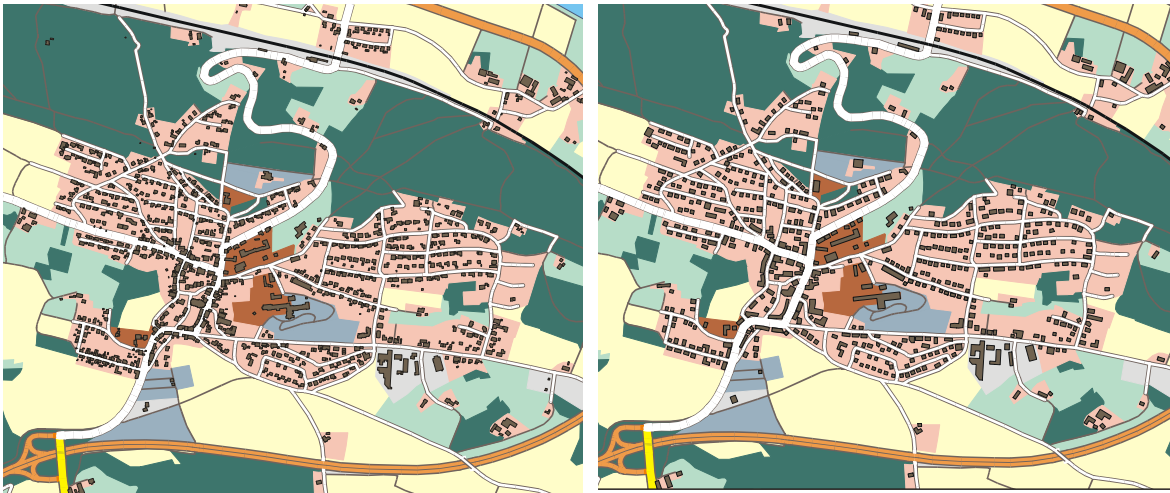


Figure 12: detail of Topographic Map 1:25000 (TK25) combined with ALK-Buildings: simple overlay and result after automated generalization

## Conclusions

The obtained results represent a satisfactory solution of cartographic conflicts by displacement (Figure 11). There is no overlapping with good results up to 1: 25.000 (Figure 12).

In further research work scale less than 1:25000 should be investigated. For smaller scales other methods like exaggeration and typification has to be developed and implemented.

The developed procedure results in a plausible solution and offers the possibility on an incremental update of map-objects.

Methods based just on geometry have to be restarted from the initial situation if

- new objects are inserted,
- old objects are deleted or
- signatures are change.

These possible operations can generate new areas of conflict; on the other hand areas with less graphical load could be used to relieve these areas in a dynamic context dependent manner.

## References

- BOBRICH, J.**, 1996, Ein neuer Ansatz zur kartographischen Verdrängung auf der Grundlage eines mechanischen Federmodells, Vol. C455. Deutsche Geodätische Kommission, München
- STAUFENBIEL, W.**, 1973, Zur Automation der Generalisierung topographischer Karten mit besonderer Berücksichtigung großmaßstäbiger Gebäudedarstellungen, PhD thesis, Fachrichtung Vermessungswesen, Universität Hannover.
- MENKE, K.**, 1983, Zur rechnergestützten Generalisierung des Verkehrswege- und Gewässernetzes, insbesondere für den Maßstab 1:25000, PhD thesis, Fachrichtung Vermessungswesen, Universität Hannover.
- LICHTNER, W.** 1976: Ein Ansatz zur Durchführung der Verdrängung bei der EDV-gestützten Generalisierung in topographischen Karten. WissArbUH, Nr.66, Hannover 1976