APPLICATION DEPENDENT GENERALIZATION – THE CASE OF PEDESTRIAN NAVIGATION

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ABSTRACT:

The need for application dependent visualization has steadily been growing with the advent of the internet and is even enforced by the availability of mobile computers. One of the assumed “killer applications” for mobile phones are location based services, allowing to present location information to a mobile user depending on his/her current position. Typical examples for such a location based service is the provision of information about restaurants in the vicinity of the user, or the shortest path from the current position to the next bus stop, etc. When displaying spatial information on a small display, the information presented has to be clear and distinct in order to be visible, and understandable by the user. This is even more true, as the mobile user is typically subjected to a high cognitive load while navigating and has to rely on extremely reduced and adequate information. An approach is presented to generate a compact description and a visualization of a route depending on the starting point and destination of the user. For a save and unambiguous guidance, it must be guaranteed that the relevant information can be grasped at a glance. This involves that important information is highlighted, whereas irrelevant information is reduced. Obviously, this is a generalization problem. Different cartographic operations will be tested and evaluated with respect to their applicability. Important objects like starting and endpoint will have to be enhanced. An important issue is the fact that different generalization levels will be applied in one description, thus there will be several “scales” within one presentation.

1. INTRODUCTION

Navigation systems are gaining an increasing popularity. Today, many middle and upper class cars are equipped with navigation systems that provide facilities for efficient road guidance from the current location of a user to his/her destination. The information provided relies closely on the underlying navigation data, i.e. the digital road map. This leads to a description that is mainly intended to be presented as on-the-spot-information along the current path. It is based on instructions related to the road geometry and describes sections and road junctions, e.g. “in 300m turn right”. Thus it is not necessarily related to a natural or human way of describing a path.

Whereas mainly geometry related instructions are appropriate for car navigation systems, things are different when it comes to mobile navigation of a pedestrian. Here, human centred instructions seem to be more appropriate. There are two main reasons for that: Firstly, in car navigation, a combination of different sensors allows for the exact determination of the current position of the driver, therefore, exact position dependent instructions can be provided and are adequate. In pedestrian’s navigation, however, the positioning accuracy is currently limited to a few hundred meters, when the user is located by mobile network cells. Even when assuming that in the future mobile devices will be equipped with more precise positioning systems like GPS, there are still inaccuracies e.g. due to multipath effects in dense city areas, that lead to the fact that the positioning accuracy is limited. Therefore, as the mobile user does not have the possibility of an exact positioning, the orientation and guidance information has to rely on intuitively understandable concepts that can immediately be recognized and matched to reality of the environment.

Secondly, today’s and also probably future display devices will be of a limited size. This naturally prevents that – like on a map – all the details of the environment can be presented. Guiding instructions have to be abstracted and reduced to the elementary important issues. Besides reducing the amount of objects to be presented, this abstraction and concentration also helps to discern between relevant and irrelevant information: only those objects have to be presented, that are important for the current task – irrelevant information can be suppressed. Importance and relevance, however, depends on several factors, like the application, the current route, and the user – therefore, this generalization has to be performed on demand and on-the-fly.

Thus, generalization is a major issue for this visualization. Furthermore, if routes are to be presented, it is of enormous importance, that the mobile, moving user is able to grasp the spatial situation at a glance. This leads to presentations, that include only the major route elements, together with important landmarks that are placed at positions, where the user has to take decisions. These presentation naturally adopt different scales in one presentation: in the vicinity of start and endpoint of a route there is detailed information presented at a large scale, whereas the information in between can be reduced to the major roads and landmarks.

In the paper an approach is presented, that generates several options for an application dependent generalization of route maps. The assumptions are that all the information is given (i.e. the route, as well as the important landmarks) – the problem to be solved is the adequate generalization and presentation of the spatial situation in order to be understandable in short time and at a glance. The approach uses the following geometric generalization functions: simplification, enhancement and displacement, that are integrated in one framework. Several examples are given that visualize the effect of the different choices of operations and parameters. A conclusion summarizes the paper and gives a short sketch of future work.

2. RELATED WORK

The automation of generalization is an issue that has been tackled by cartographers for several decades. There are well known classifications of generalization operations (e.g. Shea, K. & McMaster, R. [1989], or [Hake, Grünreich & Meng, 2002]), as well as several approaches for the implementation of the generalization methods. Current generalization research concentrates on the integration of different modules in order to achieve a holistic solution. Here, techniques from Artificial Intelligence (knowledge based systems, agents [Lamy et al. 1999]) as well as optimisation approaches [Højholt 1998, Ware & Jones 1998, Sester 2000] are used. This research mainly concentrated on the automatic derivation of traditional map products, e.g. map series of different scales. Glover & Mackaness [1999] discuss the possibility of producing application dependent presentations in different scales: Based on users needs either a tourist map, or a topographic map can be derived from one data set.

New challenges are posed with the advent of small mobile devices, that demand for quick, adequate and readable information visualization [Gartner & Uhlirz 2001]. As the small displays need a high level of abstraction, methods for on-line zooming have to be available in order to inspect details and see the overview. Thus algorithms are needed, that are able to present the information on-demand and on-line [Letho & Kilpälainen, 1999]. Due to the flexible possibility of zooming the requirements concerning the cartographic quality can be relaxed to some extent.

A popular application using spatial data in the internet is route calculation (e.g. mapblast.com, teleinfo.de). Based on shortest path algorithms, the optimal route is selected and highlighted on the corresponding map. Whereas such presentations and descriptions are very well suited for car navigation systems, their usefulness for human navigation is somehow limited: as the whole map is presented in one scale, the typically more complex information in the starting and endpoints of the route cannot be represented adequately in all details, since most of the presentation is occupied by the large part of the connection between the two points. Findings from cognitive psychology show that humans use a different way of describing ways and paths (which also can easily be supported by our personal experience when sketching a route for a friend): only the orientation and navigation relevant information is presented, unnecessary details are dropped; orientation relevant information is needed, when the user has to take decisions like turning, or changing roads; only relative lengths of the route sections are needed, not the exact distances (as people are in general not good at estimating distances). This leads to one presentation, where the information is given at different scales, namely high details (large scales) in the vicinity of start and endpoint, and small scales in between. LineGraph is an approach, that automatically generates a route description based on these principles [Agrawala & Stolte, 2001].

[Harrie et al., 2002] present an approach to derive a vario-scale presentation for different user locations, similar to mono- or polyfocal maps, often used for city maps.

3. APPLICATION DEPENDENT VISUALIZATION

There are different possibilities to graphically highlight important information in order to lead to an immediate recognition of the spatial situation by the user. One obvious way is to use different colours or textures for the objects, i.e. design a presentation based on different graphical variables [Bertin, 1983]. When dealing with small displays, the possibility to use elaborated graphical means is limited, even colour is not yet a standard. Besides the graphical variables, there is the possibility to use generalization operations leading to changes in geometry in order to emphasize relevant information.

In the following, a spatial situation is given (see Figure 1), that will be visualized with different possibilities. The idea is that a visitor looks for a specific building, here the marked target building. An adequate presentation should help him/her to immediately identify the building.

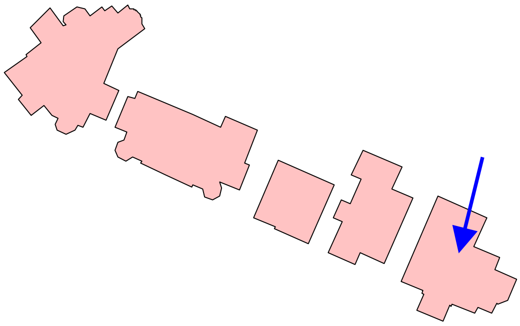

Figure 1: Original Situation and target object marked with arrow.

3.1 Graphical Variables

In the row of different buildings, the one that is relevant can be highlighted by a different colour or in different shades of grey. Also texture can be used to differ between important and unimportant information. Furthermore, the objects can be presented in different size – this aspect will be treated in the next section, however, when dealing with geometry.

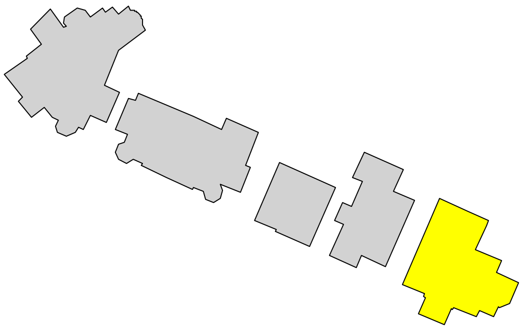

Figure 2: Graphical variable colour to emphasize the target building.

3.2 Generalization

The main idea is to present the information in different levels of detail or scales. The decision on the actual local scale depends on the application. In the following, the assumption is made, that already all relevant information is selected, i.e. generalization methods like selection and deletion have already been applied. Then the following options for generalization are possible.

3.2.1 Enhancement

Consider the row of buildings in the above example: the target building can be enhanced by enlarging it with respect to its neighbours. At the same time, the neighbours can be reduced in size in order to make the target more distinct. Another option is to decrease the enlargement factor smoothly from the target buildings down to the farthest neighbours. This leads to a more continuous transition between the representations.

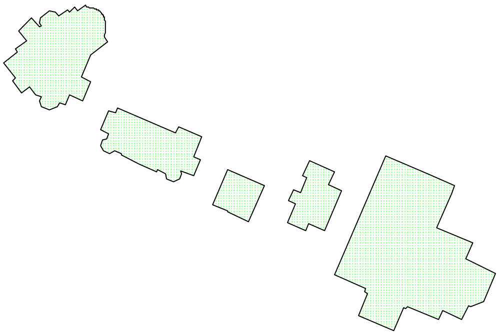

Figure 3: Enhancement: target object is enlarged with factor 1.4, whereas “background objects” are reduced by factor 0.6.

3.2.2 Simplification

The idea is to present the target building in all its details, and simplify the neighbour’s shapes. Simplification of ground plans can be achieved by specifying the minimum visible façade width of a building.

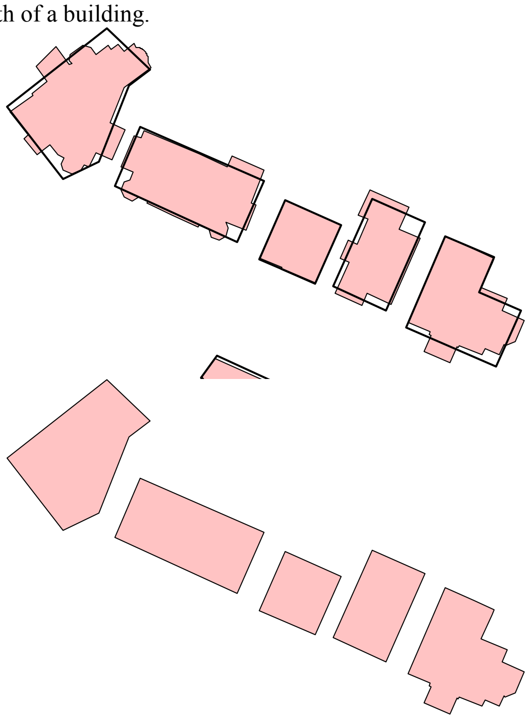

Figure 4: Simplification of object shape: a) overlay of simplified and original shapes, b) result of partial simplification: target shape without simplification.

3.2.3 Aggregation

A further decrease in the level of detail is achieved by aggregating objects that are of minor importance. Thus, several buildings in a row can be combined to form one large object; among those, the target object is separated and presented individually.

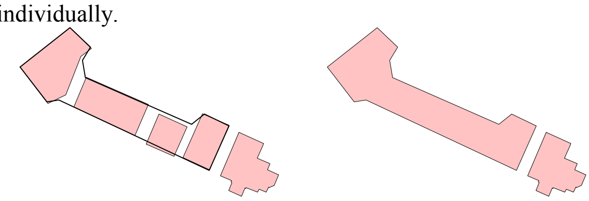

Figure 5: Aggregation of “irrelevant objects” – separation and visualization in full detail of destination object: a) overlay (outline), b) Result of aggregation.

3.2.4 Displacement

This operation is needed in order to compensate for the lack of space that was imposed by the preceding operations: when objects are enlarged, they occupy the space of neighbouring objects. In order to maintain the relative arrangements of the objects, as well as to enforce graphical constraints like minimal distances or minimal sizes, the displacement operation is needed. It has the effect of rearranging the objects while preserving their spatial distribution.

3.2.5 Presentation in 3D

The traditional way of presenting spatial information is in on a 2D map sheet. An interactive systems also allows for a 3D-presentation of a spatial situation, thus, the before mentioned operations can also be visualized in 3D. However, the provision of these operations is still in a research phase, especially the generalization of the shape of 3D buildings (cf. [Mayer 2000, Thiemann 2002]). Figure 6 gives a 3D presentation by simple extrusions of 2D-situations generalized with the before mentioned means.

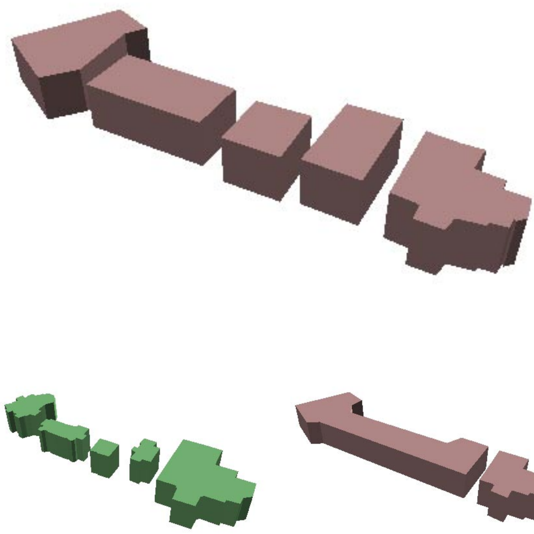

Figure 6: Visualization of different enhancement results in 3D: simplification of “background” objects (up), enlargement (left), aggregation (right).

4. REALIZATION – INTEGRATED APPROACH OF DISPLACEMENT, SIMPLIFICATION AND ENHANCEMENT

The realization of these features is achieved with an integrated approach that combines different generalization procedures. This approach is based on adjustment theory as a means to achieve an integrated optimisation of different constraining factors. Details can be found in [Sester 2000].

Adjustment theory is a means to determine a set of unknowns based on given observations. The observations are described as functions of unknowns in the so-called *functional model*; in addition, the accuracy of the observations can be described in the *stochastic model*. If the functional dependencies are not linear, they have to be linearized, leading to the fact, that approximate values for the unknowns have to be given. The unknowns are determined by the following equation:

$$\hat{x} = (A^T PA)^{-1} A^T P(l - f(x_0)),$$

where A is the Jacobean Matrix of the derivations of the functions according to the unknowns x, P is the weight matrix of the observations, l are the observations and $f(x_0)$ is the value of the function calculated at the approximate values x_0.

Obviously, the use of this scheme is straightforward, as soon as the observations and the unknowns for a given problem are identified. In the case of using adjustment theory for displacement, the unknowns are the coordinates of the points of the objects involved. The observations are distances between the objects, that have to be enforced and set to be at least as large as the minimum legible distance between the objects. Additional object specific observations can be introduced in order to define the form and orientation of the objects. These additional observations are necessary in order to be able to specify the variability of these object properties: if the form observations are assigned a high weight, it enforces that the form is kept – a low weight allows the object to vary its form, i.e. leads to deformation of the object. Furthermore, the unknown coordinates are also introduced as observations, in order to be able to assign them a high or low weight, allowing to fix an object at its original position, or allowing it to move, respectively. As distance constraints between all the objects are formulated, it is ensured that a global solution is found, where a displacement of one object occurs in accordance with all its surrounding objects, and no follow-up conflicts are triggered.

Thus it leads to a situation, where all the objects are clearly legible, as the minimum distances between all the objects are enforced. The result can be analysed by inspecting the residuals of the observations and their accordance with the introduced accuracies. E.g. the residuals in the object sides give an indication for their deformation. As a measure for the absolute positional accuracy, the change in the coordinates can be used. In this way, these measures can be used to evaluate the quality of the result and allow for self-inspection.

The integration of two other generalization operations is possible: Enhancement of an object (enlarge or reduce) is easily integrated, as this can be controlled by the form parameters (object edges) of the object. Aggregation of objects can be achieved by setting the distance between two objects to zero, instead of to the minimum distance. This leads to the fact, that the objects will be adjacent after the adjustment; merging them to form one object has to be performed in a separate step.

Simplification involves a change in the object structure itself, typically a reduction of the number of points. As such discrete changes cannot directly be achieved by the approach, these changes have to be calculated a priori and introduced into the system for a fine adjustment. This is used for building simplification in the following way: based on a set of rules a simplification of the building is achieved. The control parameter for this simplification is the minimum façade width that is just visible at the target scale. Subsequently, the exact shape adopted to the original shape is gained in the adjustment process [Sester 2000]. A similar approach is used by Harrie [2000] for the generalization of linear elements: the approximate line is calculated with the Douglas-Peucker line simplification algorithm; the fine adjustment of the line was performed in the adjustment process.

5. EXAMPLES

In the following, examples for the results achieved with the approach are given. The assumption is that the route description, starting point and destination, as well as important landmarks along the route are given, e.g. derived by approaches like [Elias 2002]. The task is to automatically visualize this situation in a way, that the important objects are enhanced and thus immediately distinguishable.

The spatial situation is given in Figure 7. In the examples only the vicinity of the destination is given for clarity. Two destination objects D1 and D2 are given to compare the different results. The results applying the generalization and visualization methods described above are presented in the following paragraphs.

Figure 7: Original situation with two different destinations D1 and D2 to be enhanced.

5.1.1 Simplification

The first set of visualizations is created by increasing the simplification the objects with increasing distance to the destination object. These Levels of Detail (LOD) are realized with the control parameter minimal façade length of a building. In Figure 8, three different LOD's are realized to enhance destination object D1: D1 is given with all its detail in the first LOD, its neighbours are presented with small simplification level (here 3m), whereas all the other objects are highly simplified with a value of 6m.

In Figure 9 the result for target object D2 is given.

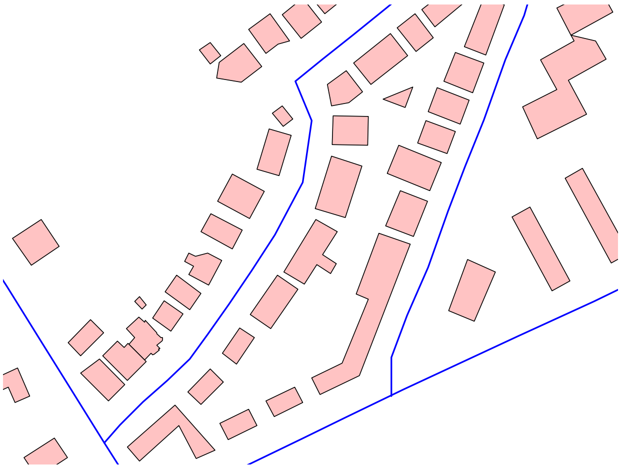

Figure 8: Objects in three different levels of detail: target object D1 in original detail, objects in close vicinity in detail level 2 (minimum façade length 3m), other objects in coarse representation (minimum façade length 6m).

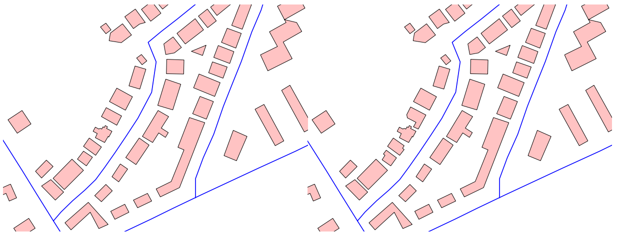

Figure 9: Enhancement of object D2: left: only two levels of detail; right: three different levels of detail (similar to Figure 8).

5.1.2 Aggregation

The second realization is based on aggregating close neighbouring "background" objects and presenting the destination object (here D2) in full detail.

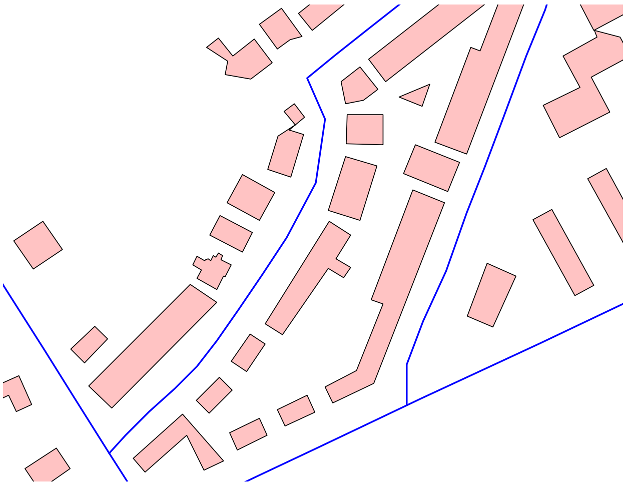

Figure 10: Aggregation of "background" objects (target object D2).

5.1.3 Enlargement

The third possibility is the enlargement of the destination object while the other objects are reduced in size. This leads to the visualization in Figure 11.

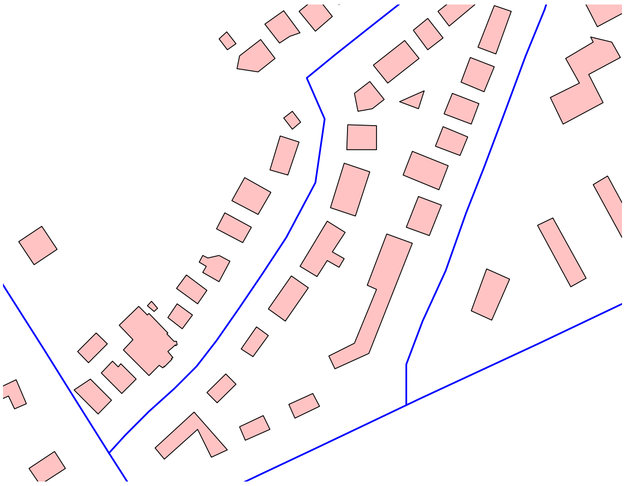

Figure 11: Enlargement of destination object and reducing of "background" objects (target object D1).

5.1.4 Visualization in 3D

Finally, these visualization can also be given in 3D. In Figure 12 selective simplification and aggregation is used.

Another degree of freedom or control parameter can be applied in 3D: the height of the objects can be set either equal for all the objects (see Figure 12), or dependent on the importance of the objects: the more important the objects are, the higher they are (Figure 13).

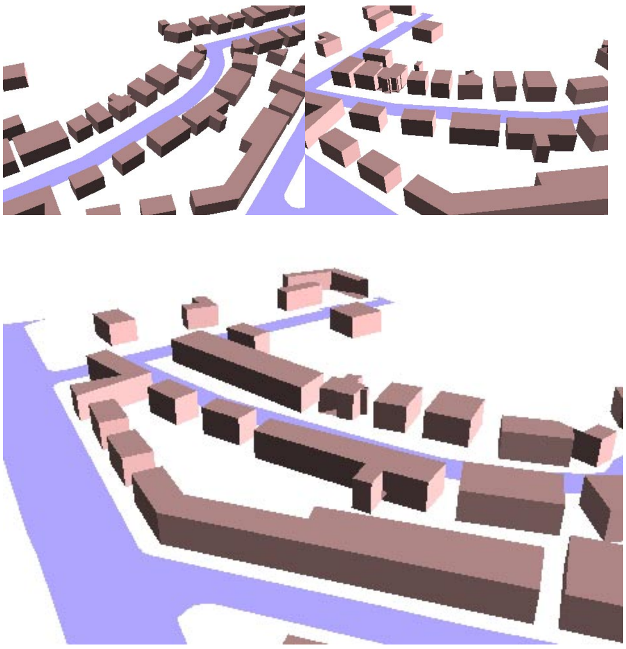

Figure 12: 3D-Visualization: simplification of target objects D1 and D2 (up) and aggregation of target object D2 (low) combined with 3D.

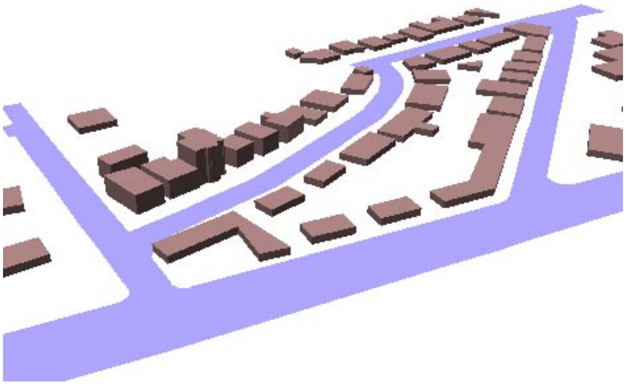

Figure 13: Objects in vicinity of target D1 are enhanced in detail as well as in height.

6. DISCUSSION AND CONCLUSION

The paper presented a toolbox of possibilities to automatically derive different visualizations depending on a given application. A target destination is enhanced with respect to its environment. The different possibilities of rendering have been automatically calculated based on an optimisation procedure, relying on least squares adjustment theory. The complexity of the algorithm depends on the number and complexity of objects involved, as the normal equations are of the dimension of the number of unknowns, i.e. the number of points. As for this application only a few objects are involved, the computational time demands are very low, and it is expected that they can be executed in real time even on a small mobile computer. This has to be verified.

Different results have been generated depending on the choice of the generalization operations. A general difficulty arises when emphasis is expressed with changes in geometry: There is always the danger that the enhanced version can be confused with. and taken for the real geometry. Therefore, future work will first concentrate on a detailed evaluation of the different results with respect to adequacy and usefulness for navigation.

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