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Automated Settlement Label Placement with Contrast and Clutter Optimization

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Abstract:

Map labels are an integral part of cartographic communication and serve as an essential tool for identifying and interpreting the depicted features. However, without labels, the informative function of maps would be significantly limited, as cartographic symbols alone are insufficient for a full understanding of the map content.

The placement of settlement labels on topographic maps is one of the most challenging problems in cartography. While a human cartographer intuitively balances readability, aesthetic quality, and cartographic conventions, replicating this process computationally requires a sophisticated multi-criteria optimization method.

In cartography, map labelling follows complex rules for choosing suitable fonts, sizes, styles, colours, and placements. They must be designed to ensure optimal readability, visual hierarchy, and graphic balance within the map content. However, in most cases, finding their optimal values tends to be rather fuzzy.

This presentation addresses the problem of automated settlement labelling, with the main goal of designing and implementing a new method that strictly adheres to established cartographic principles and rules, minimizes map clutter, and maximizes the contrast between labels and their backgrounds.

Eight cartographic rules were proposed and followed during the automated labelling process. They consider the significance of each settlement on the map, ensure that every settlement is labelled, resolve graphical conflicts with other cartographic features and labels, prefer horizontal placement of labels, and choose the optimal orientation of the label relative to the settlement. They consider whether the object is in "empty space" or is fully/partially surrounded by other objects. For this purpose, preferred directions are selected. Nevertheless, the label should be placed as close as possible to the cartographic symbol representing the settlement.

However, maps are often visually cluttered, especially in urbanized or geographically complex areas, which limits the options for optimal text placement. The number of suitable positions is significantly reduced, once map labels interact with the map content. Other factors, such as colour contrast and the graphic map load, play an important role.

Colour contrast is one of the most important visual principles in cartography. It allows users to distinguish between map elements, emphasizes the hierarchy of information, and makes the map easier to read. In cartographic practice, it is important to determine precisely whether two colours will provide sufficient contrast; several metrics are used for this purpose. Luminance contrast, defined as the ratio of the brightness of two colours, is particularly important for texts. It determines how easily text can be read or a symbol recognized. This metric was also used to determine the optimal placement of settlement labels.

Map load is a key aspect of cartographic clarity and visual effectiveness, significantly affecting the user's perception of the map. Our solution uses a fuzzy approach that combines edge detection and colour transitions. The metric assumes that sharper edges indicate greater map load. Its importance increases for medium- and small-scale maps, where higher levels of map load occur.

The main objective was to design and develop a method for the automatic generation of settlement labels on large-scale topographic maps. Our approach is universal and not tied to any particular map product. Multiple phases, including candidate position generation, relocation, optimal position selection, and assessment, are involved.

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The generation process for suitable candidate positions uses an incremental strategy (sweep line) that moves in two orthogonal directions relative to the object being labelled. If a candidate position overlaps with an existing position, it is removed. Subsequently, the remaining candidate positions are shifted toward the labelled object in two perpendicular directions. The final step is to select the optimal position that minimizes the total energy, with the user-defined priority for the four energies. They combine the distance of the label from the centroid (30%), directional priority (10%), local map load (40%), and colour contrast (20%). However, different user-defined priorities were also tested and analysed.

Based on an analysis of the official topographic map series of the Czech Republic, preferred label directions were also defined and subsequently used to find optimal candidate positions.

For minimization of the objective function, the total energy of labels, the grid-search strategy was used.

Multiple simple, more complicated, and complex situations with high map load were tested. Our results were compared with topographic maps of the Czech Republic, and a detailed statistical justification was involved. Moreover, an assessment of the current settlement labelling method used for this map series was provided.

The algorithm was implemented in Python using core geospatial libraries (Shapely, GeoPandas, Rasterio). The preliminary results are promising, confirming the applicability of the proposed approach for semi-autonomous label placement and showing its potential for further research.

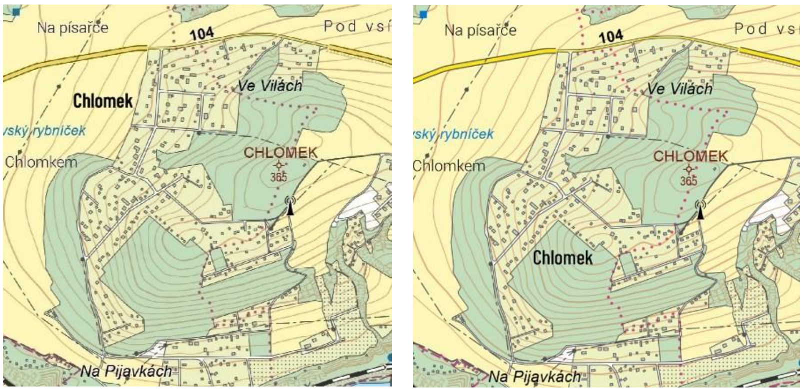

Figure 1. Comparison of automatic label placement using the proposed method (left) and reference label placement in topographic maps of the Czech Republic (right).

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