An Incremental Displacement Approach Applied to Building Objects in Topographic Mapping

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ABSTRACT

In this study, an application of displacement, one of the complicated operations of cartographic generalisation, has been performed on building objects at the rural areas where the overlay of building symbols is mostly encountered. In this context, the methods that aim to minimize the requirement of cartographer interactivity have been searched and an iterative approach has been suggested. For the implementation of this approach; displacement is iteratively performed by means of the criteria, such as distance and topological constraints, calculated permanently to control the displacement and by means of spatial analysis techniques. The results have been evaluated with the example applications and found to be quite encouraging in rural areas and provide more standardization in map production and save time as well.

Keywords: *Cartographic Generalisation, Automation, Building Displacement, Spatial Analysis.*

1. INTRODUCTION

Many National Mapping Agency's (NMA's) strategic purpose is to derive less detailed Digital Landscape Models (DLM) from high detailed and accurate DLMs and to produce maps (and Digital Cartographic Model (DCM)) from these DLMs. In this context, generalisation process constitutes the center of these productions and is to be necessary to automate this process by transforming the cartographer's knowledge and experience into computer logic and algorithm (Lee and Hardy 2005).

During the derivation process of DCM and/or DLM, the most of the efforts have been spend throughout the geometric algorithm developments. Many algorithms have been improved for certain map objects as an output of these endeavors (i.e. in order to generalize point objects (van Kreveld et al. 1997, Yukio 1997, Ai and Liu 2002), line objects (Douglas and Peucker 1973, Li and Openshaw 1992, Wang and Müller 1992, De Berg et al. 1995) and polygon objects (Monmonier 1983, Zhang and Tulip 1990, Müller and Wang 1992, Schylberg 1992a, b, 1993, Beines 1993, Su and Li 1995, Li and Su 1996, Su and Li 1997, Su et al. 1997a, b, Bader and Weibel 1997, Barrault et al. 2001, Ruas 2001, Galanda and Weibel 2002)).

Most of the researches aim to model the experience and knowledge of the cartographer. But the studies show that cartographer's interpretation is impossible to formalize (Stoter et al. 2008). Generalisation process, which is entirely a hard work, has been divided into sub processes, each of which offers different solutions for different problems. These sub processes are called generalisation operators.

Foerster and Stoter (2008) arranged a two-fold survey titled "The Current Problems of Automated Generalization of Topographic Data at National Mapping Agencies" in different countries (Belgium, Denmark, Finland, France, Germany, Holland, Ireland, and Switzerland). While the first part of this survey provides an overview of the currently applied strategies for automated generalisation, the second part, which is the starting point of this study, focused on the most important and most problematic generalisation operators in combination with feature types.

According to the survey, the degree of importance indicates how important a specific operator is to achieve successful generalisation processing and problems of operators are rated based on the degree of difficulty to achieve automated generalisation processing successfully. Based on the results of the survey, building generalisation, comprising typification and displacement operators have high level of difficulty and importance for the scale ranges from 10K to 100K. Furthermore, the difficulty of the building generalisation also varies according to the application area. Urban areas have been mostly represented with polygon geometries in a database having 25K scale map data resolution. But in rural areas, which are usually more than urban areas, buildings are mostly depicted with single point geometries (Aslan, 2003).

The cause of the graphic conflicts is a combination of the effects of geometric scale reduction, whereby features decrease in size and increase in density on the map, and the fact that map symbols are often larger than the true-scale representation of their associated real-world feature (Ware et al. 2003). The symbol specifications of the point buildings are usually the same for the 25K, 50K and 100K scale topographic maps. Due to having the same symbol sizes at the output, symbol overlapping is inevitable in smaller scale representations. This makes displacement an inevitable operation arising from the violation of the graphic constraints, such as minimum distance allowed between the symbols (Bildirici, 2000). A minimum distance is required not only between the buildings and the surrounding roads, but also between the buildings themselves. However this constraint cannot be met in some cases especially where the buildings and roads are densely seen and a solution by displacement alone is not feasible, hence displacement is usually followed by or preceded by other generalization operations such as selection, typification and aggregation of buildings. In this study, buildings have been exposed to the typification operation before the application of the displacement method described below.

2. MATERIAL AND METHOD

The graphic constraints fall within the buildings can not be entirely noticed by a human eye but can be easily and automatically delineated by computer logic. To move one or more building objects in a computer environment can be a solution where the objects are densely close to each other but it is a complicated operation, since the major challenge is to control the propagation of conflict that appears when the movement of an object may introduce another conflict with another object. To cope with this challenge and automate the displacement process, various methods have been developed. The displacement methods existed in the literature can be classified into two categories which are called incremental and holistic approaches (Regnauld and McMaster, 2007, Basaraner, 2011). Incremental approaches evaluate the proximity among the neighbor objects. The distances between object pairs are incrementally increased until the conflict is resolved and it is repeated for all neighbor objects iteratively. However holistic approaches compute the displacement for all features and apply at once (Regnauld and McMaster 2007). These approaches have been attracted many studies to reduce the conflict arisen from the displacement but can not solve it entirely, yet. Detailed investigation of the displacement approaches can be found in Regnauld and McMaster (2007).

The method suggested in this study for displacement (see in Figure 1) can be evaluated in incremental methods (Aslan, 2011). The Symbols of the buildings are converted to polygons and a certain buffers are applied for the calculation and performing the displacement processes in this study. To perform this deterministic method some calculations, detailed below, should be carried out.

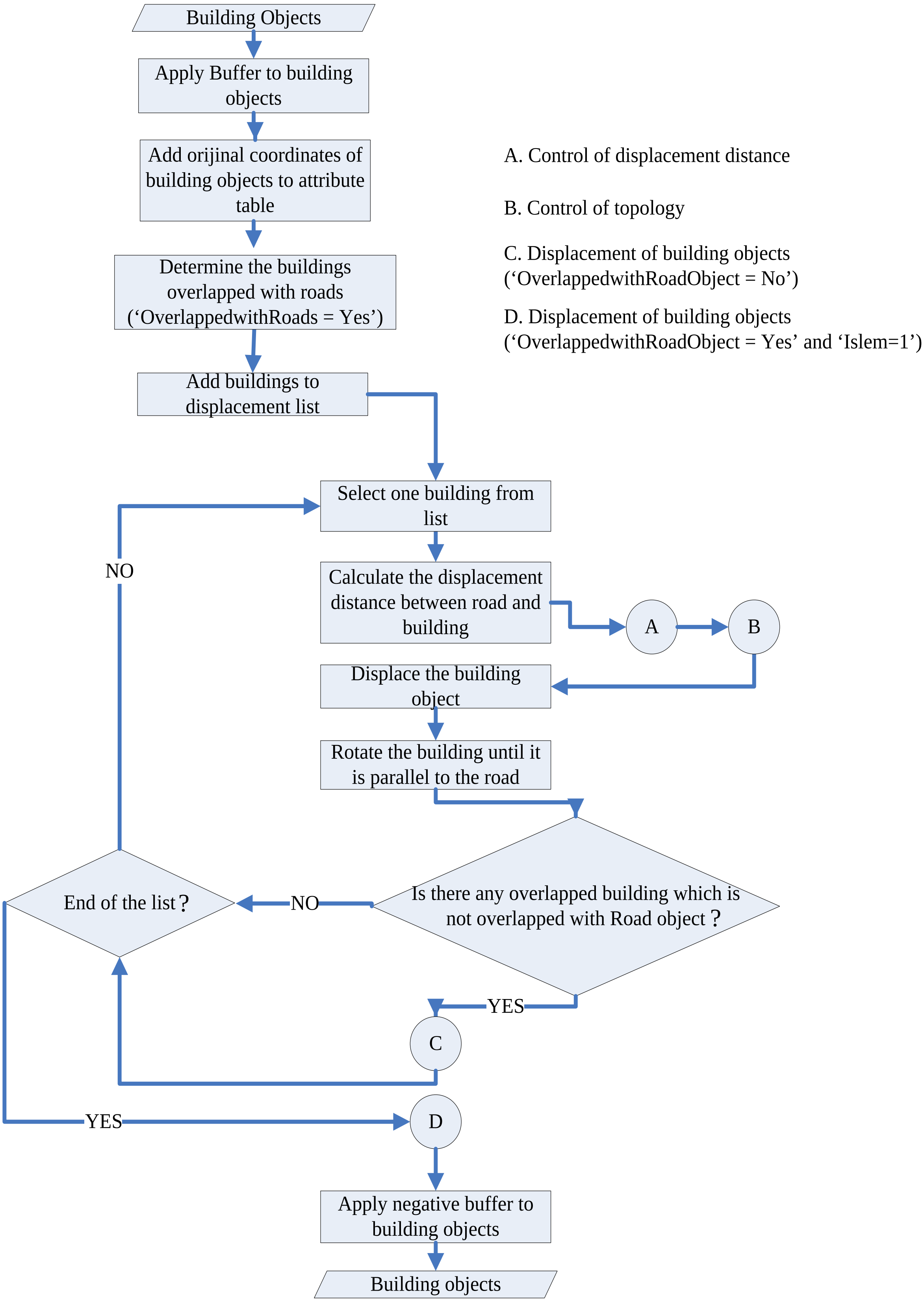


Figure 1. Displacement workflow diagram.

2.1. Displacement Parameters

2.1.1. Displacement Distance between Building and Road Objects

The minimum distance ($D_{\min}$) criterion between the building and the nearest road is calculated by taking into consideration the symbol sizes of both objects (Figure 2 and Equation 1). If the distance (D) between the objects is smaller than the minimum distance ($D < D_{\min}$), then the displacement distance ($D_{displacement}$) is calculated (Equation 2).

With the help of the position of building relative to road, the angle value (α) is calculated for direction of the displacement. Hence the new coordinates of the building object is calculated via the angle and the displacement distance (Figure 3, Equation 3 and 4).

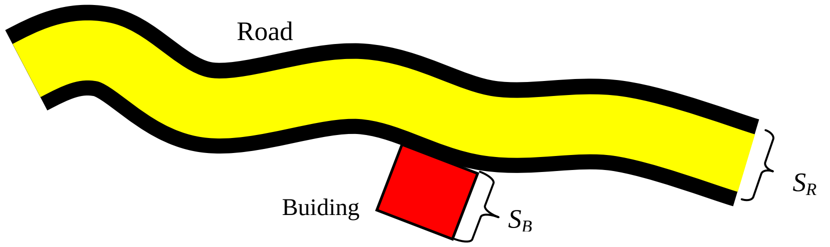


Figure 2. Road and building objects symbolized at the target scale.

$$D_{\min} = \frac{(S_R + S_B)}{2} \tag{1}$$

S_R : Symbol width of the road object

S_R : Symbol width of the building object

$$D_{displacement} = D_{\min} - D \tag{2}$$

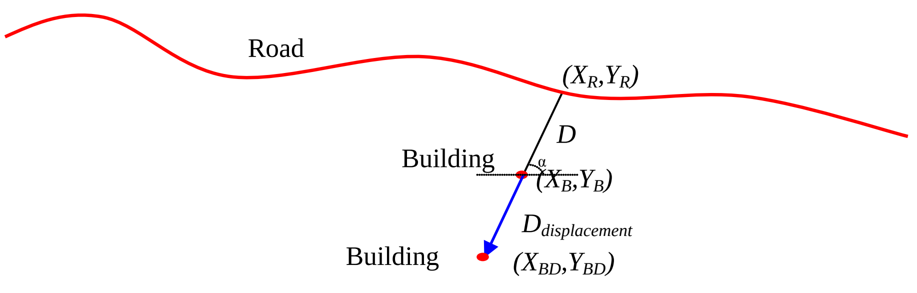


Figure 3. The new coordinates of the building object after the displacement process.

$$X_{BD} = X_B + D_{displacement} \text{ x } \cos \alpha \tag{3}$$

$$Y_{BD} = Y_B + D_{displacement} \text{ x } \sin \alpha \tag{4}$$

2.1.2. Displacement Distance among Two Building Objects

Displacement of buildings from roads can lead to another building overlapping problem. To cope with this overlapping problem, center of overlapping area is detected and then a parallel line to the centers of the overlapping building objects is calculated. So, overlapped buildings should be displaced again according to the length of the calculated parallel line (displacement distance). Both of the overlapped building objects should be displaced among each other at the half length of the calculated parallel line (Figure 4).

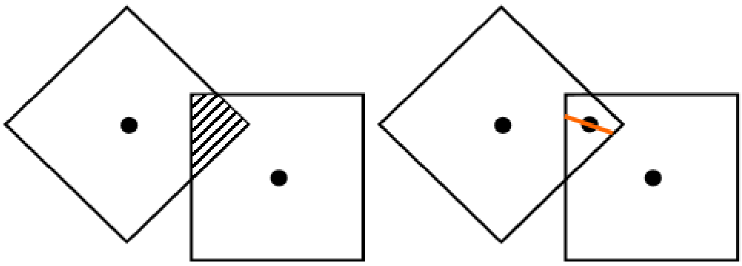


Figure 4. Calculating the displacement direction and the distance among two building objects.

3. APPLICATION

Displacement process starts with buffering process (up to $D_{min}/2$) to all building objects and overlapping with road objects are detected (D_S < D_{min}). For every candidate building object, the displacement parameters are calculated and the building object is moved and then rotate according to road object. If the new position of the building object creates a new conflict with the adjacent buildings and road again, then the displacement process goes on iteratively until no conflict remains (Figure 5). The initial and final positions of the buildings for the displacement process are depicted at Figure 6. Significant part of the displacement conflicts is resolved via this method. As for the problematic remaining, they are automatically determined and interactively solved by the cartographers with the help of an interface.

During the displacement process, the topologic consistency between building and road objects must be preserved. This means the building should not cross over the road and not change its direction according to the road. To check this consistency, a line object is created via the coordinates of the initial and final positions of the building object and is checked for any intersection existed between the road and the line objects. If an intersection exists, calculating the displacement distance process is triggered again. The intersection between line and road objects and the overlapping between road and building objects are iteratively controlled to locate the building in best position (Figure 7).

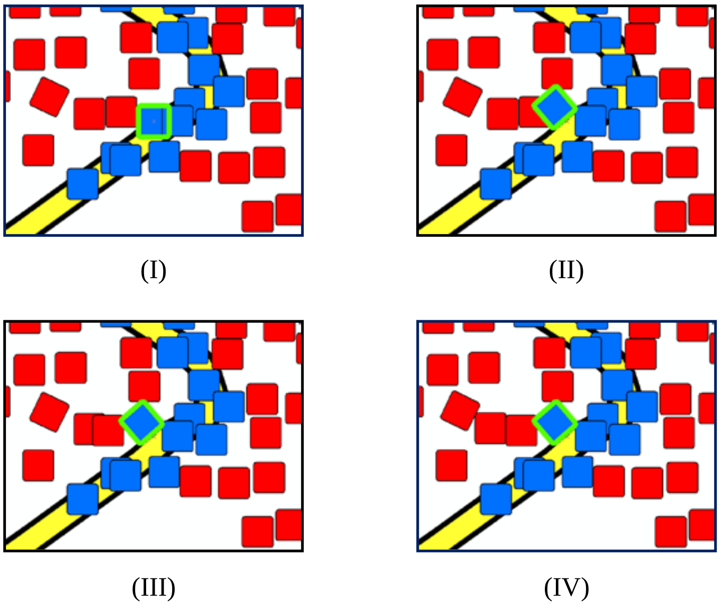


Figure 5. Displacement process for the selected building object, carried out iteratively until no conflicts remain.

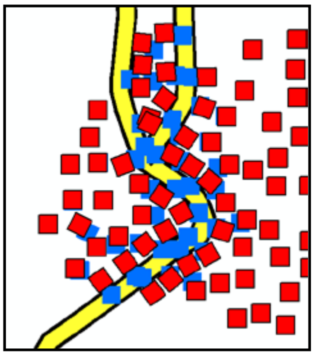


Figure 6. The initial and final positions of buildings.

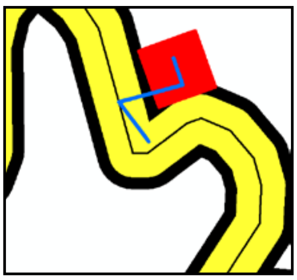
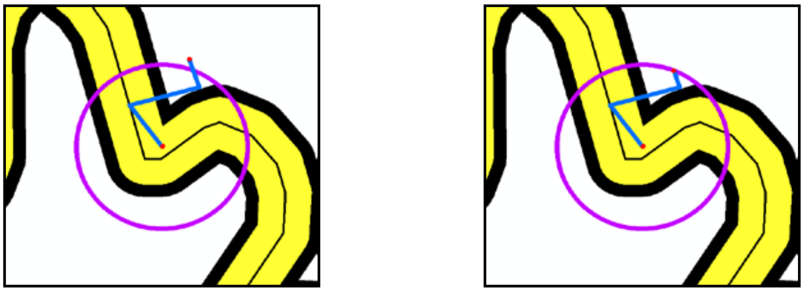


Figure 7. Displacement route of the building, formed by the displacement distance calculated iteratively.

In addition to conserving the spatial relations with the adjacent objects (topology control), maintaining certain positional accuracy is also important, within the scale restrictions. Therefore, the ideal position, detected after the topologic control, must be in a specific buffer distance which is also continually checked in each iteration. This specific distance derives from the initial position of the building object and its symbol size.

If a building object violates the buffer distance, a new displacement distance is calculated to compel the building stay in the buffer zone (Figure 8).



(a) (b)

Figure 8. (a) Violation of the buffer distance, (b) A new distance calculated for the building to stay in certain buffer zone

The source dataset used in the applications of this study is 25K scale topographic map data. It is aimed to produce generalized data appropriate for the production of 100K scale topographic maps. At first, the building objects, coming from the source data, are typified. Then the displacement process is applied, which is the main subject of this paper. The method for the building object displacement is implemented in ArcGIS software environment by developing some sophisticated tools using Visual Basic programming language and ArcObjects library. The method is performed on a PC with Intel® Core™ i5 430M processor, 2.27 GHz CPU and 4 GB RAM.

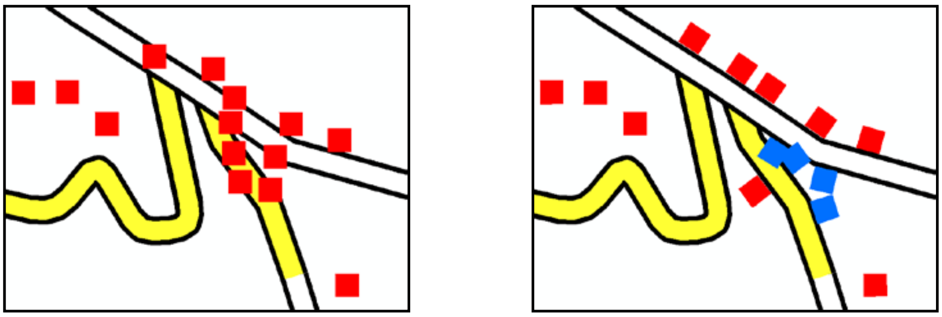
Implementations are carried out on data from different map sheets and the results are illustrated in Table 1. As to this table, approximately 90% of building objects are displaced automatically and the average processing time is 1 hours 35 minutes.

Table 1. Statistical results of the building objects displaced for the production of 100K scale topographic maps.

Sheet Name	Total Number of Building	Automatically Displaced		Number of Interactively Displaced Building	Duration (Hour:Minute:Second)
		Number of Building	Ratio (%)		
G41	11503	10662	92.69	841	05:01:42
H41	3596	3189	88.68	407	01:39:05
İ37	2129	1890	88.77	239	01:20:30
İ48	1278	1103	86.31	175	00:48:55
İ49	1490	1277	85.70	213	00:54:52
İ50	1400	1249	89.21	151	00:52:17
J19	2921	2754	94.28	167	01:30:01
J40	1369	1241	90.65	128	00:51:54
J49	2534	2258	89.11	276	01:25:58
J50	2683	2502	93.25	181	01:16:56

Traditionally, it is desired to displace as few objects as possible during the displacement process. If the displacement is mandatory for the objects, it is desired that the displacement distance not exceed the symbol size, if possible. For 100K scales, the building object has a symbol size of 50 meter. Consequently, the displacement distance carried out with an average value of 29 meter in this study, has been evaluated as appropriate for 100K scale.

An interface has been developed and formed to let the cartographers intervene interactively with the overlaying conflicts that continue between building and road objects after the displacement method described above. Figure 9 shows the conflicts that are not solved via this method. The blue buildings need to be displaced or eliminate interactively by cartographers with the help of the interface developed.



(a) Before Displacement (b) After Displacement

Figure 9. Buildings (blue) not moved automatically to best positions are displaced interactively by cartographers.

4. CONCLUSIONS

Majority of objects in medium scales are indicated with cartographic symbols instead of annotation. Buildings, which have point geometries in 25K, 50K and 100K scale maps, are represented with same symbology and the area of the symbol is getting larger in proportion to real world when the scale is getting smaller. Owing to this reality, some spatial conflicts (ie. overlapping) might exist. To represent objects legibly and sufficiently accurate at target scale, some operations like typification and displacement should be applied to the buildings. Overlay problems between buildings are solved by means of typification whilst overlays between road and building are solved by displacement operations (Harrie, 2001).

The overall aim of this study is to develop an appropriate displacement solution to the buildings especially in rural areas where the point buildings can be mostly found. To improve initial state of the building objects some constraints like minimum distance (main criteria), positional accuracy and spatial configuration ought to be complied within the displacement process. Although this method dramatically reduces the conflicts automatically, it is unfortunately not a complete solution. To obtain high accurate and standard level in a short period of production time, displacement process needs also some interactive intervention for some buildings, as well.

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